CRANFIELD UNIVERSITY

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AN EVOLUTIONARY THEORY OF SYSTEMIC RISK AND ITS MITIGATION FOR THE GLOBAL FINANCIAL SYSTEM

SCHOOL OF MANAGEMENT

PhD THESIS

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ABSTRACT

This thesis is the outcome of theory development research into an identified gap in knowledge about systemic risk of the global financial system. It takes a systems-theoretic approach, incorporating a simulation-constructivist orientation towards the meaning of theory and theory development, within a realist constructivism epistemology for knowledge generation about complex social phenomena. The specific purpose of which is to describe systemic risk of failure, and explain how it occurs in the global financial system, in order to diagnose and understand circumstances in which it arises, and offer insights into how that risk may be mitigated.

An outline theory is developed, introducing a new operational definition of systemic risk of failure in which notions from evolutionary economics, finance and complexity science are combined with a general interpretation of entropy, to explain how catastrophic phenomena arise in that system. When a conceptual model incorporating the Icelandic financial system failure over the years 2003 – 2008 is constructed from this theory, and the results of simulation experiments using a verified computational representation of the model are validated with empirical data from that event, and corroborated by theoretical triangulation, a null-hypothesis about the theory is refuted. Furthermore, results show that interplay between a lack of diversity in system participation strategies and shared exposure to potential losses may be a key operational mechanism of catastrophic tensions arising in the supply and demand of financial services. These findings suggest new policy guidance for pre-emptive intervention calls for improved operational transparency from system participants, and prompt access to data about their operational behaviour, in order to prevent positive feedback inducing a failure of the system to operate within required parameters.

The theory is then revised to reflect new insights exposed by simulation, and finally submitted as a new theory capable of unifying existing knowledge in this problem domain.

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Dr. C. Mena, Cohort leader.

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Dr. J. Jaina, Original Cohort leader.

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1 INTRODUCTION

1.1 Motivation

1.1.1 Background

This is a time of turmoil for the global financial system, and for the academic discipline of economics. The emergence and persistence of global economic distress, which surprised almost all observers who claim expertise in such matters, is still without credible explanations. Indeed, challenges to prevailing economic notions that may offer useful insights continue to be blocked by the intellectual inertia and hubris protecting cherished dogmas. Certainly, promising contributions from other disciplines bring their own conceptual controversies, but they are too often dismissed without due consideration. Then unresolved philosophical conflicts deliver the final blow to surviving attempts at new insights that have overcome all other obstacles to multi-disciplinary thinking.

Within that context of intellectual inertia, conceptual controversy and philosophical conflict, this research has set out to extend current economic thinking with insights from multiple academic disciplines in a thesis that has practical value in explaining and mitigating systemic risk of failure for the global financial system. Where inertia, controversy or conflict is encountered, it aligns itself with conversations in the literature that define the intellectual heritage being applied. The intention being to make a significant contribution to knowledge from a declared perspective through a credible piece of multi-disciplinary research which becomes the first step in on-going programme of research into the problem addressed, some of which may be conducted by other researchers in different academic disciplines. Even so, within the confines of a doctoral thesis, the number of unresolved issues to be navigated around will be greater than from similar research efforts in a single discipline.

In anticipation of those issues, and in consideration of the many people who continue to suffer the harsh realities of current global economic distress, it is perhaps fitting to end this introductory sub-section with a summary of the challenges ahead quoted from an article titled *"How Did Economists Get It So*

Wrong?" by the 2008 Nobel Memorial Prize-winning economist Paul Krugman, in the New York Times (September 6th, 2009).

> *"Few economists saw our current crisis coming, but this predictive failure was the least of the field's problems. More important was the profession's blindness to the very possibility of catastrophic failures in a market economy. ... There was nothing in the prevailing models suggesting the possibility of the kind of collapse that happened last year.*
>
> *As I see it, the economics profession went astray because economists, as a group, mistook beauty, clad in impressive-looking mathematics, for truth. ... as memories of the Depression faded, economists fell back in love with the old, idealized vision of an economy in which rational individuals interact in perfect markets, this time gussied up in fancy equations.*
>
> *Unfortunately, this romanticized and sanitized vision of the economy led most economists to ignore all the things that can go wrong. They turned a blind eye to the limitations of human rationality that often lead to bubbles and busts; to the problems of institutions that run amok; to the imperfections of markets – especially financial markets – that can cause the economy's operating system to undergo sudden, unpredictable crashes; and to the dangers created when regulators don't believe in regulation.*
>
> *It is much harder to say where the economics profession goes from here. But what's almost certain is that economists will have to learn to live with messiness. That is, they will have to acknowledge the importance of irrational and often unpredictable behaviour, face up to the often idiosyncratic imperfections of markets, and accept that an elegant economic 'theory of everything' is a long way off."*

(Krugman, 2009)

1.1.2 Systemic Crises

The inevitability of systemic crises in banking (Rochet, 2003), and by implication in the global financial system generally, suggests that long-term macroeconomic stability is unsustainable. Such crises seem to occur regularly, and they are usually attended by instability that can persist in the global economy over any time-frame, including extended periods between crises (Borio and Drehmann, 2009). However, the standard view of neoclassical economic theory, focused on dynamic equilibrium conditions of stability, struggles to explain what is happening in those circumstances. This thesis argues that an improved understanding of the fundamental nature of crises in the global financial system (Kindleberger and Aliber, 2005: 81-84; Allen and Gale, 2007: chapter 1), and their relationship to macroeconomic phenomena, can be gained by thinking about the system in crisis as having entered an operational state which is failing to maintain an adequate balance between the supply and demand of systemically important financial services (SIFS, such as short-term funding from money markets) among systemically important participants (SIPs, such as banks, intermediaries and their counterparties). From that perspective, as distress begins to propagate throughout the system, exogenous macroeconomic instability is observed to interact with endogenous operational instability, and vice versa, until a crisis is perceived when the system's operational state crosses some threshold of escalating systemic failure and approaches collapse.

Most debates about systemic crises in the literature ignore or blur this distinction between the global financial system and its economic environment. There is also a lack of consensus on definitions for key concepts, which makes research conversations difficult across that literature. Insights are offered about particular causes and effects of past crises for avoiding their recurrence, and models are proposed for financial contagion or the behavioural impacts of markets, participants and institutions, but the literature does not provide a general explanation about how these phenomena are interrelated. It is the view of this thesis that current knowledge about systemic crises could benefit from a unifying theory, capable of translating existing notions into a shared neutral context. A systems-theoretic explanation of operational distress and its propagation is argued to offer this potential, by providing new insights for recognizing, avoiding and responding to the risk of potential failure of the global financial system, wherever it may emerge in the future. Therefore, a multidisciplinary theory is outlined here for a better understanding of systemic risk, based on an operational behaviour paradigm of systemic failure (see Figure 1). It focuses on plausible explanations for assertions **A** to **F** in that paradigm, and describes how they relate to familiar macroeconomic events.

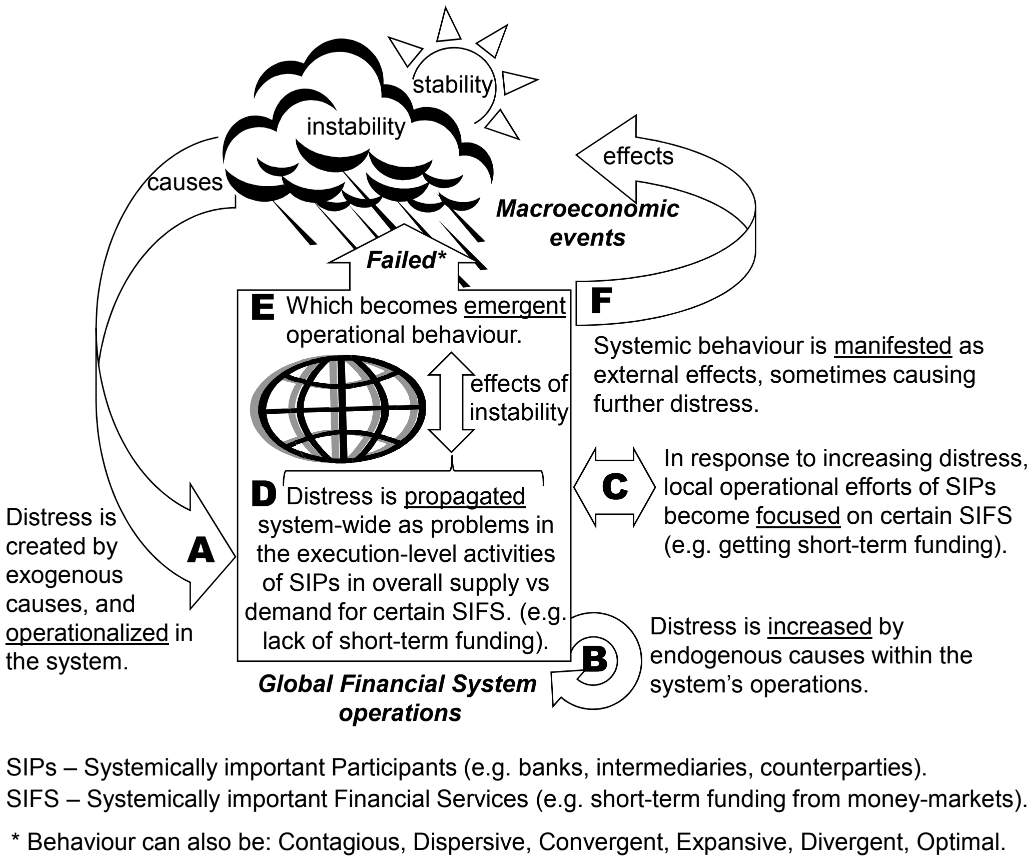


Figure 1: An operational behaviour paradigm of systemic failure

1.1.3 Research Opportunity

Since Krugman's comments in 2009 (see 1.1.1), the current crisis disrupting the world economy has continued to intensify a general perception of contemporary economics being ineffectual at best. The end of neoclassical economics is being debated, and visions of a new era are gaining support for a paradigm shift based on notions of complexity. With so much emphasis on highly introspective themes in its mainstream literature, such as theories of economic growth, recognition is dawning that scant attention has been given to useful ideas from other disciplines, such as theories on punctuated equilibrium (Bak and Sneppen, 1993) and non-linear laws in nature (Prigogine, 1997) from physics, generalized notions of entropy from computer science (Shannon, 1948), critical transitions from the environmental sciences (Scheffer et al., 2009), and catastrophe theory from mathematical topology (Thom, 1975; Zeeman, 1976). Among the controversies of this debate, agent-based macro-economic modelling and simulation approaches that implement evolutionary economic principles are seen by some as strong contenders for providing better explanations for the intrinsically complex, dynamic social phenomena of the world's evolving economy than traditional mathematical attempts.

History suggests such crises occur regularly, and recent reports by regulatory institutions indicate that risks to global financial stability are generally continuing to increase in this current period while politicians turn a blind eye. Meanwhile, confusion around the meaning of risk in general, and systemic risk in particular, is becoming a serious barrier to progress in addressing those risks. The overall critical assessment of the literature reviewed in this thesis argues that, although some progress has recently been made in understanding certain aspects of systemic risk, the paradigms currently favoured in economics for explaining it are reaching their limits of usefulness. A consensus is growing around the view that a paradigm shift is indeed required, and contributions from other academic disciplines may be essential for introducing fresh ideas. Concepts from complexity science show the most promise, but they bring their own debates to any discussion. For example, tension between constructivism and formalism in that literature is shown to be of special relevance to this thesis. In particular, the applicability to economics of notions about criticality, catastrophe and entropy is explored, and a position is taken regarding the current debates each engender. Then, agent-based computational economics is applied as an experimental approach to demonstrating how these notions may offer solutions to the research problem of this thesis.

1.2 Purpose

1.2.1 Finding a Better Explanation

The need for a better explanation of systemic risk argued by this thesis is most evident in definitions currently used in the literature (see Figure 2). They reflect a low level of understanding and suitability for thinking about that risk, and are often too vague for practical uses such as risk mitigation, being narrowly focussed on specific causes and effects.

Current definitions can be classified as causal, consequential or combined.

Causal example:

… arises from moral hazard and individual firm leverage, which can cause a large shock to the financial system. *(Dow, 2000).*
... arises from a high inter-bank correlation of returns on assets, which through various means forms a multi-agent risk shifting phenomenon. *(Acharya, 2009).*
... arises from the propagation of economic distress between agents linked through financial transactions. *(Rochet and Tirole, 1996).*

Consequential example:

… results in multiple simultaneous defaults of systemically important financial institutions. *(Huang, Zhou and Zhu, 2009).*

Combined example:

… arises from a large shock event that triggers an apparent or actual loss of economic value, with the consequence of having significant adverse effects on the real economy. *(Nicolo and Kwast, 2002).*

Critical assessment:

They are too vague for practical applications, such as providing focus for systemic risk mitigation techniques that can be applied in a variety of circumstances.

Figure 2: Examples of current definitions for Systemic Risk.

1.2.2 Introducing Clarity in Response Thinking

It is further argued there is very little consideration in the literature about how systemic failure of the global financial system materialises operationally from systemic risk (i.e. rather than why it occurs); or indeed what that failure is deemed to be, how it relates to its risk, or how to recognize when it is occurring. Only when these things are understood can the emergence, nature and timing of systemic failure be predicted from a quantified systemic risk, to suggest appropriate mitigations.

1.3 Research Overview

1.3.1 Research Problem

Although, to paraphrase Krugman (2009), a comprehensive economic *"theory of financial crises"* is certainly not attempted by this programme of research, it does aim to take a small step in that direction by finding an answer to the following question.

<u>Research Question</u> ***"How does instability of the global financial system become operationally catastrophic, and how could that outcome generally be avoided?"***

This question was constructed using keywords extracted from eight conjectures synthesised by the project 1 systematic review of literature from an identified gap in theory. The wording is deliberately open to multiple potential answers, to avoid confirmation bias. They can range from the type of research finding that declares *"There are many ways instability can become operationally catastrophic in the global financial system, and they are so different and complex that unique explanations must be applied to each";* to the other extreme where a more useful finding could declare *"A new theory is presented for systemic risk of failure, about certain phenomena that emerge when instability of the global financial system becomes operationally catastrophic, and how that outcome could be avoided".*

1.3.2 Gap in Knowledge

1.3.2.1 The evidence

The literature review and findings that demonstrate there is a gap in theory, from which the above research question was derived, are presented in Section 0 of this thesis. Direct references in that literature to this gap are discussed here.

There is a consensus among academics that a general theoretical paradigm for systemic risk of the global financial system is still missing (Beinhocker, 2011; Colander et al., 2009; Bandt and Hartmann, 2000). Hoogduin's (2010) stocktaking of issues and experiences related to financial instability also confirms the regulatory view that it remains unresolved. A good example of the views being expressed is contributed by Beinhocker (2011), who argues that theoretical and ontological implications of the *"evolution as computation literature"* have not yet been adequately explored, presenting theory development opportunities in the domain of evolutionary economic systems. However, he finds there is no direct advice in the literature on how this should be done.

From another perspective, Buchanan's (2009) article in Nature discusses this generally perceived gap in knowledge about systemic risk in his review of academic thinking on preventing another financial crisis. He reports the opinion shared by many leading academics from different disciplines that the most recent global financial crisis has been a *"massive failure of the dominant economic model",* and quotes them supporting *"the need to purge economics and finance of ideology and failed assumptions".* Then he explains the widely acknowledged role of agent-based models (ABMs) in emerging multidisciplinary contributions, and summarizes a consensus among current researchers that the *"regulatory system based on conventional economic theory has failed",* and that new multidisciplinary ideas are needed to make progress. Meanwhile, other contributions in the literature expand on the themes in Buchanan's article, such as the critique by Farmer and Geanakoplos (2009) on the *"virtues and vices of equilibrium"*. In order to address this gap in knowledge, it is generally agreed that breakthroughs are needed in experimental and evolutionary economics, agent-based modelling, and various alternative methods and multidisciplinary approaches to research in this field (Heckbert, 2009; Safarzynska and van den Bergh, 2010a; Hodgson, 2007; Windrum, Fagiolo and Moneta, 2007).

1.3.2.2 An alternative view

Allen and Gale (Allen and Gale, 2007: page 24) present the most persuasive argument against this proposed gap, summarised in their assertion *"There is no one theory of crises that can explain all aspects of the phenomena of interest".* From their extensive reviews of the literature explaining different causes and effects of past sub-systemic crises (e.g. fiscal, banking and currency crises) it seems reasonable to accept that no single theory could encompass them all. Nevertheless, it is argued in this thesis that a unifying theory is indeed missing and necessary for exposing fundamental principles in a single coherent model of systemic failure for the global financial system. Beyond any specific phenomena of interest this type of model may explicitly explain, such as how instability increases as the system approaches failure, it could also provide a general framework with the inherent capability of being used to integrate existing and new contributions from multiple disciplines to show how diverse crisis phenomena are interrelated. Therefore, it is not unreasonable to argue that a theory of this type, based on a neutral paradigm of systemic failure, could provide a single unifying thesis. Zeidan and Richardson (2010) describe the feasibility of this class of model as *"an encompassing theory to tie all the different approaches together ...* [within] *a complexity-based standard model of finance".*

1.3.2.3 This thesis

Insights from the social science disciplines of evolutionary and behavioural economics, finance, and related contributions from the inter-science fields of complex systems and critical phenomena, provide this thesis with the foundations of a proposed unifying theory that can be used to describe systemic risk of failure, and explain how it occurs, in order to diagnose the overall operational state of the global financial system and understand how to improve its resilience. A new approach is taken, by combining an operational behaviour perspective on economics and finance with notions of criticality to explore systemic risk of failure (often abbreviated to 'systemic risk' in this thesis) as a focal research problem.

Particular attention is given to operational states of the system close to failure. In that neighbourhood, strong patterns in operational behaviour are observed to emerge from normal complexities which lend themselves to theoretical analysis. Suggested applications for the theory include a pre-emptive macro-prudential approach to systemic risk of failure and its mitigation that can nurture stability even when circumstances are difficult.

1.3.3 Challenges

1.3.3.1 Theory development

There is a substantial body of literature on theory development in the social sciences, but disagreements persist about what constitutes a valid theoretical contribution (Dubin, 1978; Bacharach, 1989; Whetten, 1989; Sutton and Staw, 1995; DiMaggio, 1995; Pawar, 2009). The nature and quality of theory offerings in multidisciplinary work is even more prone to dispute, due to differences of tradition in such matters as: the distinctions between theory construction and just theorising (Weick, 1995); different kinds of good theory (DiMaggio, 1995); strong or weak theories and the use of illustrative or definitive data (Sutton and Staw, 1995); and single or multiple paradigm adoption (Gioia and Pitre, 1990). In this thesis, insights from multiple informing disciplines are combined with new propositions to outline a single unifying theory. It synthesizes knowledge from that combined literature, with evolutionary economics in mind as the core discipline.

Current theorising about systemic risk varies significantly in economics, from narrative-style descriptions evidenced by empirically-based quantification methods (Bartram, Brown and Hund, 2007), through a focus on framework or model development (Bhattacharyay, 2003; Huang, Zhou and Zhu, 2009; Ho and Saunders, 1980), to mostly conceptual and formally declared theory development (Acharya, 2009). All of these contributions are justifiably valued in the literature. Their differences simply illustrate the spectrum of detail, empirical assurance, formalism and confidence of the theorising presented in just a single discipline. This thesis seeks to fit into the more conceptual end of that spectrum, with an emphasis on demonstrating the principles of a new multidisciplinary theory of systemic risk, explaining phenomena that emerge in the overall operational behaviour of the global financial system modelled as a dynamical complex system responding to collective participation behaviour. It does not attempt to model some formal mathematical representation of a narrow aspect of the behaviour of individual financial or economic participants in that system, for example, as a stochastic Markov process (Safarzynska and van den Bergh, 2010a).

Even so, significant challenges to multidisciplinary theory development need to be addressed. Although calls for research in this problem area of systemic risk suggest there is an appetite for such contributions (Allen and Gale, 2007; Kambhu, Weidman and Neel, 2007: Introduction; Nelson and Winter, 1982), the academic scope of most published papers is still confined to economics literature. Why that should be is debatable, but theory development with references beyond the familiar ideas and research traditions of a single academic discipline is known to benefit from using a pragmatic philosophy of research as an essential tool for mediation between diverse viewpoints (Morgan, 2007; Creswell and Plano Clark, 2007: 22-27). Therefore, until there is agreement among overlapping literatures on how to deal with conflicting demands, it would seem good research practice to apply pragmatism where necessary, while declaring key choices, trade-offs and intentions and explaining the rationale behind them. Where appropriate this thesis will do so, thereby enabling readers to make explicit distinctions between considerations of research preferences and the potential usefulness of insights being presented.

1.3.3.2 Agent-based simulation

Bankes (2002) summarizes the challenges and opportunities of agent-based simulation. Although this article was written over ten years ago, his comments still apply now. They can be characterized as 'improving credibility' in social science research when using this innovative tool. The key challenges he mentions of fundamental relevance to this thesis are all aspects of gaining acceptance for using the tool and the findings it generates (Figure 3).

Computationally-based arguments are described as being capable of overcoming the restrictive and unrealistic assumptions made by more 'accepted' alternative formalisms based on mathematical analysis, such as linearity, homogeneity, normality and stationarity, but he observes there is a lack of clarity about the requirements for establishing credibility in those arguments. This thesis adopts his recommendation to apply the standards of rigour used by experimental science in forming conclusions, rather than the standards of deductive proof favoured by mathematics. However, issues around methodological controversies and the suitability of techniques for validating results and demonstrating plausibility remain unresolved in the literature. Each of these will be explicitly addressed as discussed in the previous sub-section.

1. Improving credibility (Bankes, 2002).
   - Computationally-based arguments.
   - Rigour.
   - Experimental science.
   - Methodological controversy (simulation).
   - Results validation
   - Findings/interpretation plausibility.
2. Dealing with emergence (Bankes, 2002).
   - Graphical representation.
   - Formal definitions.
   - Quantitative tests.
3. Shift to a new paradigm (Helbing, 2012).
   - Improved simulation tools.
   - Move beyond descriptive to explanatory models.
   - Appropriate methodologies.

Figure 3: Main Challenges

Regarding the credibility of software tools available for computational modelling and simulation, there are notable differences in the capabilities and acceptance for research use among the tools readily available to the unsponsored doctoral researcher. Older tools are little more than sub-routine libraries hosted in the development interface of standard programming languages, with crude graphical interfaces and charting facilities for presenting simulation output. More recently developed tools usually have fully embedded features such as parameter-space exploration and built-in agent artefacts, with object-oriented programming features. However, every tool has major weaknesses and there is no established standard for tool selection to fit a research purpose. The choice made by this programme of research was NetLogo, because it is a single integrated tool that is stable and well-proven, with a successful history of use in many simple research simulations, and is known to be an easy tool in which to build, verify and simulate models. Its best feature is that it allows almost total focus on model development, with no need to modify the tool's built-in functionality, and the code syntax is easily read and verified against textual model specifications by non-programmers.

Other useful features of NetLogo allowed this research programme to push the current envelope regarding computational economic models. For example, built-in 3D rendering enabled the design of three different simulations embedded as separate surfaces within one 3D agent-space. Similarly, its built-in distinction between mobile 'turtle' agents and stationary 'patch' agents helped to simplify theory validation by triangulation between micro-level system participation among invisible turtles, meso-level financial effects shown in the simulation dashboard, and the movement of macro-level turtles over patches in a 3D representation where phenomena emerge for explanation by catastrophe theory.

Finally, Bankes' observations about an almost exclusive use of graphical demonstrations of emergence in current research, and the importance of advancing agent-based research beyond that limitation, resonates surprisingly well with the intentions of this thesis in defining systemic failure as an emergent phenomenon where systemic risk has breached certain regulatory thresholds at different levels.

"*Thus, emergence can be characterized by a measure of macroscopic behaviour achieving a threshold value in a simulation built from microscopic behaviour. The discipline of defining these macroscopic measures and using them to assess behaviour quantitatively across ensembles of alternative agent-based models can make rigorous what has often been polemical. And when this rigour becomes routine, the advertised revolution in social science will be well on its way to being achieved*" (Bankes, 2002).

1.3.3.3 Experimentation

The computational model proposed by this thesis can be described as a detailed model (Helbing, 2012: sub-section 1.3.2) with many variables, parameters and initial conditions, incorporating three distinct sub-models, each with their own agent-sets. It is nowhere near as complex as the types of large-scale simulations of weather patterns, asteroid impacts or bridge collapses run on supercomputers (Post and Votta, 2005), but it is designed for similar theory development (or prediction) purposes, and has the same challenges. These are quite distinct from the purposes and challenges of simple models, and require radically different approaches to experimental design, verification, validation and theory testing.

1.3.4 Approach

With the above-mentioned challenges in mind, the pragmatic approach of this multidisciplinary thesis is summarised by the intention: to develop a new theory capable of unifying multi-disciplinary insights relevant to explaining systemic risk of failure of the global financial system; expressed informally and formally using declared theory development principles; by constructing a highly simplified computational representation of that system viewed from a national perspective; capable of describing how systemic failure occurs, defining the risk of that occurrence, and showing how it can be diagnosed and mitigated; validated by simulation of the Icelandic financial system collapse between the years 2003 to 2008; and corroborated by theoretical triangulation with catastrophe theory.

In that approach, realist constructivism is the research philosophy considered to offer the best potential for developing an improved understanding of intractable problems with nonlinear characteristics (Crnkovic, 2010) such as systemic failure. It has a capacity for achieving reconciliation between insights from different research traditions, by incorporating them as simple metaphorical references (Guba and Lincoln, 2005: chapter 8; Cornelissen, 2006; Weick, 1989) designed into a verified computational representation used for operationalising the proposed theory in simulation experiments. Hypothesised results from successfully tested simulations of this type can therefore be argued to have a propositional mode of pragmatic validity (Worren, Moore and Elliott, 2002), which requires explicit hypotheses that are testable, operational definitions of constructs, and descriptions with embedded rules for operationalising the theory. Agent-based computational modelling and simulation are the preferred constructivist methods for this purpose, with an ability to handle greater system complexity than their mathematical equivalents (Helbing, 2012), when applied within a suitable research methodology for theory development by simulation.

The approach also adapts suggestions from multi-paradigm perspectives on theory building in organisational studies concerning goals for guiding effort

(Gioia and Pitre, 1990). The goals chosen are: *"to describe and explain in order to diagnose and understand"*; reflecting the relative importance of clarification through novel theory over prediction or proof in this theory development research.

Finally, pragmatism is introduced in this thesis by: the use of mixed methods, whereby constructivist modelling is augmented with quantitative financial analysis and qualitative evaluations of simulated phenomena.

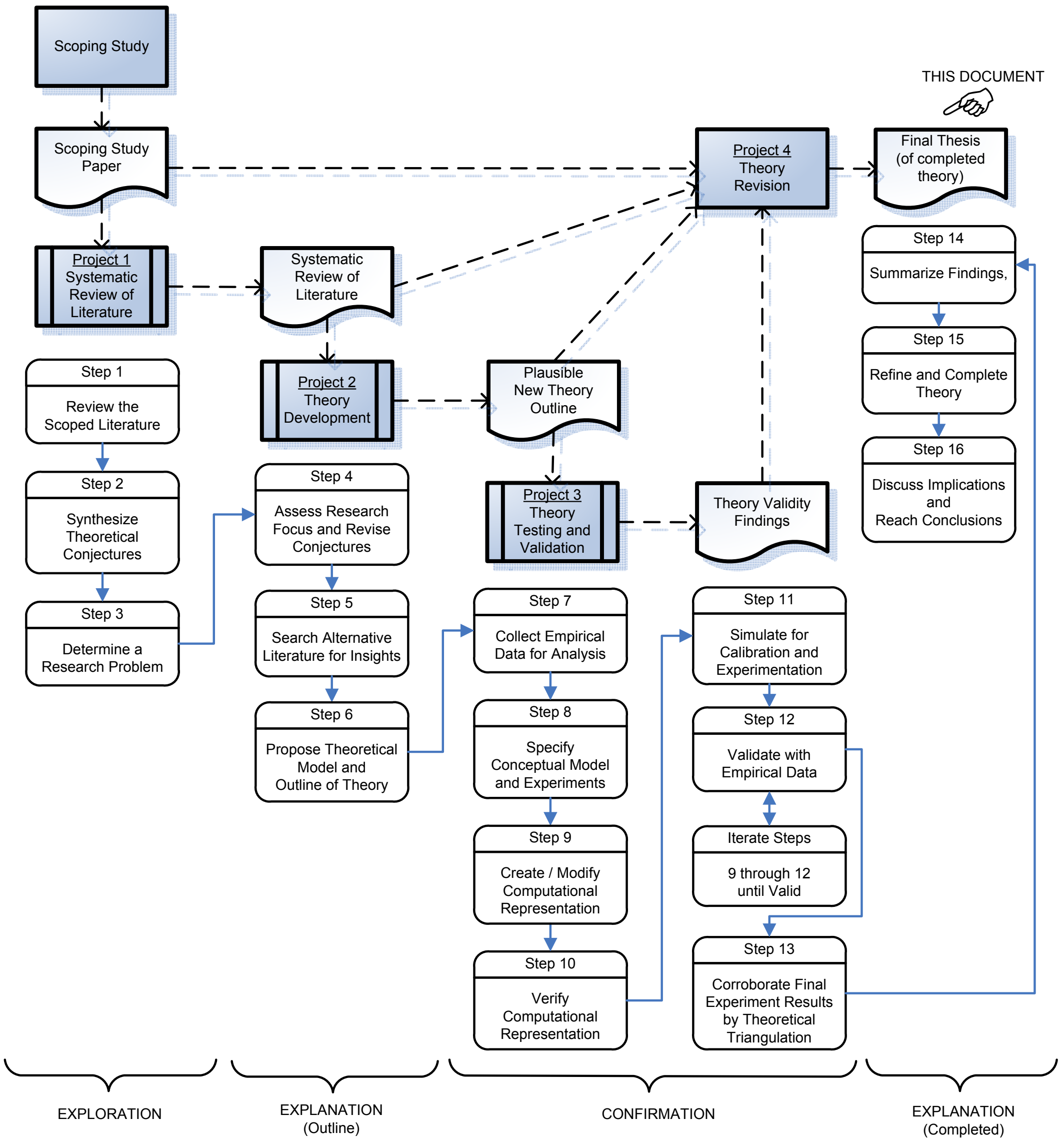


Figure 4: Research methodology - Davis, Eisenhardt and Bingham, 2007.

1.4 Claims

An new theory is presented that extends and unifies current theory about systemic risk of failure, to explain how instability of the global financial system becomes operationally catastrophic, and how that outcome could be avoided.

After a systematic review of literature, the eight conjectures of interest from project 1 are revised in the light of findings from a further exploratory search of literature, suggesting a theoretical model topology based on a cusp catastrophe-type behavioural surface representing all potential operational states of the global financial system. Theory is developed from this model using concepts of complexity and principles from evolutionary economics, viewed from an operational behaviour perspective, comprised of 13 propositions grouped into explanations for: *"recognising systemic failure"*, the *"operational state of participation"*, and a *"systemic risk of failure to operate"*. Out of which 5 hypotheses predict the implications of this theory for validation and testing.

1.4.1 Key Innovations and insights

The key claims of this theory are:

i. It provides a clear, formal definition of systemic risk of failure and related terms, of practical value for economic discourse and policy making decisions, removing current ambiguities, inconsistencies and confusions.
ii. It introduces entropy as a component in this probability-based definition, to incorporate a measure of uncertainty.
iii. It transcends current explanations of systemic risk that are limited in applicability to specific crises or circumstances, by offering propositions and hypotheses explaining general phenomena observable in many financial crises, thereby contributing a general theory.
iv. It introduces an operational behaviour perspective on the global financial system, which has the potential to overcome many of the philosophical difficulties of involving such notions as the 'perception' of probability and exposure inherent in current ideas of risk to that system.

v. It bases that operational behaviour perspective on a new interpretation of supply and demand interactions among systemically important participants over a functionally defined set of systemically important financial services.

vi. It explores that operational behaviour perspective and discovers new applications of existing insights about criticality, disorder and catastrophe from complexity science.

vii. It provides a rare demonstration of the dynamics of catastrophe theory in a non-trivial way, to explain how systemic failure materialises in the global financial system from systemic risk; moving understanding of that theory's relevance beyond its mostly static, illustrative uses found in current literature explaining the causes and effects of systemic risk.

viii. It pushes the envelope of current accepted practice in simulation-based theory testing by demonstrating a propositional form of pragmatic validity through the notion of theory triangulation for a single-case validation, single-run simulation of a detailed computational model.

1.4.2 Contribution to Theory

1.4.2.1 An new paradigm

An operational behaviour paradigm of systemic failure is introduced for the global financial system, extending current theory about systemic risk of failure to explain how instability becomes operationally catastrophic, and how that outcome could be avoided (see Figure 1). It uses the notion of operational distress from proposition 12 to explain how execution-level supply and demand activities of collective participation behaviour emerge as operational behaviour at system level, potentially leading to systemic failure, encapsulated in the transformation:

$$\text{Distress: Conditions}(\varDelta_{t+1}) \mapsto \text{Current}(B_{t+2}, \tau, \gamma, \varphi), \tag{26}$$

(see full explanation in sub-section 4.9.5).

1.4.2.2 A definition of systemic failure

Explanation of that paradigm begins with a series of propositions leading to a definition of systemic failure in proposition 9, outlined as:

$$\Finv_t \coloneqq \left\{ \{\xi_{v,}\xi_{v+1,} \dots , \xi_{v+(\mu-1)}\} \,\middle|\, \xi_t \in \Finv_t,\ v \in T,\ \mu > 1,\ t = v + (\mu - 1) \right\}, \quad (19)$$

(see full explanation in sub-section 4.9.2).

1.4.2.3 A formal definition of entropy in systemic risk

Then applying the concept of entropy to the uncertainty implicit in any determination of the probability of systemic failure over some useful future time-span, produces the new interpretation:

$$\text{Entropy}(p_{t:u}) = - \sum_{i=t+1}^{u} p_t^i \log p_t^i. \quad (22)$$

(see full explanation in sub-section 4.9.4).

1.4.2.4 A formal definition of systemic risk of failure

Ultimately, this leads to the proposal of a probability metric for systemic risk of failure incorporating entropy as a measure of uncertainty, expressed as:

$$\text{Risk}(\Finv_u, t) \coloneqq \{ p_t^u, \text{Entropy}(p_{t:u})\}, \quad (23)$$

(see full explanation in sub-section 4.9.4). Although this definition satisfies the thesis goal assertion of describing and explaining systemic risk of failure, calculating a precise probability with its uncertainty qualifier may still be beyond reach. However this thesis shows that a combined directional and velocity indicator of that risk may be feasible if it is based on simulated predictions.

1.4.2.5 Relevance to the programme research problem

The main contributions to theory summarised in the preceding sub-sections are operationalised in a way that can be traced back to the programme research problem by refuting a null hypothesis, and linking hypothesised predictions to a goal assertion derived from that problem (see sub-section 8.1).

1.4.3 Contribution to Practice

1.4.3.1 A practical definition of systemic risk of failure

For practical purposes, the formal definition in expression 23 can be restated in less formal terminology as: *"a measure of the overall probability at a current time of the system entering an operational state of systemic failure by a specified* *time in the future; qualified by a measure of uncertainty determined by the system's entropy for a series of probabilities about a succession of future operational states considered to be (e.g. by simulation) capable of that outcome by the specified time; in the absence of new mitigation efforts".*

1.4.3.2 Recommended changes to practices

Macroprudential tools incorporating the principles of this theory, or derivative models, could be used in monitoring distress as it propagates and simulating intervention effects to identify appropriate actions. These might include creating disincentives for growth in concentrations of participation involving certain SIFS; or using funds that would otherwise be employed in quantitative easing in addressing gaps in demand or supply; or influencing the interplay between diversity and exposure. Naturally, any such macroprudential initiatives must be aimed at system-wide effects globally, otherwise any sub-systemic response would likely be sub-optimal in its effects, potentially becoming a new source of systemic risk.

1.4.4 Contribution to Policy

Macroprudential oversight is therefore argued to require improved operational transparency from system participants, and prompt visibility of data about their operational behaviour, in order to prevent positive feedback inducing a failure of the system to operate within required parameters. This translates into changes and additions to policy, which in turn call for new regulatory practices. The policy and practice recommendations of this thesis are:

i. Operational performance parameters should be identified, communicated, and required to be maintained by systemically important participants; and performance confirmation data should be provided by them; to enable constant prudential monitoring of the system's operational behaviour; for continual updating and publication of operational behaviour assessments of the global financial system, and regional or national financial sub-systems; for the benefit of all system participants.

ii. Then a policy of pre-emptive operational intervention should be assigned ownership among senior regulators, for ensuring positive feedback from emergent operational behaviour is prevented from inducing a failure of the system to operate within the parameters established in policy 'i'.

1.5 Thesis Structure

Sections in this thesis are organised according to a logical progression of research topics, which is not always the sequence in which research was conducted. This sub-section explains how they interrelate.

A review of the extended core literature in section 2 of this thesis covers steps 1, 2, and 3 of project 1 and step 5 of project 2 in the research methodology (see Figure 4). Discussions about step 4 and step 6 of project 2 are then split into two sections, by covering theory development issues in section 3 followed by a presentation of the constructed theory in section 4.

Steps 7 to 13 of project 3 covering theory testing and validation are discussed in section 5, then section 6 summarises the findings from steps 14 and 15 of project 4 and refines the theory. Finally, after the general discussion from step 16 is presented in section 7, overall conclusions (also from step 16) are considered in section 8 for their implications regarding the overall purpose of this research and its success in addressing the goal assertion.

2 LITERATURE

2.1 Introduction

After a brief description of the systematic review in sub-section 2.2, relevant conversations found in its first extract of literature from multiple academic disciplines are identified in sub-section 2.3. Selected contributions to each conversation within scope are then critically assessed in sub-section 2.3.16, to determine a core literature of 'exemplars' informing this thesis, and the results of a thematic synthesis of conjectures from those exemplars is presented in sub-section 2.3.17. Then applicable new insights discovered by a further more exploratory search of alternative academic disciplines are combined with these earlier findings, and reviewed as an extended core literature in sub-sections 2.4 to 2.8, from which a research question is derived in sub-section 2.9. This two-step approach for reviewing the literature is shown in Figure 5. Appendix D provides supporting materials from the literature reviews that are not essential for following the rationale of this thesis, and Appendix C summarizes the review protocol followed.

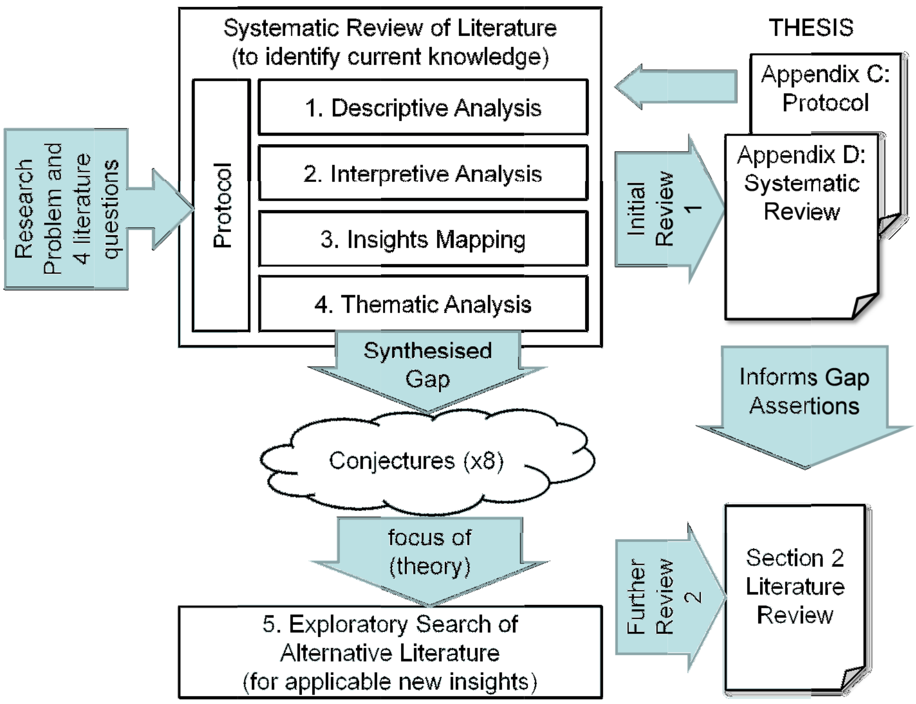


Figure 5: Literature Review Approach

During project 1 of the research methodology (see Figure 4), the systematic review of literature adapted a standard process prescribed by Cranfield University School of Management (see Figure 6), whereas the exploratory search of project 2 simply involved running the systematic review search strings again at a later date to look for new contribution exemplars published after August 17th 2011, and then following references in the bibliographies of selected contributions that cited potentially relevant literature not scoped into the initial systematic review. New in-scope exemplars were not found, and so existing literature analysis remained valid. However, new out-of-scope contributions were found and directly combined with previously identified core contributions. They are reviewed together as an extended core literature in sub-sections 2.4 to 2.8 to explain how sections 3, 4, 5 and 6 of this thesis were informed by existing knowledge.

Qualitative methods used by this two-step approach combined both descriptive and interpretive thematic synthesis (Thomas and Harden, 2007; Barnett-Page and Thomas, 2009). They produced an assessment of the explanatory value of current primary research within scoped-in core literature for a pre-defined set of literature questions (see Figure 7) by using descriptive schemes of analysis, declared interpretations, and a weighted scoring method (see more detailed explanations in Appendices C and D), to synthesise a gap in knowledge interpreted from insights mapped to each question out of lines of thinking (see Appendix D.5).

2.2 Systematic Review

2.2.1 Process and Methodology

The process followed by the systematic review of literature is described in Appendices C and D, and summarised in Figure 6 together with the review methodology applied. The purpose was to systematically search and review a potential gap in theory about catastrophic instability of the global financial system, and identify where there may be opportunities to improve understanding about how to mitigate its systemic risk of failure.

The review began with output from the scoping study, which identified 5 literature domains, 3 themes and 14 research conversations of significance to its purpose, with a preliminary appraisal, literature hypothesis, research focus and problem statement (see detailed findings of this scoping study in Appendix D).

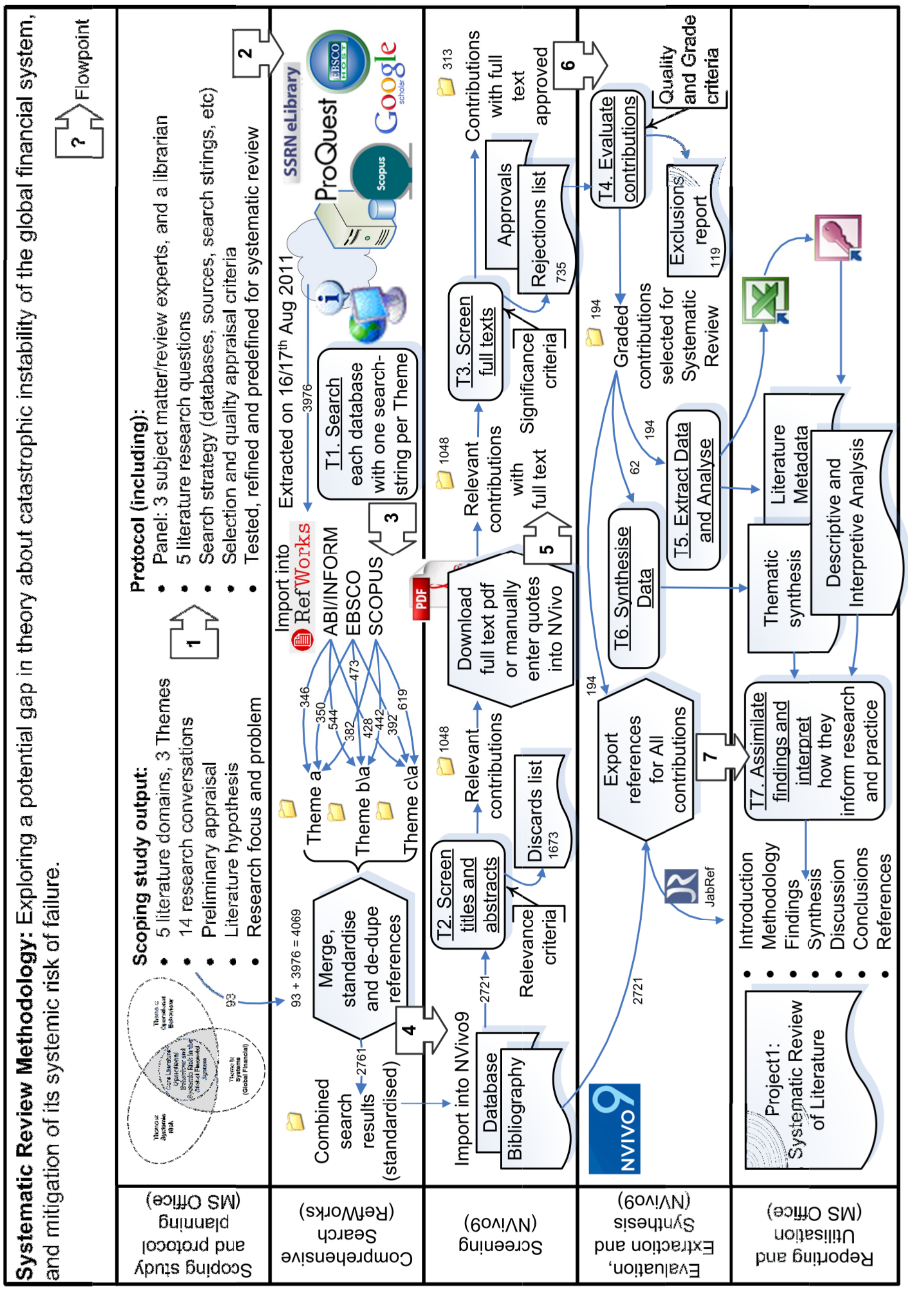


Figure 6: Systematic Review Process and Methodology

Figure 6 shows how Cranfield's standard process for a systematic review of literature was adapted, as swim-lanes or horizontal paths along which actual progression through the methodology occurred as specified by the review protocol, together with notes about individual tasks and their inputs, outputs and associated literature volumes. It summarizes how 4069 individual contributions of mostly academic literature were extracted from multiple sources on 16/17th August, 2011, and carefully filtered down to 194 selected contributions, out of which 62 were identified as core contributions and used to synthesize 8 conjectures in response to the 4 literature review questions (see Figure 7).

2.2.2 Literature Review Questions

Questions for the literature review were devised from a literature hypothesis about a gap in theory suggested by 14 research conversations discovered during the scoping study. They were phrased in a way intended to establish the general level of understanding in academic literature about instability of the global financial system. If a gap in theory about systemic risk exists, it was expected to be apparent within broader findings about instability, thereby avoiding confirmation bias caused by making the questions too specific to that risk.

Literature Hypothesis

"There is a gap in knowledge and associated theory about how (not why) systemic risk of failure of the global financial system operationalises as systemic failure, and how that risk could be mitigated."

With reference to the Global Financial System …

Q1. What is the nature of catastrophic instability or total collapse of this system?

Q2. What is meant by the risk of such an occurrence?

Q3. How does that risk materialise?

Q4. What can be done to mitigate that risk?

Figure 7: Systematic Literature Review Questions

2.2.3 Scope of Literature

A scope of literature for systematic review was determined from keywords used in both the literature hypothesis and the review questions, by selecting the entire literature domains of 4 academic disciplines normally associated with those keywords and one further domain comprised of domain-subsets from a combination of 'other' disciplines that share those keywords. Overlaps of those domains suggested three themes in this scope of literature: 'systemic risk', 'systems' and 'operational behaviour'. Then the focus of review attention became sub-sets **a**, **b** and **c** representing the most relevant literature from those themes, and their various unions and intersections identified in Figure 8.

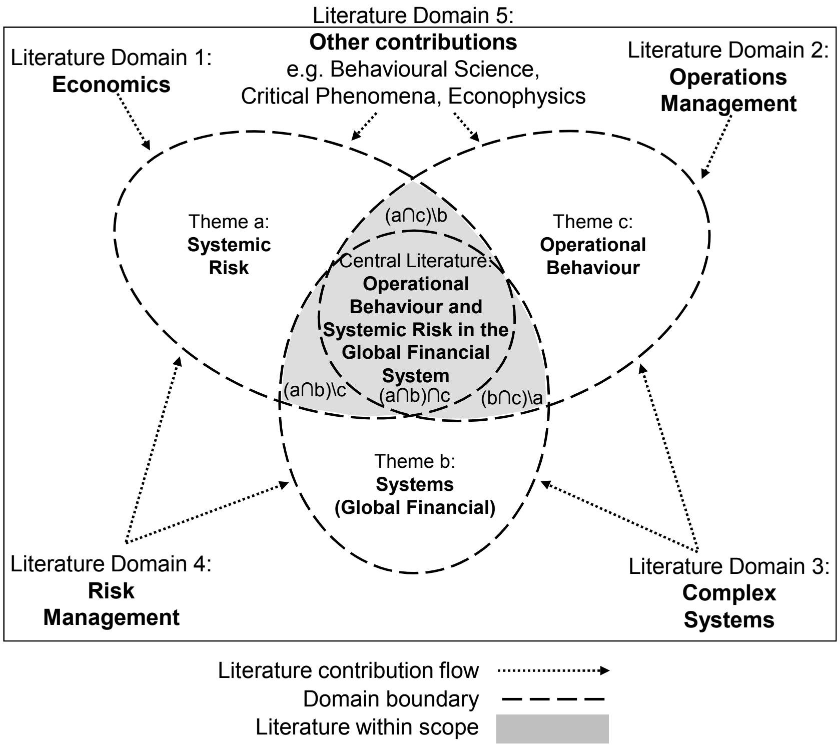


Figure 8: Literature Domains within Scope

2.2.4 Search

2.2.4.1 Strings

Search strings were constructed for each literature theme, from sub-strings containing keywords relevant to the 4 review questions (see Table 1), with care being taken to minimize query overlap so there would be fewer duplicated contributions found when query results were combined. Aside from that limitation, the strings were deliberately designed to collect as many relevant unique contributions as practical. This was considered necessary for demonstrating a gap in theory, and the credibility of a new contribution, because the notion of a 'theory' has a wide range of meanings across the multiple domains of literature in scope (see discussion in 1.3.3.1), requiring a comprehensive evidence-base.

Systematic Review Questions (with reference to the global financial system)		**Literature Domain Themes**		
		a **Systemic Risk**	**b\a** **Systems (Global Financial)**	**c\a** **Operational Behaviour**
	Base string for each theme ⇨	TITLE (systemic risk)	TITLE (bank OR banks OR banking OR financial)	TITLE (operat* OR behav*) AND TITLE (bank OR banks OR banking OR regulat* OR firm*)
			AND	AND
Q1	**Nature:** What is the nature of catastrophic instability or total collapse of this system?		TITLE (cris* OR fail* OR crash* OR collaps* OR vulnerab* OR instability OR stability)	(breakdown OR mania* OR panic*)
Q2	**Meaning:** What is meant by the risk of such an occurrence?		AND (risk*)	(OR threat* OR expos*)
Q3	**Materialization:** How does that risk materialize?			(OR exuberan* OR greed* OR appetite* OR fear* OR hazard* OR collect* OR evol* OR bubble OR subprime OR sub-prime OR suppl* OR demand*)
Q4	**Mitigation:** What can be done to mitigate that risk?			(OR mitiga* OR risk*)
			AND NOT (systemic risk)	AND NOT (systemic risk)
	Complete string for each theme ⇨	TITLE (systemic risk)	TITLE (bank OR banks OR banking OR financial) AND TITLE (cris* OR fail* OR crash* OR collaps* OR vulnerab* OR instability OR stability) AND (risk*) AND NOT (systemic risk)	TITLE (operat* OR behav*) AND TITLE (bank OR banks OR banking OR regulat* OR firm*) AND (breakdown OR mania* OR panic* OR threat* OR expos* OR exuberan* OR greed* OR appetite* OR fear* OR hazard* OR collect* OR evol* OR bubble OR subprime OR sub-prime OR suppl* OR demand* OR mitiga* OR risk*) AND NOT (systemic risk)

Table 1: Derivation of search strings from review questions

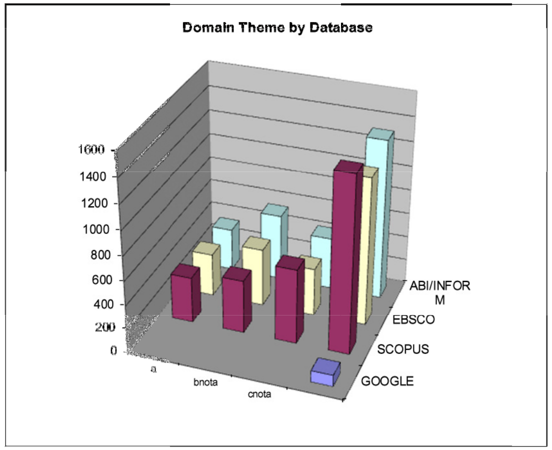
2.2.4.2 Results

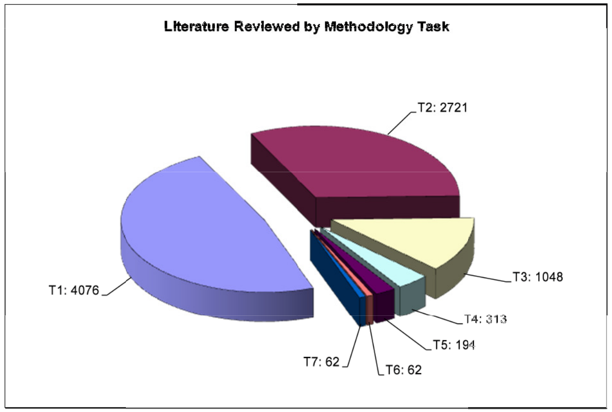
A summary of the number of contributions analysed during each task of the methodology is presented in Table 2, with sub-totals by category for statistics such as discards, approvals and significance (to the 14 research conversations).

By the end of the search task T1, after a few additional contributions were added as shown, the overall number of collected contributions was 4076 (as distinct from the combined number of 4069 returned by the search strings). Out of this total, 1308 were dropped as duplicates and 47 as corrupted records, leaving 2721 contributions that were actually reviewed. After task T4 this number was filtered down to 194 contributions selected for evaluation by conversation/ significance criteria. From that set of 194 selected contributions, task T5 extracted a core subset of 62 'exemplars' of distinct lines of thinking (LoT) which were also mapped to one or more significance criteria, and were used for thematic analysis, conjecture synthesis and findings interpretation in tasks T6 and T7. This is only 2% of the overall number of 4076 collected contributions. Although this is a small percentage, in total the 62 exemplars participated 306 times in 11 research conversations, which is an average of nearly 5 conversations each.

Methodology Task		Domain Theme				Task Literature			
	Database	a	bnota	cnota	Totals	In	%T1	Drop	Retain
T1. Search	ABI/INFORM	346	544	428	1318				
	EBSCO	350	473	392	1215				
	SCOPUS	382	442	619	1443				
	GOOGLE (Suppl)				93				
	RefWorks Totals	1078	1459	1439	4069			1308	2761
	Corrupted records						1.2%	47	
	Own Papers (entered in Nvivo)				3				
	Other Literature (entered in Nvivo)				4				
	Overall Results				4076	4076	100%	1355	2721
T2. Screen Titles and Abstracts (for Relevance)						2721	67%	1673	1048
T3. Screen Full Texts (for Approval)						1048	26%	735	313
T4. Evaluate Contributions (for final Selection)						313	8%	119	194
T5. Extract Data						194	5%	132	62
T6. Synthesize Data						62	2%		
T7. Assimilate Findings and Interpret						62	2%		

Reasons		Discarded as not Relevant 'Drop' column = Sum of Discards								Rejects	T3: Approved by Significance and T4: Selected by Significance 'Retain' column = contributions mapped to one or more Significance Criteria 'Drop' column = Rejects not mapped to any Significance Criteria														Excluded for Quality 'Drop' column = Sum			Graded Selections for Review 'Retain' column = Sum		
Database	Dupl	D01	D02	D03	D04	D05	D06	D07	D08	s	S01	S02	S03	S04	S05	S06	S07	S08	S09	S10	S11	S12	S13	S14	G06	G05	G04	G03	G02	G01
ABI/INFORM	791																													
EBSCO	494																													
SCOPUS	17																													
GOOGLE (Suppl)	6																													
RefWorks Totals	1308																													
Corrupted records																														
Own Papers (entered in Nvivo)																														
Other Literature (entered in Nvivo)																														
Overall Results																														
T2. Screen Titles and Abstracts (for Relevance)	20	593	319	117	443	39	74	36	32																					
T3. Screen Full Texts (for Approval)										735	23	17	117	84	18	118	63	56	85	13	8	76	42	22						
T4. Evaluate Contributions (for final Selection)										119	23	16	85	73	17	82	50	34	52	5	4	54	31	20	26	8	85	23	5	166
T5. Extract Data										132			49	53	16	59	32	19	22		2	28	20	6						62
T6. Synthesize Data																														
T7. Assimilate Findings and Interpret																														





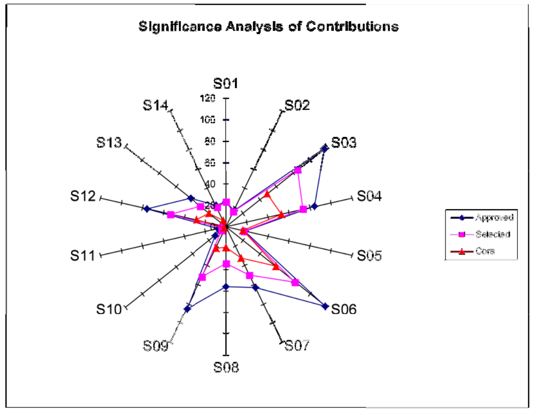


Table 2: Systematic Review of Literature, Summary Data.

2.2.5 Findings

Sub-sections 2.3.1 to 2.3.15 in this review describe contributions to each of the 14 research conversations found in the selected literature, followed by a critical assessment of their significance to this thesis in sub-section 2.3.16.

2.3 Conversations

2.3.1 Discussions: about theory development (S01)

The contributions participating in this first conversation were recognized for their significant insights in explaining the meaning of the phrase 'a gap in theory' from the literature hypothesis of that study. The 4 lines of thinking identified within this conversation were:

2.3.1.1 Nature of Theory (S01.1)

This is known to be a source of contention among academic disciplines, and poses a serious challenge to the acceptance of potential new multi-disciplinary theory. There are 7 contributions within the selected literature that offer insights to this line of thinking. Among them is a definition of theory that is widely accepted in the social sciences, contributed by Wacker (1998) from the operations management literature. He proposes four criteria which a theory must satisfy, calling for: conceptual definitions, domain limitations, relationship-building and predictions. To be a 'good' theory he also suggests it must apply the virtues of uniqueness, parsimony, conservation, generalizability, fecundity, internal consistency, empirical riskiness, and abstraction. Therefore, regardless of the research methodology used, he argues that good theory-building research should define the variables, specify the domain, build internally consistent relationships, and make specific predictions. Similarly, Whetten (1989) addresses the absence of a broadly accepted framework of expectations and standards in the organizational sciences by translating the general works of Kaplan and Dubin into simple concepts for discussing the merits of conceptual writing in that discipline. After identifying the constituent elements of theory, he establishes standards for the theory-development process, and summarizes the expectations of reviewers in seven key factors to be considered when judging theoretical papers: *"what's* *new?"*; *"so what?"*; *"why so?"*; *"well done?"* (reflects seasoned thinking, completeness and thoroughness); *"done well?"* (well written); *"why now?"*; and *"who cares?"*.

Then 2 contributions examine what theory is not, offering a counterpoint to the above-mentioned arguments for defining what it is. Sutton and Staw (1995) list five elements that are often confused with theory, and are used in lieu of it: references to theory, data, lists of variables or constructs, diagrams, and hypotheses. After describing how such elements arise in research manuscripts, they examine how journals contribute to this state of confusion. However, they agree that if a theory is particularly interesting, the standards that journals use should be relaxed somewhat when evaluating how well it is tested or grounded. For example, they suggest that major contributions can be made even when using data that is more illustrative than definitive. In the same paper, they do also make a positive assertion about theory, describing strong theory as understanding the detail systematic reasons 'why' phenomena occur. DiMaggio (1995) comments on Sutton and Staw by expanding on three views about what good theory should be: theory as covering laws, theory as enlightenment, and theory as narrative. He goes on to argue that many of the best theories are hybrids of these, and then elaborates on the *"vexing choices"* to be made: *"clarity versus defamiliarization, focus versus multi-dimensionality, and comprehensiveness versus memorability"*.

The final 3 contributions look at research philosophy aspects of theory. In their review of the advice on methodologies and methods offered to early-career researchers, Mackenzie and Knipe (2006) argue that the use of mixed methods should be discussed more, particularly when addressing the perceived dichotomy between qualitative and quantitative research methodology. On the topic of theory, they make a distinction between theory and a theoretical framework of logically related assumptions, concepts and propositions. They explain the latter is sometimes referred to as a paradigm. Although, they agree that notion of a paradigm in research conflicts with other definitions, such as a particular combination of epistemology and ontology from an interpretive framework used to make claims of new knowledge. Their conclusion is that this inconsistent use of terminology can be confusing for researchers.

From the human resources literature, Worren, Moore and Elliott (2002) look at the contrasts between practice and theory, to ask how theories in management can be developed and used as cognitive tools by practitioners. To address the flaws of traditional criteria for scientific validity, they develop a framework and offer examples for a pragmatic form of validity encompassing the characteristics of useful knowledge according to three representational modes: propositional, narrative, or visual. Then they explore the implications for theory building and research in extending such evaluation criteria as explanatory power and falsifiability to incorporate this notion of pragmatic validity.

Finally, Beinhocker (2011) argues that the theoretical and ontological implications of *"evolution as computation literature"* have not been adequately explored for evolutionary and institutional economics. He further argues that if the perspective they offer is not embraced, those fields of economics will continue to suffer a proliferation of ad hoc theories, ontological disputes, and a lack of rigour.

2.3.1.2 Theory Development (S01.2)

There are also 7 contributions within the selected literature of this line of thinking. The most influential work is Dubin (1978), who's stated objective was to provide *"a handbook of practical usefulness that may become a frequently consulted source ...* [of reference about building] *viable models of the empirical world that can be comprehended by the human mind"*. There is some overlap with the previous line of thinking (*S01.1*) in that contributions to theory development often begin with a definition of theory. In Chapter 1 Dubin quotes Karl Popper's definition of the nature of theory, from 'The Logic of Scientific Discovery' (1959): *"Theories are nets cast to catch what we call 'the world': to rationalize, to explain, and to master it. We endeavour to make the mesh ever finer and finer"*. Dubin uses the terms theory, theoretical model, model, and system interchangeably, to stand for a closed system from which predictions about the nature of man's world are generated that are open to some kind of empirical test.

There are 2 other contributions in this line of thinking from the selected literature that directly address theory building. Gioia and Pitre (1990) argue for a multiparadigm approach to theory building using a metaparadigm perspective intended for establishing correspondences between paradigms and theory construction efforts. A narrower approach is adopted by Pawar (2009), who focuses on hypothesis specification in organizational studies. In his section on the relevance of this book, Pawar confirms that a lack of clarity exists in the literature about what theory is, and there is general confusion about how to incorporate a ‘proper’ theory into a paper.

In their definition of mixed methodology research, Johnson, Onwuegbuzie and Turner (2007) argue that this type of research is one of three major research paradigms: quantitative research, qualitative research and mixed methods research. After reviewing the debates about singular and universal truths versus relative truths, they present definitions of this approach collected from leading researchers. Then they summarize the issues that arise in current work.

Three contributions about simulation research complete this line of thinking, by describing how the research method of simulation (Dooley, 2002) can be used to build and test theories. Epstein (1984) examines the varying degrees of adequacy that can be achieved when building and testing theory by simulation, and argues that plausibility proofs should be the expected outcomes. Then Bankes (2002) summarizes the potential for building theory with agent-based modelling to demonstrate emergent phenomena in the areas of research where complexity science overlaps social science.

2.3.1.3 Theory Testing (S01.3)

In the line of thinking specifically about theory testing there are 3 contributions within the selected literature. A summary of the model construction and assessment of an artificial stock market is presented by LeBaron (2002). Then Lustick (2000) describes the challenges and opportunities of a constructivist approach to the study of collective identity using agent-based models. He shows how macro-patterns emerge from micro-interactions, and how they can be studied systematically. At the other end of the testing process, Windrum, Fagiolo and Moneta (2007) examine the methodological challenges of agent-based economics models, and discuss the prospects of three alternatives for their empirical validation: indirect calibration, the Werker-Brenner approach, and the history-friendly approach.

2.3.1.4 Theory in Economics (S01.4)

Hodgson (2002) introduces the 6 contributions to this line of thinking with a defence of biological analogies that apply Darwinism to socio-economic evolution, and argues that viable evolutionary economics must be Darwinian in some fundamental sense. Then he expands on these notions in Hodgson (2007) by explaining how evolutionary and institutional economics have become the new mainstream of thinking. He argues that one of the major priorities of these challenges to orthodox economics is the development of new theoretical alternatives to neoclassical equilibrium approaches, and emphasizes the importance of interdisciplinary dialogue in achieving that goal. Zafarzynska and van den Bergh (2010a) look at formal aspects of evolutionary-economic modelling in their broad classification of methods into: evolutionary game theory and selection dynamics, evolutionary computation and multi-agent models. They organize the components of such models into nine classifications: diversity, innovation, selection, bounded rationality, diffusion, path dependency and lock-in, coevolution, multi-level and group selection, and mechanisms of growth. Then, for the components of each classification, they clarify the choice range, formal expression, associated assumptions, and possible technique for formalization.

Although Heckbert (2009) deals with the challenges of validating agent-based models, his contribution is placed with this line of thinking on theory in economics because he also addresses the problem of calibrating agent-based models with experimental techniques that use human participants. This generates economic theory by studying human behaviour, in order to identify rules and conditions for calibrating artificial agents before simulation begins. A similar aside is provided by Upper (2011), in his critical assessment of the economic theory implications of the modelling assumptions in simulations that attempt to estimate the danger of contagion in exposures arising from participating in the interbank loan market. Tesfatsion (2006) brings this line of thinking back to a constructivist approach to economic theory, by defining agent-based computational economics (ACE) as: *"the computational study of economic* *processes modelled as dynamic systems of interacting agents"*. Her conclusion is that ACE models *"could facilitate the development and experimental evaluation of integrated theories that build on theory and data from many different fields of social science"*.

2.3.2 Assessments: of a potential gap in theory (S02)

This conversation had 16 contributions in the selected literature, all sharing a single line of thinking, namely: there is a potential gap in theory informing the research problem. The following 7 contributions are the most credible and recent examples from this conversation with references to that potential gap in theory.

Buchanan (2009), in his review of current scientific opinion across multiple disciplines about what he calls the recent *"financial meltdown"*, reports the general consensus that there has been a massive failure of the dominant economic model. He finds there is a widely perceived need for some fresh thinking, not just more of the same type of theory. Agent-based techniques are discussed as probable ways that thinking can be developed, and Helbing is quoted as calling for the need to re-imagine the social and economic sciences on a larger scale, and to bring experts from different fields together to create new ideas by 'colliding' complementary knowledge much as new particles are created in particle colliders.

In his own paper, Helbing (2010) expands on these views. After summarizing the properties of complex systems, and identifying factors related to the emergence of systemic risks in socio-economic systems, he lists the success stories of research in some application areas of complexity science. They include the Nobel prizes of Ilya Prigogine, Thomas Schelling, and Paul Krugmann. However, he argues that *"crises still occur because the system dynamics are not well enough understood, leading to serious management mistakes"*. In conclusion, he calls for more research in closing the gap between existing socio-economic problems and solutions, by building greater research capacities and establishing 'integrative systems design' as a new study direction.

Allen and Snyder (2009) agree that financial crisis literature still lacks a systemic understanding. In their section on new thinking, they describe complexity theory, complex adaptive systems and evolutionary economics as the best approach towards understanding the current crisis, and recommend a departure from the neoclassical general equilibrium model and other explanations from mainstream economics.

When Govtvan and Mansurov (2011) examined approaches to the estimation of systemic risk in the financial sphere, they also observed that there has been insufficient development of *"many theoretical and practical matters"* connected with the problem of systemic risk.

Zeidan and Richardson (2010) analysed the financial crisis through the complexity theory lens, and concluded that the two main approaches to complexity in economics, econophysics and econobiology, only address specific aspects such as the network topologies of banking systems and the genetic algorithms used in predicting bank failures. They argue there is a need for an encompassing theory that can tie all the different approaches together in a complexity-based standard model of finance.

In their stocktaking of issues and experiences relating to macroprudential instruments and frameworks, from a BIS paper by the Committee on the Global Financial System, (Hoogduin, 2010) calls for more research contributions to *"big gaps in the nexus between the real economy, the financial system, and monetary policy"*. It also welcomes latest research involving complex systems and related research analysing the financial system as a complex dynamic network of agents.

Then, most recently, Beinhocker (2011) writes that *"evolution as computation literature"* introduces a new stream of interdisciplinary research that can make a powerful contribution to evolutionary theories of economics by explaining processes of order and complexity in the economy.

2.3.3 Theories: about systemic risk (S03)

Among the 85 contributions to this conversation in the selected literature, there are 10 lines of thinking:

2.3.3.1 Candidate Theories (S03.1)

However, only 8 contributions from this literature can claim some credibility as a candidate theory of systemic risk. Acharya (2009) stands out as an exemplary contribution to theory in economics, but the others all have some inadequacies (see sub-section 2.3.16 for a comparative assessment).

Acharya models systemic risk as the endogenously chosen correlation of returns on assets that give rise to a risk-shifting incentive for banks to undertake correlated investments. In doing so he focuses on specific financial aspects of these phenomena in the current systemic crisis, implicating recent innovations and practices, but cannot explain the observed phenomena of past crises or their potential future variations. For these reasons, although he has made a well-structured contribution to theory, it does not constitute a general theory capable of addressing most potential crises. Nevertheless, his model shows that prudential regulation should operate at a collective level, as a function of each bank's joint risk with other banks together with its individual bank risk.

2.3.3.2 Other insights (S03.2)

There are other contributions from this literature that offer alternative forms of conceptualization for systemic crises. The following 7 lines of thinking address specific types:

S03.21 Catastrophe. The notion of a catastrophe model is presented by Pruden, Paranque and Baets (2004) to illustrate how a catastrophe model from the behavioural sciences can be used to explain how a trader or investor may profit from behaviour observed in a stock market. In modelling that behaviour, they use a cusp-catastrophe type model as a positive scientific theory of 'why' it occurs, and technical market analysis provides a nominal theory of rules and principles about 'how' it occurs. Their model describes how the forces of greed and fear drive imbalances between buying power and selling pressure to explain behaviour such as irrational exuberance. Its main weakness is shared by all literature in this line of thinking, namely their use of catastrophe theory merely as an illustrative framework. Technical market analysis produces their main findings.

Other models of this type use different behavioural parameters. For example, Ho and Saunders (1980) use the interplay between a bank's net asset cash flows and its net deposit flows.

S03.22 Evaluation. All of the contributions to this line of thinking are incomplete or inadequate in some way. This is illustrated by Huang, Zhou and Zhu (2009), who provide a coherent framework for measuring the systemic risk of a group of major financial institutions, but the indicator of systemic risk they use is based on ex-ante measures of market perceptions, which are too subjective to offer any accuracy.

S03.23 Propagation. Although contagion is often mentioned by contributions in the selected literature, there are only a few contributions that focus on modelling how this phenomenon propagates. Upper (2011) looks at simulation methods to demonstrate the danger of contagion in interbank markets, Gai and Kapadia (2010) examine how contagion occurs in financial networks, Martinez-Jaramillo et al (2010) estimate the distribution of losses for the banking system within a network contagion model, and Uhlig (2010) models a systemic bank run.

S03.24 Network. As with contagion, network effects are also mentioned often by contributions in the selected literature, such as Rochet and Tirole (1996), but true network models are rare. Elsinger, Lehar and Summer (2006) offer an exception that proves this rule. They carried out a systematic analysis of the impact of a set of macroeconomic risk factors on a group of banks, and built a network model of their mutual credit relations. This uncovered exposures to aggregate risk at system level, enabling them to make one of the first attempts to measure risk for the entire banking system, rather than at the level of individual institutions.

S03.25 Criticality. Among the contributions that address models of criticality, the most interesting is Helbing's (2010) review, which offers broad perspectives on this growing multi-disciplinary field. He refers to the potential of criticality notions in complexity science and related fields of knowledge, but falls short of explaining how such models can be developed, and does not attempt to offer new models to demonstrate that potential for this line of thinking. Criticality modelling is clearly in the early stages of establishing itself in the literature domains of systemic risk and financial stability, and it is struggling to find credible applications among this research. A few contributions were even screened out of the selected literature because they failed the protocol's quality criteria for some reason. However, the general consensus in that literature takes the view such notions have an unrealized potential which are likely to become a major strand of future research.

Promising recent examples include Venkatasubramanian (2011), who considers the challenges and opportunities in managing the risk of potential fragility in complex engineered systems. He builds a view of common underlying patterns from incidents of failure across multiple industries, and calls for a more *"prognostic approach"* which can anticipate problems and replace the current react-and-fix methodology with one of managing systemic risk. For a more direct focus on the financial system, Zeidan and Richardson (2010) analyse the current financial crisis through the lens of complexity theory, to understand how to fill the gap in knowledge highlighted by the inability of current models to signal this crisis. They examine approaches from econophysics and econobiology, and consider the misleading nature of regulatory concepts about linear thinking and mild randomness (e.g. Gaussian distributions), arguing that regulators should not be asking questions about how stringently to regulate the system, but instead should be asking more fundamental questions about what is being regulated.

S03.26 Operations. Although operational models are pervasive throughout the selected literature, they are rarely described or named as 'operational'. Among the contributions that focus on operational models in this line of thinking, only 3 of them refer to 'operations' in some way, and just one of them makes a direct reference to an 'operational framework.' The latter contribution is from Gai, Jenkinson and Kapadia (2007), who look at the challenges of implementing a more rigorous and practical operational framework for improving the regulation of financial stability. They use models developed by the Bank of England to assess how the probability and potential impact of systemic crises has changed over the recent past, and find that although systemic crises are less likely in the future, they will potentially be more severe.

S03.27 Behaviour. The dominance of behavioural finance in systemic risk and financial instability literature is reflected in more than 40 contributions of behavioural models to this line of thinking. Perhaps the best-known representation of this literature is contributed by Shiller (2003), who describes behavioural finance as collaboration between finance and other social sciences such as psychology and sociology. Shiller explains how, since their dominance of academic thinking in the 1970s, the notions of efficient markets theory and rational expectations models have come to be recognized as being riddled with anomalies. After illustrating some of these, using his concept of irrational exuberance to describe the self-limiting behaviour of bubbles, he urges that future research should maintain a more eclectic approach, which is indeed what is found in this line of thinking. Dow (2000) provides a good example of that in his survey of systemic risk research and his discussion of moral hazard, initial shocks and distress propagation.

2.3.3.3 Related Concepts (S03.3)

This line of thinking gathers a collection of indirectly related concepts not present in other lines of thinking about systemic crisis models, frameworks and simulations. Goldstone and Janssen (2005) is a good example. They describe how agent-based models can explain collective behaviour computationally, providing a process-oriented alternative to descriptive mathematical models. However, it does not make the link between these models, the collective behaviour of participants in the financial system and systemic crises.

2.3.3.4 Foundational Contributions (S03.4)

Seminal or ground-breaking research is represented by this line of thinking, which created the foundations for thinking within several other conversations. They are collected here for reference. Examples include Zeeman's (1976) article on Catastrophe Theory, Shiller's (2000) article on Irrational Exuberance, and the article by Axelrod and Hamilton (1981) on The Evolution of Cooperation.

2.3.4 Perspectives: on the system (S04)

Among the contributions to this conversation in the selected literature, there are 8 lines of thinking about the nature of the global financial system (GFS) and its various component sub-systems:

2.3.4.1 Banking System (S04.1)

Among the contributions to this line of thinking, May and Arinaminpathy (2010) stands out as a contribution to literature that attempts to explain the interplay between the characteristics of individual banks and the overall dynamical behaviour of the GFS. For example, they explore simple mathematical caricatures for banking ecosystems, suitable for proposing a basic model of banking capable of providing a relatively simple metaphor that can offer interesting and potentially important insights. Uhlig's (2010) model of a systemic bank run takes a similar perspective. Whereas, other contributions in this collection are more focused on individual bank perspectives within the context of the banking system, such as the role of bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005) and the failure mechanics of dealer banks (Duffie, 2010).

A further 2 contributions to this line of thinking refer to the Shadow Banking System. In their exploration of the linkages between greed and governance in the GFS, Weitzner and Darroch (2009) describe how development of the Shadow Banking System and opaque products has been motivated by greed, in order to make governance of related activities difficult at institutional and market levels. Later, Van Doren (2011) supports the view of Gorton and Metrick (2010), who argue that the financial crisis of 2008 is best understood as a collapse of the shadow banking system, which occurred because the market did not understand the role of that system, or the true causes of the financial crisis. From these contributions it is clear that any model developed by the research following this systematic review will have to incorporate this shadow system, otherwise key influences on the overall GFS will be overlooked.

2.3.4.2 Complex System (S04.2)

This line of thinking differs from *S03.25* in that it refers here to a general complexity perspective on the GFS, not different models of criticality for the GFS. There are 2 principal contributions. One of them (Zeidan and Richardson, 2010) has already been discussed because it contributes to both lines of thinking. However, May, Levin and Sugihara (2008) specifically address the complexities of tipping points, thresholds, breakpoints and regime shifts of financial systems. They describe how changes in the overall state of a complex system can become catastrophic, at which time it typically exhibits some form of hysteresis. Those changes are explained as being derived from how the system is organized, its internal feedback mechanisms, and certain latent linkages that are often unrecognized. Once set in motion they can become explosive, with the effect that recovery from catastrophe is usually much slower than the collapse, and in extreme situations may be irreversible. Their contribution is placed here because, as mentioned in *S03.21*, most references to catastrophe theory use it for illustration or context, with some other perspective actually generating research results. In this case it is an understanding of how complex systems deal with change that informs their findings.

2.3.4.3 Economic System (S04.3)

Among the many contributions to this line of thinking, Helbing (2010) has already been discussed in the context of a potential gap in theory and models of criticality, but he also raises interesting implications for the GFS when it is considered to be an economic system. From that perspective, complexity theory is shown to predict that experience-based or intuitive approaches to understanding how social and economic systems function often lead to the illusion of control, and a *"dangerous logic of failure"*, with occurrences of paradoxical system behaviours, unwanted side effects, and sudden regime shifts, in which the causes and effects will not be proportional to each other. Although, the theory is also said to suggest that it is possible to use the self-organizing, adaptive nature of such systems to achieve favourable economic outcomes.

Stiglitz (1999) nicely summarizes the views of most other contributions to this collection, into 10 basic points and 3 methodological observations on reforming what he calls the global economic architecture. However, throughout the main text he refers to such things as interventions to stabilize capital flows, which generate high costs and limit benefits. All of which indicate that he is referring to a dynamic system not a static architecture.

2.3.4.4 Financial System (S04.4)

A more traditional financial system perspective on the GFS is taken by the large collection of contributions to this line of thinking. Gramlich and Oet (2011) offer a recent example in their assessment of the structural fragility of the GFS. They explore the elements of that fragility, and suggest how to conceptualize and quantify related issues for developing early warning systems. A different approach is offered by Wagner (2008), who argues the counter-intuitive case for not providing regulatory relief to banks for diversification, by showing how their stability level reduces for various reasons if they do diversify, even though their risk-sharing is diminished.

Loretan (1996) combines a financial system perspective with economic models, in a good example of cross-over literature, which also includes Minky's (1993) economic views in his Financial Instability Hypothesis, and a more recent theoretical study on the estimation of systemic risk in the 'financial sphere' by Govtvan and Mansurov (2011). Indeed, cross-over thinking from other system perspectives often refers to this financial perspective in a similar way.

2.3.4.5 Insurance System (S04.5)

Among the insurance contributions in the selected literature, there are only a few that view the GFS as a system of insurance. Schich (2010) examines how certain financial instruments that provide an insurance function were at the core of recent difficulties, directly exposing many insurers to the epicentre of the financial crisis in a systematic way. Then he considers the adverse ways in which insurance companies have been affected by the current financial crisis through their investment portfolios, due to deteriorating market valuations. Concentrated insurance-related exposures to credit risks, market risks, and mortgage guarantees are revealed in many financial groups that are active in insurance markets, although the overall solvency of the insurance sector does not appear to be threatened, yet.

On that same theme, O'Brien (2010) considers how to set a minimum solvency margin for the insurance sector, and assesses the implications of the global financial crisis for each method. In conclusion, he recommends a regulatory focus on stress tests which uses a more robust approach to calculating the probabilities of breaching that margin.

2.3.4.6 Market System (S04.6)

The market system view of the GFS in this line of thinking is surprisingly under-subscribed in the selected literature. In their examination of the associations between market crises, the financial system and the real economy, Scardovi, Gatti and Ventola (2010) argue there are five basic pillars currently supporting the global financial system. Three of them are market-related: market liquidity, funding structure and its mismatch, and asset quality in terms of the solvency of counterparties or the feasibility of debt recovery. Although they make no direct reference to a market system, their summary of events leading up to the current financial crisis, and their market-driven prognosis of the way forward relies heavily on a market paradigm of phenomena that occur in the financial system. Ball (2009) takes the view that Eugene Fama’s notion of ‘The Efficient Market Hypothesis’ has suffered from recent critiques of its many anomalies allegedly exposed during the current financial crisis, which he argues cannot be explained by a strict interpretation of that theory. However, he maintains that even if it is not a complete representation of how markets behave, the theory is durable despite its inevitable and painfully obvious limitations. His analysis of the systemic nature of bubbles, and the contributing role of market prices in valuations, confirm his interpretation of the GFS as a market system.

Other contributions include simulations of market systems, used to represent the GFS. Iori, Jafarey and Padilla (2006) simulate systemic risk in the interbank market, while LeBaron (2002) describes the building of an artificial stock market, to illustrate how simulations can be built for financial markets in general. The key principle behind this type of simulation is that financial markets are modelled as market systems.

2.3.4.7 Operational System (S04.7)

Out of the entire selected literature, Shleifer and Vishny (2010) is probably the closest to an example of a theory of GFS operations. It is placed here among the contributions to an operational system perspective on the nature of the GFS because it takes an operational approach to theorising about financial intermediation. In particular, it points to the instability of highly leveraged banks that contribute to systemic risk by their profit maximizing operational behaviour.

Other contributions explore how competitive versus monopolistic banking systems operate (Boyd, De Nicola and Smith, 2004), fault-lines in the way the GFS operates (Pattanaik, 2008), and the benefits of a central counterparty in reducing the systemic risks resulting from transactions in OTC derivatives (Duffie, 2010).

2.3.4.8 Regulatory System (S04.8)

The most recent example among the contributions to a regulatory system line of thinking is Fisk (2011). He argues that the real failure of the current financial crisis should not be attributed to the regulators, but to their oversight system, the meta-regulation framework. This is equated in his article to the risk-regulatory sub-system of engineering systems. Then the evolution of financial crises is explained in terms of the stages of an engineering systems failure, and the functions of its risk-regulatory sub-system. Similarly, the article by Rochet (2009) proposes a new regulatory system for the 'too big to fail' (TBTF) problem, based on an industrial reorganization approach to systemic institutions, including interbank and money markets. In his other contribution to this line of thinking, Rochet (2010) develops these ideas into a call for the adoption of a 'platform-based' approach to regulating systemic risk of the GFS. This is aimed at protecting 'platforms' (vital parts of financial infrastructure), not individual banks, with a new system of regulations. Sy (2009) takes the same view, but is more specifically focused on credit rating agencies and rated markets.

Levine (2000) finds that both bank-based and market-based systems can operate effectively, but neither is better than the other. He concludes that in fact, the legal framework critically influences long-run growth, and so GFS focus should be on creating a sound legal environment.

2.3.5 Definitions: of systemic risk, or similar terms (S05)

Among the 17 contributions to this conversation in the selected literature, there are 4 lines of thinking:

2.3.5.1 Causal (S05.1)

The contributions to this line of thinking each offer a causal definition. For example, Acharya (2009) models systemic risk as the endogenously chosen correlation of returns on assets held by banks. This is a positive causal definition, from a theory that uses an equilibrium characterization of systemic risk. According to that model, it arises due to four factors: (i) in extension, by a spill-over effect after a bank failure, when depositors migrate to surviving banks; (ii) through network externalities such as the payments and settlements systems; (iii) through the failure of a few big banks; and (iv) through asymmetric information about the positions that different banks hold, as when the cost of a healthy bank's capital rises after the failure of its peers. Rochet and Tirole (1996) offer a transactional alternative in their contribution on interbank lending. They define systemic risk as being caused by the propagation of an agent's economic distress to other agents linked to that agent through financial transactions.

Kane (2010) argues that official definitions of this type lead to an incomplete diagnosis of the roots of systemic risk, and misguided strategies of regulatory reform. Then he discusses a series of complementary ways of advancing towards the goal of a better definition, but does not actually formulate one! The other contributions in this line of thinking either: offer equally incoherent discussions about the causal trade-off between regulatory capital requirements and 'efficiency' (Tsomocos, 2003); or focus on causal factors that are difficult to evaluate, such as moral hazard (Dow, 2000); or conclude that attempting to produce a 'proper definition' of causes may be a waste of time (Mundy, 2004).

2.3.5.2 Consequential (S05.2)

The single contribution in the selected literature to this line of thinking (Huang, Zhou and Zhu, 2009) uses the price of insurance against the consequences of financial distress as the measure of systemic risk. Towards that objective, they define systemic risk as *"multiple simultaneous defaults of large financial institutions"*. However, they do not show how that insurance may affect defaults.

2.3.5.3 Combined (S05.3)

In this line of thinking, Martinez-Jaramillo et al (2010) take an operational view. They refer to systemic risk as *"the risk of the occurrence of an event that threatens the well functioning of the system of interest (financial, payments, banking, etc.), sometimes to the point of making its operation impossible"*.

Schwarcz (2008) comes up with a much wider, more integrative legal interpretation in his testimony before the U.S. House of Representative Committee on Financial Services on October 2nd, 2007. He offers a working definition that holds systemic risk to be: *"the risk that an economic shock such as a market or institutional failure triggers (through panic or otherwise) either the failure of a chain of markets or institutions, or a chain of significant losses to financial institutions, resulting in increases in the cost of capital or decreases in its availability, often evidenced by substantial financial-market price volatility"*. This definition has so many embedded assumptions and is sufficiently vague that it has little practical value for either academic or regulatory purposes.

An alternative, implicit definition of systemic risk in this line of thinking is contributed by Mishkin's (1992) influential article from the financial instability literature. If systemic risk is understood to mean financial instability that creates the risk of a financial crisis outcome, then Mishkin defines that outcome as: *"a disruption to financial markets in which adverse selection and moral hazard problems become much worse, so that financial markets are unable to efficiently channel funds to those who have the most productive investment opportunities"*. As with the Schwarcz definition, this is sufficiently vague to be unusable.

2.3.5.4 Similar terms and meanings (S05.4)

Contributions to this line of thinking are mostly reviews of definitions in systemic risk literature, containing conclusions about the state of its terminology. Govtvan and Mansurov (2011) provide the most recent assessment of this literature among selected contributions, in which they find that *"there is no unique, established definition of systemic risk"*. They go on to attribute this situation to the insufficient development of many theoretical and practical matters connected to this problem. A common feature of contributions to this conversation is the failure to offer adequate explanations for the notion of 'probability' in their definitions of systemic risk, which is a major part of any risk definition. They focus on the causes and effects of systemic risk, but not how that risk refers to the likelihood of systemic failure. For example, is it a probability or a value-at-risk? If it is a probability, does it remain constant over some period of time, or does it relate specifically to an assessment at a current point in time? Furthermore, how does it vary over time? These questions remain broadly unanswered.

2.3.6 Forms: of distress in the system (S06)

Among the 82 contributions to this conversation in the selected literature, there are 8 lines of thinking:

2.3.6.1 Banking Distress (S06.1)

All of the contributions to this line of thinking are from the financial crisis literature, and take a broad perspective on distress. The most recent is by Rotheli (2010), who attempts to describe the important determinants of the current crisis. He identifies the bounded rationality of banks, the credit cycle, monetary policy, rating agencies and bank regulations. When Rochet (2003) examined why there are so many banking crises, his main conclusions were: (i) although many banking crises have been initiated by financial deregulation and globalization, these crises were largely amplified by political interference; (ii) supervision systems face a fundamental commitment problem, analogous to the time consistency problem confronted by monetary policy; (iii) the key to successful reform is the independence and accountability of banking supervisors. Similar sentiments were expressed by Minsky (1977), who described in his theory of systemic fragility the fundamental nature of this type of observed phenomena as *"incoherent behaviour"* by key participants in the economy, generally characteristic of a financial crisis among fragile financial structures, whereby their reaction to disturbances amplifies rather than dampens the initial disturbance. Boyd, DeNicola and Smith (2004) look at variations in this condition of general distress between competitive versus monopolistic banking industries.

2.3.6.2 Economic Distress (S06.2)

This is a popular line of thinking, with a diverse range of interpretations. However, in his discussion of systemic risks in society and economics, Helbing (2010) shows that linear, experience-based, or intuitive approaches to economic systems often fail to explain the way they actually function, particularly when economic distress emerges during sudden regime shifts. This theme of shifts to a new regime is expanded on by Asensio and Lang (2010) in their proposal of a

Keynesian view of the current financial crisis. They discuss how Keynes's theory emphasizes the way fundamental uncertainty inhibits self-regulating mechanisms, and how this is relevant to financial and economic meltdowns after which new regimes often introduce extended periods of degraded economic performance.

Other examples in this line of thinking include the idea of responding to economic distress by rebalancing the global economy through policy changes (Freedman et al., 2010), boom and bust phases in the economy (Allen and Snyder, 2009), and growth and stagnation mechanisms of economic distress (Foster and Magdoff, 2009).

2.3.6.3 Financial Distress (S06.3)

This is the single line of thinking with the most contributions of insights from the selected literature. The generally accepted understanding of how financial distress arises is summarised by Minsky (1993), who observes that *"from time to time, capitalist economies exhibit inflations and debt deflations which seem to have the potential to spin out of control"*. His 'financial instability hypothesis' holds that the effects of financial distress arising from business cycles are compounded out of (i) the internal dynamics of capitalist economies, and (ii) the system of interventions and regulations that are designed to keep the economy operating within reasonable bounds. Wolfson (2002) examines this theory from a global perspective, and concludes that Minsky's debt-deflation process has so far (by 2002) been averted, and he contends that a major revision of the optimistic expectations of a boom period has not occurred since the Great Depression due to the intervention of the Federal Reserve as lender of last resort.

Benediktsdottir, Danielsson and Zoega (2011) draw similar lessons from the collapse of Iceland's banking system in October 2008, and ultimately blame what they call the *"small country syndrome"* for problems of explosive growth and unsustainably high leverage in that sector, which they argue were exacerbated when the central bank found itself incapable of serving as the lender of last resort for a banking sector of that size.

2.3.6.4 Market Distress (S06.4)

Among the many contributions to this line of thinking, two of them provide good examples of the view there is an interdependent relationship between bank competition, financial stability and the risk of bank failure (Berger, Klapper and Turk-Ariss, 2009; Martinez-Miera and Repullo, 2010). They respectively discuss the traditional 'competition-fragility' view, and its alternative 'competition stability' view, and both agree there are contradictory findings in the literature. But Martinez-Miera and Repullo make the strongest case that there is a U-shaped relationship between competition and the risk of bank failure.

In his review of the Efficient Market Hypothesis, Ball (2009) concludes that market distress will always find ways to emerge, by examining the *"inevitable and painfully obvious limitations"* of this hypothesis. However, he still asserts that it has a durable relevance, and proceeds to dispel misreading of the theory and logical inconsistencies in academic commentary about its role in the current financial crisis.

Other contributions consider such things as the non-rational behaviour responses of market agents (Loretan, 1996), and mechanisms of market distress contagion between the financial sector and the real economy (Scardovi, Gatti and Ventola, 2010).

2.3.6.5 Monetary Distress (S06.5)

In this line of thinking, Brunetti, Filippo and Harris (2011) provide the strongest explanation for how monetary distress arose out of monetary policies during the current financial crisis. The results they present suggest that when counterparty risk poses systemic risk for the interbank market, the central bank should not simply inject capital into the system but rather should focus on providing interbank loan guarantees or engage in direct asset purchases. This is different to the focus of Tsomocos (2003), who extends the GEI (General Equilibrium with Incomplete Markets) model with monetary and default notions, to explore monetary considerations as equilibrium phenomena.

Davis (2005) takes an interest in monetary distress from a completely different perspective in his examination of the requirements of pension reform. He then describes how monetary policy interacts with the demands of the population ageing process, as a future challenge to financial stability and potential new source of systemic risk.

2.3.6.6 Operational Distress (S06.6)

This line of thinking only has 8 contributions in the selected literature. As mentioned elsewhere in this section, many insights refer implicitly to operational matters. However, these contributions make explicit references to operational distress in the GFS, and many also contribute to other lines of thinking.

Nicolo et al (2004) use data from more than 100 countries to document trends in bank consolidation, internationalization and conglomeration to explore the extent to which the individual and systemic risks of financial firms are affected. They find these trends may neither yield safer financial firms nor resilient banking systems, as conventional wisdom suggests. A different strand of this same line of thinking is followed by Shaffer (2007), who shows that the systemic costs of aggregate business failure in the banking industry are lower when the industry is fragmented than when it is concentrated in a few firms. This leads to concerns for regulators about proposed risk-related policies on aggregate concentrations in the industry. At the next level down in this line of thinking, Acharya et al (2009) conduct a comparative analysis between different periods in a longitudinal study of banking activity in the USA from 2002 to 2Q 2007, to explore the systemic implications of changes in the financial leverage practices and banking models adopted by financial services firms. They conclude that moral hazard problems, excess liquidity and the mis-pricing of risk do not fully explain the evidence, and suggest that distortions induced by regulation and government guarantees should also be considered. At this same level, Bikker and Metzemakers (2005) look at procyclicality created by unsound loan loss provisioning. They show this procyclicality exists, and it is linked to changes in GDP and credit portfolio risk.

Then at individual firm level, Duffie (2010) looks at the mechanism by which dealer banks (i.e. banks that provide intermediate markets for securities and derivatives) can fail, and the policies available to address the systemic risk of their failures. They identify a form of bank run that differs markedly from conventional commercial bank runs. Another strand of contagion is discussed by Love (2010) from the practitioner literature, and Krozner (2000), who examine central counterparties and clearinghouses, respectively. They both conclude these GFS participants are important to controlling systemic risk in periods of financial crisis. Furthermore, Love argues that revisions to the regulatory framework regarding perceived settlement risks in the markets for over-the-counter (OTC) derivatives, should call for these contracts to be cleared through a central counterparty.

Finally, on the specific subject of operational distress arising from particular securitisation practices that are often cited as a cause of the current financial crisis, Shin (2009) attributes the reason why sophisticated financial intermediaries continued to make sub-prime loans, and why such intermediaries acquired and held securities containing such loans on their own balance sheets rather than passing them on to other investors, could be explained by the operational imperative to use up slack in balance sheet capacity during a credit cycle upturn.

2.3.6.7 Regulatory Distress (S06.7)

The contributions to this line of thinking reach similar conclusions regarding the role of regulators in increasing distress during this current financial crisis.

Calomiris (2010) provides the most comprehensive assessment of the issues behind systemic risk of failure arising from regulatory distress, and suggests regulatory improvements that can be made. He argues that the financial crisis is not so much a story of government *"errors of omission"*, but *"errors of commission"*. Although banks were allowed to avoid regulatory discipline due to the inadequate application and enforcement of existing regulations, he maintains that this was only one of four categories of government error that were instrumental in producing the crisis: lax interest rate policies; numerous government policies specifically promoting unwise risk taking by financial institutions, as in sub-prime lending; regulations limiting who can buy stock in banks that made effective corporate governance of large financial institutions virtually impossible; and ineffective prudential regulation of banks, including the ill-considered reliance on credit rating agencies' assessments of risk. Then he proposes 12 policy reforms.

Other contributions include: the historic evidence presented by Kaufman and Scott (2003); exploration of the regulatory factors contributing to the problems of the credit transfer market (Espenilla Jr., 2009); and an assessment of the effects of bank capital regulation on the sub-prime mortgage crisis (Petersen et al., 2009).

2.3.6.8 Sudden Shock (S06.8)

Contributions to this line of thinking tend to refer to shocks to the system in a generic sense, and take a model-driven or simulation approach to explaining how systemic risk arises. Martinez-Jaramillo et al (2010) is representative of this thinking, by describing how a network can model the GFS as the 'system of interest', in which systemic risk has two main components: a random shock that weakens one or more financial institution, and a transmission mechanism which transmits and possibly exacerbates negative effects among the rest of the system. They show how this model enables the distribution of losses to be separated into the losses incurred by the initial shock, and the losses resulting from the contagion process.

This view is shared by Dow (2000), who examines how the moral hazard and leverage of individual firms can create small shocks that are amplified by the GFS. An alternative, inter-temporal global model of the shock effects produced by 'sudden switching' in expectations about risk premia is contributed by McKibbin and Stoeckel (2009).

2.3.7 Mechanisms: of systemic failure (S07)

Among the 50 contributions to this conversation in the selected literature, there are 3 lines of thinking:

2.3.7.1 Contagion (S07.1)

Among the contributions to this line of thinking in the selected literature, 3 strands of explanations can be found regarding 'how' distress propagates and 'how' failure materializes by contagious means. Views on propagation are represented in this literature by the work of Martinez-Jaramillo et al (2010) who separate systemic and contagious elements of financial crises, and Uhlig's (2010) model of a systemic bank run describing the fear aspects of uncertainty aversion in bank runs. Then the mechanisms of contagion are represented by Acharya and Yorulmazer (2008), in their explanation of the likelihood of information contagion inducing banks to herd with other banks in order to undertake correlated investments, thereby minimizing its impact on the expected cost of borrowing, and maximizing profits. Finally, the general effects of contagion are explored by Akhigbe and Madura (2001), who examine why those effects vary among bank failures. One of their conclusions is that the total risk shifted to surviving rival banks, following a bank failure announcement, is inversely related to their capital levels.

2.3.7.2 Emergence (S07.2)

Explicit descriptions of the systems concept of emergence are not provided in the selected literature. However, this line of thinking is represented by various implicit interpretations found in a few contributions. Govtvan and Mansurov (2011) describe it as a new 'market tone' produced by changes in the system that may be useful in the diagnosis of crisis potential, whereas Yang, Mu Yao (2009) provide a catastrophe model of emergence as an outbreak of brittleness at critical points in system behaviour. In their historical analysis, Jorda, Schularick and Taylor (2011) also make an implicit interpretation by showing that credit growth is the best predictor of emergent financial instability.

2.3.7.3 Collapse (S07.3)

This general term has special meaning in this line of thinking for some contributions to the selected literature. Benediktsdottir, Danielsson and Zoeg (2011) draw lessons from the collapse of Iceland's banking system in October 2008. They describe how distress was allowed to propagate by the banking industry's political connections and through tacit support from the authorities, enabling senior bank managers and key stakeholders to benefit while shifting risk to domestic and foreign taxpayers and foreign creditors. Ho and Saunders (1980) take another approach when they describe the results of such events in their application of the theory of catastrophe to bank failure. They argue there is a crucial relationship between the power of regulatory intervention and depositor confidence levels, which is both necessary and sufficient for collapse to occur. Panageas (2010), on the other hand, interprets it as a systemic collapse of financial institutions' net worth, beyond the protection of bailouts.

2.3.8 Recognition: of the potential for systemic failure (S08)

Among the 34 contributions to this conversation in the selected literature, there are 5 lines of thinking:

2.3.8.1 Early Warning Systems (S08.1)

Among the various contributions to this line of thinking, three stand out as being particularly noteworthy. In his framework of macro-prudential leading indicators for monitoring the vulnerability of financial markets, Bhattacharyay (2003) provides a simple methodology for constructing benchmarks for early warning signals, and a set of composite indicators. Davis and Karim (2008) actually compare two early warning systems,'logit' and 'signal extraction', and find that the former is the most appropriate approach for the GFS. A multidisciplinary approach is taken by Scheffer et al (2009), who review current knowledge about complex dynamical systems to establish what is known about predicting critical points (sometimes known as tipping points) ahead of sudden shifts to contrasting dynamical regimes. They find that work in different scientific fields is beginning to confirm that predicting the approach of a critical threshold may be feasible through generic early warning signals for a wide class of dynamical systems.

2.3.8.2 Criteria (S08.2)

The line of thinking that establishes clear criteria for recognizing systemic failure potential is not well supported in the selected literature. One of the first real attempts to contribute standard measures as criteria for quantifying systemic risk for the GFS came from Martinez-Jaramilo et al (2010). The criterion proposed by Huang, Zhou and Zhu (2009) is the price of insurance against financial distress to calculate a theoretical insurance premium that would be charged to protect against losses exceeding 15% of the total liabilities of the system.

Govtvan and Mansurov (2011) contributed their alternative in a more watered-down version of the Martinez-Jaramillo contribution in the form of acceptable macro-levels of risk. However, this line of thinking remains under-developed.

2.3.8.3 Stress Testing (S08.3)

This line of thinking has few contributions in the selected literature, possibly due to stress-testing being driven by the regulatory practitioner literature. In the academic literature, Canedo and Jaramillo (2009) apply an integrated micro-macro approach to stress testing a 'system' of financial institutions. They identify the fragility of the system through a probability distribution of losses for the system as a network of bilateral interbank exposures, which can be used for stress testing both individual bank default probabilities and interbank exposures.

Other indirect references to stress testing can be found in recommendations for the use of 'ratings maps' (Sy, 2009), and suggestions for central banks to release stress test results for individual banks instead of country or regional level summaries (Brunetti, Di Filippo and Harris, 2011).

2.3.8.4 Measuring Implications (S08.4)

There are several contributions to this line of thinking. Out of the four most representative two are from the practitioner literature and two are academic, although one of the academic papers is practitioner-oriented because it takes 'a risk management approach.'

Borio and Drehmann (2009) make the most recent contribution in the published regulatory literature from the Bank for International Settlements. They confirm that policymakers are still a long way from developing a satisfactory operational framework for financial stability measurement. Then they highlight the key issues to be addressed when responding to that challenge, and suggest an outline of the most promising way forward. For example, on the measurement of system-wide risk they suggest a set of priorities, such as the need to include endogenous amplifying mechanisms. Similarly, Haldane, Hall and Pezzini (2007) write in the published regulatory literature from the Bank of England. They describe a 'new approach' in the form of a methodology for assessing risks to overall financial stability which includes: identifying vulnerabilities, selecting stress scenarios, measuring the impact of vulnerabilities, and assessing *"aggregate financial system risk"*. Lehar (2005) takes a more direct approach by defining systemic risk as the probability of systemic crisis. First, he computes the probability that banks with total assets of more than a certain percentage of all banks' assets will go bankrupt within a short period of time. He assumes a bank to be bankrupt if the market value of its assets falls below the face value of its debt within the next six months. Then surprisingly, when he computes the alternative probability that more than a certain fraction of all banks will go bankrupt at the same time there appears to be a remarkable correlation between these two numbers in his simulation data, considering they are not probabilities of the same phenomenon. After further simulation, his proposed measurement of systemic risk becomes an estimate of these joint dynamics for risk management.

In the academic literature, perhaps the most prominent contribution comes from Rochet (2009), who reveals loopholes in the supervisory/regulatory framework, and proposes new measures of systemic risk exposure to address the problem.

2.3.8.5 Concentrations (S08.5)

In this line of thinking, there are a number of contributions discussing the behavioural effects of moral hazard (Wolf, 1999; Dow, 2000; Berger, Klapper and Turk-Ariss, 2009), and 'too-big or too-connected to-fail' (Rochet, 2009; Duffie, 2010; Gramlich and Oet, 2011).

Other contributions published around the same time but offering very different insights include Rochet (2010), who takes the view that the regulatory perspective on systemic risk should be changed drastically. He argues that, to a great extent, the contagion phenomena that took place in the interbank and money markets during the current financial crisis were the necessary outcomes of passive attitudes in banking supervision that allowed large banks to develop complex and opaque networks of bilateral obligations that made them 'too-big-to-fail.' Then he proposes the adoption of a platform-based regulatory perspective on systemic risk, in place of existing institutional-based regulation, with a system-wide shift to central counterparty clearing. However, Zhou (2010) challenges the general validity of the 'too-big-to-fail' argument. In his study of the relationship between the size and importance of financial institutions, Zhou found that size should not be considered a suitable proxy of systemic importance, and he provided an estimation methodology for calculating that importance using a multivariate extreme value theory (EVT) framework. A third strand of this line of thinking is provided by Hashmall (2010), who challenges the narrow focus on banking in proposed changes to the financial services regulatory system, by arguing for even wider application of 'too-big-to-fail' regulations to include non-bank financial institutions.

2.3.9 Responses: to the potential for systemic failure (S09)

Among the 52 contributions to this conversation in the selected literature, there are 4 lines of thinking:

2.3.9.1 Governance (S09.1)

Two representative papers in this line of thinking summarize the governance issues highlighted by research into mitigating and regulating systemic risk. Among the seven principles in their new architecture for financial stability, Garicano and Lastra (2010) suggest in their principle 6 that *"the macro supervisor must not limit its reliance on self-regulation"*. Their argument is that managers who act in the interests of their own institution could still act in ways that are contrary to the interests of the financial system as a whole. So they conclude that better corporate governance is not the solution to problems generated in this way. Therefore, in their principle 7 they propose that 'international supervision must move from a loose network to a hierarchical structure' to address the interconnectedness of the global financial system.

Illustrations of what happens when governance is not in place are provided by Sigurjonsson (2010), who looks at governance and risk management inadequacies demonstrated by the Icelandic banking system collapse in October 2008. He describes how this collapse was interwoven with corporate governance issues, and lists a number of reasons why corporate governance arrangements within Icelandic banks failed. They include a mismatch between incentive systems, lack of self-regulatory procedures and mechanisms, and ineffectual risk management that allowed the main boards of Icelandic banks to ignore evidence of risk escalation.

2.3.9.2 Intervention (S09.2)

The contributions to this line of thinking can be represented by four distinct strands of research. Central bank intervention in the interbank market during the sub-prime crisis is explored by Brunetti et al (2011), who found that intervention consistently created greater uncertainty in the market, by failing to communicate findings. They suggested that the central bank should release stress testing information about individual banks, provide interbank loan guarantees, and engage in direct asset purchases rather than simply testing and providing more capital.

Xafa (2010) reviews the specific role of the International Monetary Fund (IMF) during the recent global crisis, and finds that it has emerged as a powerful institutional force informing official action in various ways. Its key role is described as identifying contingent risks that threaten global economic and financial stability, and developing appropriate policy responses. The unprecedented interventions initiated by G20 leaders in November 2008, to prevent a disorderly failure of systemically important institutions, are an example of the IMF exercising its role. Whereas, Rao (2010) examines bailout interventions by regulators, outside stakeholders and debt-holders, and explains benefactor aspects of their necessity, size and efficient execution when applied to overcoming the liquidity problems and general insolvency of financial institutions. Conversely, beneficiary aspects of interventions are explored by Panageas (2010), such as the disincentives to manage risk or volatility properly when bankruptcy looms, because internal shareholders benefit from allowing increases in volatility up to some 'pain' threshold below which external stakeholders are motivated to provide a bailout.

2.3.9.3 Regulation (S09.3)

Among the contributions to this line of thinking, there are several perspectives on regulating systemic risk, but arguably only four distinct strands of research. Calomiris (2010) leads the contributions asking questions about the role of financial innovation, and its regulation and reform, when used to side-step restrictions that would otherwise have limited activities in which people wished to engage. He concludes there were many distortions in policies, regulations and supervision that gave rise to the subprime turmoil, and suggests policy reforms to deal with them.

On the general case of bank capital regulation, Petersen et al (2009) find that Basel regulations seem to have exacerbated the subprime mortgage crisis. Similarly, Karras (2009) finds that although credit risk derivatives provide effective insurance on the assets of banks, their lack of regulation can have a negative impact on the behaviour of banks, leading to aggressive credit expansion, credit risk concentrations, and disequilibrium elsewhere in financial markets. Gunnarsson (2011) describes how regulators responded to these and other challenges after the Icelandic banking crisis of 2008. He characterizes the situation they faced as a case in which the banks were not only ‘too-big-to-fail’, but ‘too-big-to-rescue’. Then he proceeds to describe regulatory actions that were taken, starting with the Emergency Act that provided supervisory authorities with emergency powers over banks in danger of becoming insolvent.

2.3.9.4 Risk Management (S09.4)

This line of thinking mostly provides mitigation insights from the selected literature. Although the nature of these contributions is diverse, the following three examples give an idea of the wide range of research interests they represented. Renn and Klinke (2004) propose a new way of thinking about risks from the biology literature. They call for a holistic and systemic concept of risk, which requires an expansion of the scope of risk assessment beyond its two classic components: extent of damage and probability of occurrence. They argue that it is no longer sufficient to simply look at the probability distribution of potential losses associated with a risk source, and suggest that a more stringent and logically well-structured decision-making process is required.

Bikker and Metzemakers (2005) examine the potential for procyclicality created by unsound loan loss provisioning, to which they assert the Basel accord pays little attention. From observations gathered across 29 OECD countries, they confirm there is a direct negative relationship between GDP growth and provisioning, which they suggest implies that banks’ provisioning behaviour might be procyclical.

On the subject of securitisation as a risk management technique for enhancing financial stability, Shin (2009) examines the reasons why the technique has acquired a bad reputation for allowing bad loans to be passed on to unsuspecting investors. After considering the supply- and demand-side mechanisms for the growth of credit, he finds that the importance of securitisation is derived from the greater risk-taking capacity of the shadow banking system that led to an increase in the supply of credit. However, he shows that during an upturn in the credit cycle there is an imperative to find new assets to fill the balance sheets of financial intermediaries, and this induces a lowering of lending standards. When the ensuing credit bubble burst, those intermediaries ended up holding both their own bad loans and other firm's securitized loans on their balance sheets. This suggests that securitization was not simply used to pass bad loans on to unsuspecting investors, but was rather used as both a risk management technique and an investment. Consequently, financial intermediaries ended up as victims of their own misuse of securitisation.

Other more mainstream contributions come from Rotheli (2010), who addresses the bounded rationality of risk management, and Kane (2010), who calls for a redefinition of the incentives of risk managers.

2.3.10 Effects: of systemic failure (S10)

This conversation had several interesting contributions in the selected literature, all providing similar explanations for the effects of systemic failure or catastrophic instability. The following single contribution summarizes the most coherent and recent assessment.

Asensio and Lang (2010) take a Keynesian perspective on the current financial crisis, and show that waiting for a quick return to some 'natural order' predicted by mainstream economists would be the worst thing to do. They discuss Keynes's theory on how fundamental uncertainty inhibits self-regulating mechanisms, its relevance to economic meltdowns, and ways to get out of them. Then they argue that the memory of such collapses *"durably curbs all risk-taking decisions"*; that even the expected returns on productive investments should be downgraded; and that a regime shift may eventually take place characterized by relatively high long-term interest rates, a low rate of productive capital employment, and significantly high unemployment rates. Unless, that is, the combined actions of authorities and economic institutions succeed in restoring a 'state of confidence'.

2.3.11 Recovery: from systemic failure (S11)

This conversation had only 4 contributions in the selected literature. They were published over a three year period, and so probably reflect relevant circumstances and research conclusions from the early days of this current financial crisis in 2008, right up to the mid-2011 extraction date of this review. A description of these contributions follows, in reverse chronological order of their publication.

Acharya, Shin and Yorulmazer (2011) examine the relationship between crisis resolution and bank liquidity. They argue that choices in the levels of liquid asset holdings made by banks are counter-cyclical, being inefficiently low during economic booms but excessively high during times of crisis. They attribute this counter-cyclicality to the fire-sale pricing of assets following a large number of bank failures making it an attractive proposition to maintain high levels of liquidity in order to purchase assets at these prices, and vice versa when banks are not failing, assuming relative expertise in liquidity management is similar between banks. Then they present evidence consistent with these predictions, from which they infer that ex-post interventions to resolve banking crises may reduce incentives to hold liquid assets, and therefore should be conditional on appropriate levels of those assets.

Asensio and Lang (2010) call for the combined actions of authorities and economic institutions to restore a 'state of confidence', by managing monetary and fiscal instruments to generate economic recovery led by a *"significant fiscal policy supported by coordinated temporary deficits and truly accommodating and coordinated monetary policies"*. Freedman et al (2010) follows this argument through with a description of the policy choices that would help support global demand on a more sustainable basis. They offer an analysis of both downside and upside scenarios to outline major risks and opportunities facing the world economy going forward from the current deep recession. In particular, they emphasize the importance of governments taking actions to return the financial sectors of their economies to health, the importance of avoiding protectionist measures, and the need for increases in government infrastructure investment expenditures. Blankart and Fasten (2009) examine the theoretical basis for spending billions in fighting financial and economic crises, and propose a contractual model of next steps that involves an exchange of protection against systemic risks in return for significantly increased regulation of the banking sector. After which they evaluate the practicalities of enforcing this contractual framework internationally.

2.3.12 Involvement: in the system (S12)

Among the 54 contributions to this conversation in the selected literature, there are 5 lines of thinking:

2.3.12.1 Collective (S12.1)

The contributions to this line of thinking combine broad concepts from the sociology, psychology, information science and economics disciplines. They also have a natural chronological order of reasoning over a period of some 40 years. The following four contributions are representative of what this literature says.

Granovetter (1978) introduced the notion of a threshold of collective behaviour, which is the number and/or proportion of others who must make a particular decision before a given actor does so. Although Granovetter interprets the implications of these thresholds in terms of cost/benefit equilibria, they have wider implications for the concept of 'herding'. When Lux (1995) attempts to formalize herd behaviour, or mutual mimetic contagion in speculative markets, he concludes there is a basic cyclical mechanism around fundamental values of assets that take the form of 'fierce self-amplifying reactions of speculators' to small deviations from their equilibrium value. Although this provides an obvious explanation for excess volatility, it also applies to mean-reversion, when an endogenous breakdown of a bubble occurs and excess profits vanish.

Shaffer (2007) then looks at the cost of systemic risk as an effect of collective behaviour, by examining aggregate concentrations that present themselves as aggregate business failure in the banking industry, to identify a theoretical basis for risk-related policy concerning such concentrations. Then Acharya and

Yorulmazer (2008) explain how the profit-maximizing effects of information contagion induce individual banks to herd with other banks. They show why banks herd and undertake correlated investments to minimize the impact of information contagion from news about similar activities by other banks, such as commonality in lending to certain industries, on the expected cost of borrowing. From that initial work, the most prominent contribution to this line of thinking was made by Acharya (2009) through his theory explaining aggregate risk-shifting incentives at a collective level of operations.

2.3.12.2 Deliberate - Strategic or Tactical (S12.2)

Among the contributions to this line of thinking, there is one distinct strand of research with inconclusive findings, and a few miscellaneous insights.

The strategic and tactical debates about the systemic effects of diversification, integration, consolidation and levels of competition are joined by five contributions. Strategic consolidation is examined by Nicolo and Kwast (2002) and Nicolo et al (2004). They argue that if firm inter-dependencies, as measured by correlations of stock returns, provide an indicator of systemic risk potential, then a sample of large and complex banking organizations that were involved in consolidation activity in the US over the period 1988-1999 suggests that consolidation has contributed to systemic risk potential. On a different level, Poirot (2001) explains how integration of the Russian financial system into the global financial system nearly led to the collapse of both in 1998, due to *"a vicious circle of chaotic hysteresis and financial fragility"* characterized by speculative financing.

Wagner (Wagner, 2006) takes a different approach by looking at the tactical diversification of risks at financial institutions. He finds that there is an optimal degree to which such institutions can diversify, beyond which adverse effects begin to increase the likelihood of systemic crises. Martinez-Miera and Repullo (2010) find that, contrary to the accepted view that competition reduces the franchise values of banks and induces them to take more risks, opposite effects can be observed. However, they show there is actually a U-shaped relationship between competition and the risk of bank failure.

2.3.12.3 Dysfunctional (S12.3)

The contributions to this line of thinking offer an important but disparate cross-section of insights.

Dysfunctional aspects of moral hazard are represented by Weitzner (2009), who explores the linkages between greed and governance failures in both financial institutions and financial markets. Acharya and Richardson (2009) provide the best explanation of two methods by which banks evaded regulatory capital requirements, and link them to the reason why the housing bubble had such an impact on the financial system when it burst. One method was the securitization of mortgages in off-balance-sheet entities, to avoid regulatory requirements to hold significant capital buffers against their potential default. The other was the relaxation of capital requirements for AAA-rated tranches of securitized mortgages that are retained on-balance-sheet. By repackaging mortgages into mortgage-backed securities in this way, both on and off their balance sheets, banks were able to reduce their regulatory capital obligations significantly. Acharya and Richardson conclude that this regulatory arbitrage effectively concentrated the risk of mortgage defaults in the banks, and rendered them insolvent when the housing bubble burst. Incentives to behave dysfunctionally are also described by Panageas (2010), who develops a model that explains the interplay between shareholders who deliberately allow volatility in a firm's finances to increase, so they can avoid bankruptcy costs by exploiting the implicit protection of bailout options, and the response of external stakeholders. His model demonstrates the qualitative features of widely adopted risk management rules within stakeholder firms that can account for phenomena such as 'flight to quality' when the net worth of financial services firms fall below an endogenously determined threshold.

2.3.12.4 Ignorant (S12.4)

There are 3 contributions that stand out in this line of thinking, described in an increasing order of intensity for the ignorance phenomena identified, as follows:

Holland (2010) presents the case for knowledge and learning failure in banks, in the context of this current financial crisis. He argues there is a lack of banking knowledge and history among bank board directors, top management and regulators. The conclusion he draws suggests this fundamental knowledge gap and its causes, concerning banks' understanding of their organizations, intermediation and risk management in an active market setting during a time of rapid change must be addressed in any lasting solution to the crisis. In Rotheli's (2010) description of important determinants of the current financial crisis, the notion of ignorance is taken further by his use of the behavioural notion of bounded rationality to explain how over-optimism and over confidence led bankers to take on ever larger challenges in the pursuit of growth, no matter what risks were involved. Miller and Rosenfeld (2010) describe this ignorance more precisely as intellectual hazard, and define it as being pervasive, and existing whenever *"production becomes segmented into complex organizational forms … that can pose a threat to the stability of the entire system of markets or institutions"*. In particular, they describe how problems with intellectual hazard manifest themselves at the point where economic boom turns to bust, when actors who have never experienced such changes, or are unprepared, handle decisions poorly or panic. Then they proceed to review the three broad categories that can serve to organize different manifestations of intellectual hazard: complexity biases, incentive biases, and asymmetry biases. They conclude that this type of hazard impairs the acquisition, analysis, communication, and implementation of information within an organization, and the communication of such information between that organization and external parties. Finally, they suggest possible reforms to mitigate intellectual hazard in corporate governance, governmental supervision and oversight, stress testing, and changes in the education of the personnel in financial institutions.

2.3.12.5 Procedural (S12.5)

Out of the few contributions to this line of thinking, two distinct strands of research can be identified:

Duffie (2010) is representative of contributions to operational aspects of this line of thinking. He describes a new form of bank runs suffered by banks that intermediate markets for securities and derivatives, and the mechanics by which these dealer banks can fail. Then he suggests policies and procedures available to mitigate the systemic risk of their failure. Alternatively, Rizzi (2008) explains behavioural biases that are reinforced by organizational procedures, such as misaligned compensation systems, and outlines a supplemental behavioural risk framework.

2.3.13 Operations: of the system (S13)

There are 31 contributions to this conversation in the selected literature, with 5 lines of thinking:

2.3.13.1 Cycles (S13.1)

Two main strands of contribution to this line of thinking can be found in the selected literature. Procyclicality is represented by Bikker and Metzemakers (2005), Espenilla (2009) and Goodhart (2010). They explain that although financial intermediation is inherently cyclical, and the financial system tends to respond in a pro-cyclical way that increases systemic risk, a less procyclical financial system may be an achievable goal. However, they describe how this will need to overcome the proven inability of banks, policy makers and regulators to iron out such cycles, due to alternating periods of greed and fear. After some analysis of the causes and effects of pro-cyclicality, Goodhart concludes that the effect of this current crisis will be an increase in the spread between deposit and loan rates charged by the banks. As this cost of intermediation rises, he predicts that future financial intermediation will be diverted through new channels, possibly via securitization again. In that event, new risks will arise as the next financial crisis begins to unfold.

The other strand within this line of thinking explores economic cycles of instability, or boom and bust, represented by Minsky (1977; 1993) and Jorda, Shularick and Taylor (2011).

2.3.13.2 Innovation (S13.2)

Although dubious motivations for creativity are often blamed as a cause for this current financial crisis in the selected literature, Espenilla (2009) still argues for allowing uninhibited banking innovation. Wallison (2008) agrees, and provides a thorough explanation of the most criticised of all innovations: credit default swaps. He argues that popular assessments are misinformed, and concludes that excessive restrictions in the availability and use of credit default swaps would create considerably more risk than they would eliminate.

2.3.13.3 Interconnectedness (S13.3)

Many of the contributions to this line of thinking from the selected literature were published before the 2008 start of the current financial crisis, and the rate of contribution was losing its momentum. However, the crisis has recently revived interest. Kroszner (2000) may offer an explanation for this in the lessons he draws from previous crises, when he explores the potential of a wider role for clearinghouses in the future for mitigating systemic risk propagation, through providing coinsurance among the members of more markets. The nature of this systemic risk mitigation has perhaps been understood well enough by regulators that opportunities for further research were considered to be limited.

Since 2008, new insights have been contributed about dynamic linkages between major US banks and macro-financial conditions (Huang, Zhou and Zhu, 2009), and the network effects of interbank loan guarantees and counterparty risk (Brunetti, Di Filippo and Harris, 2011).

2.3.13.4 Resilience (S13.4)

Most of the contributions to this line of thinking are recent and distinct strands of research that refer to aspects of the global financial system's fragility, resilience or both. The two contributions that are representative of this literature are:

Schleifer and Vishny (2010), who propose a theory of financial intermediaries operating in markets influenced by investor sentiment, revise traditional theories of financial intermediation by extending their coverage of deposit taking and lending activities to include modern banking involvement in originating and distributing securities, trading, and lending or borrowing money in financial markets. Their theory predicts that profit-maximizing behaviour by banks across this full range of activities can make them unstable, creating a fragile financial system with increased systemic risk.

Gai, Jenkinson and Kapadia (2007) take the alternative view that changes in the global financial system due to innovations and integration have served to improve its resilience, making systemic crises in developed countries less likely than in the past, but potentially more severe.

However, the most recent view is provided by Gramlich and Oet (2011), who look at the structure of the GFS to explore its vulnerabilities and concentrations.

D.4.13.5 Visibility (S13.5)

The contributions to this line of thinking illustrate an interesting phenomenon which may arguably require more research. ‘Visibility’ is intended to mean the extent to which the operational activities and methods of financial institutions are open to scrutiny, particularly for innovations that are not yet regulated.

On the subject of retrospective visibility, Goodhart (2007) describes the difficulty of putting together a coherent story of ‘everything that has happened’ when writing about the background to the current financial crisis. He gives the example of the innovative new banking strategy titled ‘originate and distribute’, which was behind their aggressive move into securitization, well beyond traditional banking activities. Part of the problem of understanding what banks got up to is the opacity of their operations, often justified for reasons of commercial secrecy.

That operational opacity is also shared by other financial institutions, such as credit rating agencies. In his discussion of the procyclical nature of rating agencies, Sy (2009) is critical of the way they help to fuel investments during ‘good times’, and accelerate market losses in ‘bad times’. One suggestion he makes is to use ratings maps as a way for policy makers to identify the channels through which rating downgrades can lead to increases in systemic risk. However, more transparency and standardization would be needed from ratings agencies in their methods and criteria of rate assessments.

Two alternative interpretations of visibility are provided by an analysis of the way ‘fair value accounting’ rules may have severely undermined the reported condition of financial institutions (Magnan, 2009), and information inadequacies of regulatory oversight (Fisk, 2011).

2.3.14 Reviews: of systemic crises and failures (S14)

There are 20 contributions to this conversation in the selected literature, with 3 lines of thinking:

2.3.14.1 Current Crisis (S14.1)

As would be expected, most reviews in this conversation focus on this line of thinking. They all refer to broadly the same time frame and events. The three most interesting and comprehensive reviews are considered to be:

Foster and Magdoff (2009), who contribute the most comprehensive review of the current financial crisis, up to its publication in 2009. Their main argument is that both the financial explosion in recent decades and the financial implosion now taking place are to be explained in terms of *"stagnation tendencies within the underlying economy"*. Edey (2009) provides a brief chronology, looks at the underlying causes and economic impacts supported by key data and charts, then considers policy responses with a 'look ahead' into the future that sees signs of improved conditions. An alternative perspective is offered by Benediktsdottir, Danielsson and Zoega (2011), who focus entirely on the crisis as experienced by the Icelandic financial system. Their stated objective was to draw lessons from this episode for other countries. In conclusion, they argue that both the size of the financial sector in relationship to its central bank capabilities and its unsustainably rapid growth were a problem.

2.3.14.2 Other Specific Crises (S14.2)

There are only a few contributions to this line of thinking in the selected literature, among which the following two are most representative:

Poirot (2001) reviews the Russian financial crisis of 1998, when the former Soviet Union embarked on a programme of reforms to create a market economy. He explains the poor economic performance of the Russian economy in the late 1990s, and the financial crisis at the end of that period, in terms of chaotic hysteresis and financial fragility characterized by speculative financing, which was made even worse by the integration of Russia into global financial markets. He argues that consequently the level of systemic risk increased for both the

Russian financial system and global financial system, and led to the near collapse of both in the summer of 1998.

Kong and Wang (2009) take a completely different approach by reviewing the 16 early warning signals from their simulation of a potential crisis in the Chinese economy. By using factor analysis to study the sources of China's financial risk, and a back-propagation neural network model of the Chinese financial system, they predicted the state of financial risk in 2008, after the commencement of the global financial crisis in 2007.

2.3.14.3 General Crises (S14.3)

The contributions to this line of thinking from the selected literature are quite varied in their objectives and conclusions. Four examples illustrate this point.

Jorda, Schularick and Taylor (2011) study long-run data about the experiences of 14 developed countries over 140 years (1870 – 2008), and they identify five episodes of global financial instability in the past 140 years. When they examine the macroeconomic dynamics before each episode, they find that credit growth tends to be elevated and short-term interest rates tend to be depressed relative to the normal rates at other times. Their overall conclusion is that credit growth is the single best predictor of financial instability.

In their history of financial crises, Kindleberger and Aliber (2005) review the circumstances of past crises, and present an economic model of a general financial crisis in the tradition of classical economists such as John Stuart Mill, Alfred Marshall, Knut Wicksell and Irving Fisher, based on instability in the supply of credit. Then they examine the variable nature of systemic shocks from one speculative boom to another, and explore how circumstances play themselves out in different scenarios.

Reinhart and Rogoff (2009) review eight centuries of financial folly. They use data about financial crises that combines geographic breadth with historical depth to challenge the popular 'this time is different' syndrome, and describe the worldwide consequences of different types of crashes and catastrophic instability.

Franklin and Gale (2007) present their review of the history of financial crises, and an explanation of the modern theory of intermediation, with a detailed guide to current theoretical modelling approaches. Topics are addressed separately, as in *"the business cycle of bank runs"*, *"types of equilibrium"* and *"incomplete contracts"*, and they conclude that there is no single theory of financial crises.

2.3.15 Summary of Conversations

Out of task T4 in the systematic review methodology (Figure 6), 194 contributions were selected for informing the review. Table 30 in Appendix D4 provides a descriptive analysis of conversations found in this literature, further analysed by lines of thinking (LoT). A comparative analysis between approved and selected contributions to each conversation is summarised in Figure 9 below, followed by a critical assessment of core contributions. When considering data presented in the below chart, it should be remembered that any single contribution can participate in multiple conversations.

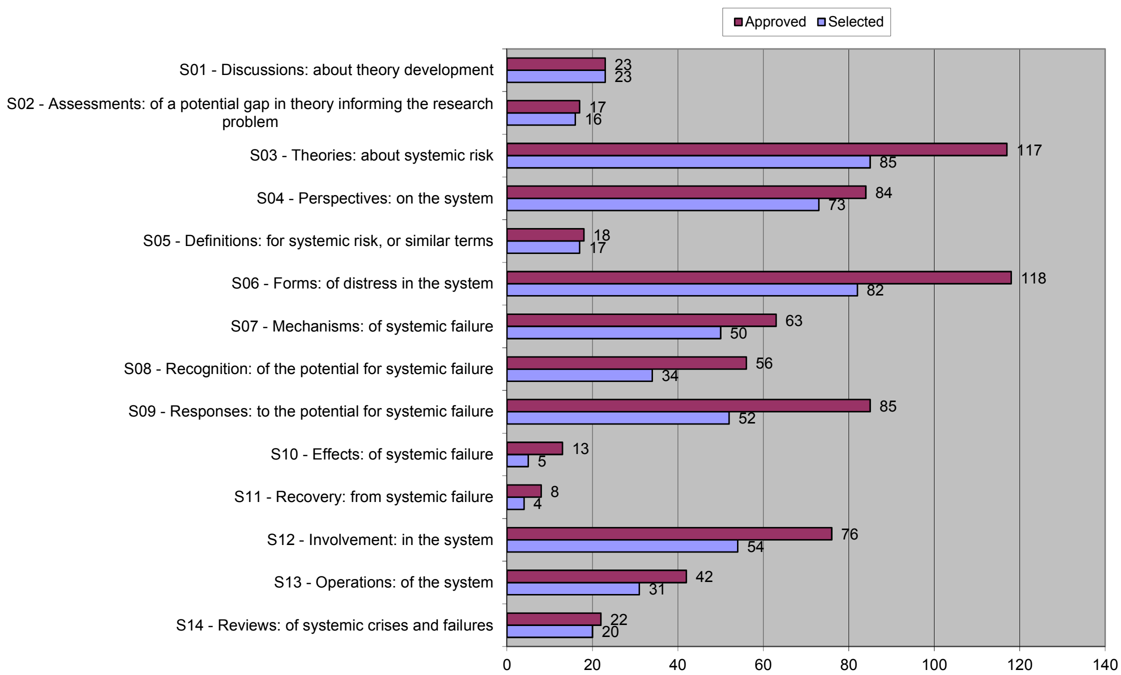


Figure 9: Conversations in the selected literature of 194 contributions

2.3.16 Critical Assessment of Core Literature

2.3.16.1 Introduction

The subset of contributions used here for assessment was defined by this review as the knowledge contained in a core literature of 62 contributions, extracted from the selected literature of 194 contributions in task T5 of the review methodology, that were identified as 'exemplars' of insights from distinct lines of thinking for answering the literature questions. These contributions represent the distilled essence of similar knowledge in the broader selected literature, and were used in thematic synthesis to manage the number of contributions to be processed. They are critically reviewed in this sub-section, alongside some references to the broader selected literature, to summarize the foundations in that literature for the synthesis results, and for the conclusions drawn in subsequent sections of this review.

2.3.16.2 Theories of Systemic Risk

There are few economic theories that directly address systemic risk. Govtvan and Mansurov (2011) describe systemic risk as being a concept that is *"... most complicated and poorly studied"*. They attribute this to, *"... the insufficient development of many theoretical and practical matters connected with this problem"*. However, they share a fundamental confusion with many other researchers in this field, illustrated by Miller and Rosenfeld (2010), who refer to *"an important but previously unrecognized systemic risk ... intellectual hazard"* in their description of behavioural biases that interfere with accurate thought and analysis within complex organizations. Their statement confuses what is essentially a cause of systemic risk with systemic risk itself. There is no such thing as 'a' systemic risk, or the plural 'systemic risks'. There can only be one risk of the entire system failing, systemic risk, which has multiple causes and effects, except when an overall breakdown of multiple different systems is being discussed as in Helbing (2010).

Acharya (2009) is probably closest to a 'good' theory, as defined by DiMaggio (1995). The substance of this theory is logically coherent, methodologically sound, and well presented. Where it may be open to criticism is in its lack of supporting data from theory testing and validation. As a conceptual paper, it stands purely on proofs for the mathematical expressions of its propositions, without demonstrating that those expressions do in fact describe reality. However, this is not in itself an insurmountable problem. Often contributions to this literature are presented as frameworks, models, or even just concepts. They generally fall into three categories, differentiated by their definition of systemic risk: casual, consequential, or both. Conjectures are developed to explain how causes or consequences arise, but the fundamental failure that may materialize remains unexplored. In an engineering example, this equates to attributing the structural failure of a bridge to bad traffic flow management, and ignoring evidence of a pre-failure crack in a support pillar that collapsed.

Causal definitions are illustrated by Dow (2000). He suggests that systemic risk arises from moral hazard and individual firm leverage, which can cause a large shock to the financial system. While Acharya takes the view that it arises from a high inter-bank correlation of returns on assets, which through various means forms a multi-agent risk shifting phenomenon. Contagion is favoured by Rochet and Tirole (1996) who refer to the propagation of economic distress between agents linked through financial transactions. The approach taken by Huang, Zhou and Zhu (2009) uses a consequential definition, where systemic risk results in multiple simultaneous defaults of systemically important financial institutions. Whereas Martinez-Jaramillo, et al (2010) illustrate the combined view that systemic risk is caused by a random shock event that weakens financial institutions, with the consequence of having significant adverse effects on the real economy. A common feature of these examples, and most of the literature they represent, is the confinement of their scope of reference to the economics domain of literature, and their explanation of systemic risk in terms of specific past events. Therefore, a useful objective for this programme of research may be to contribute a multi-disciplinary outline of new theory, concerned with the fundamentals of operational behaviour approaching systemic failure that explains how insights from different literatures can be integrated to address systemic risk in any circumstances in which it may arise in the future.

2.3.16.3 Related Theories of Economics

Indirect approaches to the risk of failure of financial systems can be found elsewhere in economics, as in the literatures of financial stability and financial crises. For example, the financial instability hypothesis (Minsky, 1993) argues the fragile nature of capitalist economies, and their tendency to fall into depression after debt-financed euphoria. Haldane, Hall and Pezzini (2007) take a different approach in their examination of how to predict the potential location and possible scale of 'financial earthquakes', by introducing notions of risk transmission mechanisms. The predictive approach is also taken by Bhattacharyay (2003), who proposes a leading indicators framework for monitoring financial vulnerability. However, as with theories of systemic risk, this review argues that many of these ideas can be translated to a more fundamental explanation based on a financial system's operational behaviour.

2.3.16.4 Critical Phenomena

Helbing (2010) summarizes the sources and drivers of systemic risks in various socio-economic systems, and provides an example of financial market instability. He also describes relevant properties of complex systems in his review of the literature, including: self-organized or self-induced criticality; the limits of predictability, randomness, turbulence and chaos; and the logic of failure. A conclusion he draws from these ideas is that such systems cannot be easily controlled, according to research showing that counter-intuitive and unintended effects are to be expected from conventional attempts at controlling complex systems. He then relates the challenges of managing complexity to a variety of scientific techniques in the literatures of non-equilibrium statistical physics, non-linear dynamics and chaos theory, catastrophe theory, and critical phenomena.

Out of this wealth of multi-disciplinary insights, it is catastrophe theory (Thom, 1975; Zeeman, 1976) that makes a widely adopted contribution to modelling the risk of failure of financial systems. The theory has been used previously in many contexts, including a model of bank failure (Ho and Saunders, 1980), a stock exchange model of irrational exuberance (Pruden, Paranque and Baets, 2004), and brittleness analysis of a loans sub-system (Yang, Mu and Yao, 2009). There are many other promising lines of research which are also relevant to the declared focus of this thesis on operational states of the system close to failure, such as the use of dynamical systems theory from the critical phenomena literature to identify early warning signals of the 'critical slowing down' phenomenon in approaches to thresholds of critical transitions (Scheffer et al., 2009). However, these insights will remain fragmented until some means of unifying them is introduced. For example, when model systems have been used previously to combine notions in this way (May and Arinaminpathy, 2010; Beale et al., 2011), new explanations began to emerge about how herding behaviour generates risk concentrations in system operations. Perhaps if understanding about systemic risk of failure is moved from its current narrow types of focus, as in the popular balance-sheet perspective, to a system-wide operational perspective that unifies other notions with catastrophe theory, new explanations may become apparent. Then a plausible answer to the research question of this review may be some explanation of systemic risk of failure presented for the first time in terms of potential catastrophic changes in the system's operational states that emerge from concentrations in operational behaviour.

2.3.16.5 Regulatory Attention

Speculation and theorising about the causes and consequences of financial crises started to intensify as the first decade of this millennium came to a close (May, Levin and Sugihara, 2008; Allen and Gale, 2007: chapter 1; Foster and Magdoff, 2009). At the same time, belated regulatory attention began rationalizing why the recent so-called sub-prime crisis occurred, and furthermore why it appears to be continuing. While collective behaviour is blamed by regulators (Borio and Drehmann, 2009); there are calls from others for rethinking the role of regulation in the light of its contributions to this crisis (Slattery and Nellis, 2011). Meanwhile, regulatory literature has begun to lead the way in encouraging the development of practical new macroprudential methods and tools for dealing with systemic risk (Bullard, Neely and Wheelock, 2009). For example, the use of simulation techniques from agent-based computational economics (ACE) has been suggested to expose the many remaining inadequacies in how the financial system is regulated (Hoogduin, 2010). Consequently, receptiveness seems to be emerging among regulators for radical new instruments of systemic risk mitigation, which could become the proposed contribution to practice of this programme of research. Although the question of which macroprudential authorities have the responsibility, or indeed the authority, for deciding and delivering that mitigation is still far from settled.

2.3.16.6 Assessment

It is the overall assessment of this review that, although good progress has recently been made in understanding certain aspects of systemic risk, the paradigms currently favoured in economics for explaining it are reaching their limits of usefulness. For example, the most explicit claim to be a theory of systemic risk (Acharya, 2009) is based on the dominant equilibrium paradigm of economics, and uses a balance-sheet perspective in its model. This is a well-structured contribution of theory containing useful insights, but does not offer a general theory capable of addressing most potential crises. It focuses on specific financial aspects and risk-shifting phenomena of the current systemic crisis, implicating recent innovations and practices, but cannot explain other observed phenomena of past crises or their potential future variations. A more general treatment of the issues calls for relevant contributions from other academic disciplines to be explored.

The core literature of this review contains many insights from a wide range of disciplines that were found to address narrow aspects of the research problem of this review. However important gaps were found, and a new unifying thesis is argued to be necessary for bringing those insights together within a new explanatory paradigm that transcends the limitations of current understanding.

2.3.17 Thematic Synthesis

2.3.17.1 Introduction

Figure 36 in Appendix B describes the entire thematic synthesis process, and how fundamental artefacts of analysis are derived from core literature. Appendix D presents and discusses the detailed analysis generated by the systematic review from those artefacts, and sub-sections that follow here in the main thesis summarise the findings of that detailed analysis.

2.3.17.2 Analysis

A thematic analysis of the core literature found in the scoped-in areas of Figure 8 from sub-section 2.2.3 is presented in Table 3. It maps the significance of 20 relevant lines of thinking (LoT) about answer themes identified for each of the literature review questions. Each cell contains the highest weighted score (from Appendix D.5) of explanatory value provided by insights among core literature contributions to a particular LoT about an answer theme for a specific question. Gaps in explanatory value are identified by only showing low scores of ≤ 3, and outlining clusters of low or missing scores as bordered regions of cells. Then assertions about those gaps are made using keywords and phrases from row and column labels by interpreting the mappings represented by combinations of cells within those bordered regions.

Keywords and phrases in row and column titles that are emphasized in bold throughout Table 3, Table 4 and the detailed analysis in Appendix D.5 from which those tables are derived, originate from core literature metadata listed in Appendix D.6. In Table 3, two sets of gap assertions are interpreted from these emphasized texts as follows:

- The text of assertion-rows 'a' to 'e' that are collectively labelled (i) in the right-most column is derived from individual row titles of LoT in the left-most cell of each row, and the answer-column titles of bordered regions that each row intersects - labelled (iii) in the bottom-left rows;
- whereas the text of assertion-rows 'f' to 'j' labelled (ii) in the right-most column are derived from individual answer-column titles of bordered regions and the set of LoT titles of the rows that intersect those regions.
- The focus of interpretation is bordered regions of cells with low scores. Within those regions, either a specific low score is shown for insights contributed by a LoT for an answer theme of a question, or a tick indicates the score is adequate, or a blank denotes a LoT is not relevant to the answer theme or question.

For example, assertion 'a' refers to 'catastrophe' from the LOT row title of S03.21, and 'nature' from the answer-column title for Q1:A1.

Lines of Thinking (LoT) - Explanatory Gaps (where **explanatory value scores are ≤3** for Answers to the Literature Questions from core literature contributions) Scores extracted from the detail Analysis of Appendix D.5.	**Literature Search Questions and Answers (Themes)** (showing gaps in explanatory value from Lines of Thinking)																	**Gap assertions for synthesising new conjectures** (Summarizing inadequacies of the literature from the detail Thematic Analysis of Appendix D.5; with assertions about explanatory gaps derived from highlighted key words in the titles of associated Questions/Answers and LoT. For derivations see (i) for row assertions from LoT, (ii) for column assertions from Answer-column titles and related LoT, and (iii) for Answer-column titles).
	Q1 (Systemic risk: **Nature**)					**Q2** (Systemic risk: **Meaning**)				**Q3** (Systemic risk: **Materialisation**)				**Q4** (Systemic risk: **Mitigation**)				
	A1	A2	A3	A4	A5	A1	A2	A3	A4	A1	A2	A3	A4	A1	A2	A3	A4	
Systemic risk ...																		**(i) Assertions derived from Lines of Thinking / rows**
S03.1 Theories: about systemic risk - Declared candidates	3	3	2	3	2													→ a. Theoretical notions of **catastrophe** are not convincingly applied to explaining the **nature** of GFS instability. *(Gap I)*
S03.21 Theories: Other insights **- Catastrophe**	✓	✓	0	0	0													
S03.22 Theories: Other insights **- Evaluation**				I										3	2	2	1	→ b. **Evaluation** models for **mitigation** assessment are needed. *(Gap II)*
S03.23 Theories: Other insights **- Propagation**	3	0	0													II		
S03.25 Theories: Other insights **- Criticality**	1	2	0															
S03.26 Theories: Other insights **- Operations**	0	0	0						III	3	2	2	0					→ c. It is not well understood how systemic risk **materialises** as a failure of GFS **operations**. *(Gap III)*
S03.27 Theories: Other insights **- Behaviour**	✓	0	0															
S04.20 Perspectives: on the system **- Complex**	2	3	0							1	0	2	0					
S04.30 Perspectives: on the system **- Economic**				2	0					2	2	2	6					
S04.70 Perspectives: on the system **- Operational**	0	2	2	0	0		X		IV	2	2	0	1					
S04.80 Perspectives: on the system **- Regulatory**				3	0					3	2	3	3					
S05 Definitions: for systemic risk						✓	2	2	✓									
S06.6 Forms: of distress **- Operational**	2	3	2					IX		3	2	0	0					
S07.1 Mechanisms: of failure - Contagion	3	0	0															
S07.2 Mechanisms: of failure - Emergence	✓	2	0															
S07.3 Mechanisms: of failure **- Collapse**	3	3	2															
S08.2 Recognition: of failure potential **- Criteria**									V	0	0	✓	0					→ d. There is little basis for deciding the **regulatory criteria** for how systemic failure of the GFS will be determined to have **materialised**, for pre-emptive **intervention** or reactive **mitigation** purposes. *(Gaps V and VI)*
S09.2 Responses: to failure potential **- Intervention**		VIII												2	2	6	2	
S09.3 Responses: to failure potential **- Regulation**												VI		3	2	4	0	
S09.4 Responses: to failure potential **- Risk Management**												VII		2	0	0	0	→ e. There is no basis for selecting appropriate techniques of systemic risk of failure **mitigation** for **risk management**. *(Gap VII)*
(iii) Answer-column titles																		**(ii) Assertions derived from Answer-column titles and Lines of Thinking**
Q1:A1 Its **nature** is **systemic**	↳																	→ f. Instability of the GFS has not been explained in terms of the **operational behaviour** of a **complex system**. *(Gap VIII)*
Q1:A2 Its **nature** is **critical**		↳																→ g. The state of crisis or total **collapse** the GFS can enter (i.e. its state of **criticality**) has not been explained as an **operational** state. *(Gap VIII)*
Q2:A2 and A3 Its **meaning** is **defined** by **causes** and **consequences**						↳	↳	↳	↳									→ h. There is no consensus about a comprehensive **definition for systemic risk** of failure of the GFS. *(Gap IX)*
Q1:A3, Its nature is **global** Q3: A1 to A4, Through (any means of) **materialisation**			↳							↳	↳	↳	↳					→ i. The **global** mechanism by which **distress propagates** and **materialises** throughout the GFS has not been explained as an **operational** process. *(Gaps VIII and IV)*
Q1:A4 and/or A5, Its nature is **financial** and/or **structural** Q3:A2, Through interaction with the **economic environment**				↳	↳						↳							→ j. There is no **regulatory** concept of how GFS **operations** interact **financially** or **structurally** with the **economic environment**. *(Gaps X and IV)*

Table 3: Thematic Analysis

2.3.17.3 Synthesis of Conjectures

Once gap assertions were interpreted by thematic analysis in Table 3 (see right-most column items 'a' to 'j'), it became possible to build a set of conjectures representing a logical progression of reasoning about new ways to apply existing knowledge, derived by combining and re-stating assertions as conjectures using similar keywords and phrases (see Table 4). Although many alternative sets of conjectures can be built in this way, possibly resulting in quite contradictory progressions of reasoning, a compensating advantage of this type of synthesis is that it exposes the underlying qualitative assessments, interpreted implications, and rationale of assertions that form the basis of subsequent theorising. It therefore enables critical assessments about the value of any proposed new theory to be better informed, by placing them in the context of a coherent model of current understanding on which claims are based. Reading the columns of Table 4 from left to right presents an audit trail of reasoning for conjectured answers that have not previously been articulated for each literature review question. Then organising the complete set of conjectures in their numbered sequence presents them as an initial theoretical argument for establishing a gap in theory (see Table 5), answering the literature review questions (see Table 6), and constructing a research question for new theory development.

Literature Search Questions about the GFS	**Gaps / Questions / Answers /** from LoT (see Table 3)	**Gap Assertions** (see Table 3, (i) and (ii). Keywords and phrases are re-highlighted below for conjectures)	**Conjectures addressing this Gap** (numbered as a logical progression of reasoning, derived by combining and re-stating gap assertions as new conjectures using similar keywords and phrases).
Q1. What is the nature of catastrophic instability or total collapse of this system?	**I.** Q1:A1 to A5 from S03.1, S03.21	a. **Theoretical** notions of **catastrophe** are not convincingly applied to explaining the **nature of GFS** instability.	C1. If the essential **nature of** the **GFS** is represented as a **complex system** by a model describing the dynamics of all discrete potential **operational states** the GFS is able to assume, and that model is based on an **operational behaviour** paradigm, then it could be used for research into an operational perspective on the GFS and its systemic risk of failure. C5. A succession of such shifts in actual **operational states** over a period of elapsed time could therefore be used in a **theory** to represent GFS **operational behaviour**, such as: **catastrophic instability**, or **total collapse**, when those shifts end in an actual operational state of systemic failure.
	VIII.Q1:A1 from S03.23 to S07.3	f. **Instability** of the GFS has not been explained in terms of the **operational behaviour** of a **complex system**.	
	VIII.Q1:A2 from S03.23 to S07.3	g. The state of crisis or **total collapse** the GFS can enter (i.e. its state of criticality) has not been explained as an **operational state**.	
	VIII.Q1:A3 from S03.23 to S07.3 **IV.**Q3:A1 to A4 from S04.70 to S04.80	i. The global transmission mechanism by which **distress** propagates and materializes throughout the GFS has not been explained as an **operational process**.	C3. From which, **distress** in the GFS could be interpreted by the model as: an **operational process** whereby undesirable effects for system participants arise from participation behaviour in a part of the system; that become unsupportive of overall system operations; generating perceived disincentives or actual barriers to supportive participation in other parts of the system, or perceived incentives for unsupportive participation.
	X.Q1:A4 and A5 from S04.30 to S04.80 **IV.**Q3:A2 from S04.20 to S06.6	j. There is no regulatory concept of how GFS **operations interact** financially or structurally with the **economic environment**.	C8. The GFS could therefore be shown to **interact** with its **economic environment** by a two-way process of transformation between its endogenous **operations** and exogenous macro-economic circumstances.
Q2. What is meant by the risk of such an occurrence?	**IX.**Q2:A1 to A4 from S05	h. There is no consensus about a comprehensive **definition for systemic risk of failure** of the GFS.	C6. Which suggests that **systemic risk of failure** could be **defined** for the GFS as: the probability at a current time that a series of potential operational states of the GFS will manifest an operational behaviour capable of leading to the materialisation of that risk as an actual operational state of systemic failure; by a specified time in the future; in the absence of new efforts to mitigate that risk; through some process of distress generation and propagation; to emerge in the economic environment as a financial crisis.
Q3. How does that risk materialise?	**III.**Q3:A1 to A4 from S03.26	c. It is not well understood how systemic risk **materialises** as a failure of GFS **operations**.	C2. In that model, **systemic failure** of the GFS could be understood to **materialise** as: an operational state that defines the system-wide consequence of aggregate distress among system **operations** exceeding distress tolerance and resilience **criteria**; producing a sustained inability of the entire system to operate as required.
	V. Q3:A1 to A4 from S08.2 **VI.** Q4:A1 to A4 from S09.2, S09.3	d. There is little basis for deciding the regulatory **criteria** for how **systemic failure** of the GFS will be determined to have materialised, for pre-emptive intervention or reactive mitigation purposes.	
	VIII.Q1:A3 from S03.23 to S07.3 **IV.**Q3:A1 to A4 from S04.70 to S04.80	i. The global **transmission mechanism** by which **distress propagates** and materialises throughout the GFS has not been explained as an **operational** process.	C4. This operational interpretation implies that **distress propagates** from where it arises to other parts of the GFS by: some collective behaviour **transmission mechanism** that spreads concentrations in unsupportive participation behaviour; increasing the intensity of collective focus on that behaviour; and generating further distress in more parts; to potentially emerge as a shift in the system's actual **operational** state.
Q4. What could be done to mitigate that risk?	**II.** Q4:A1 to A4 from S03.22	b. Evaluation **models** for **mitigation assessment** are needed**.**	C7. A **model** based on this definition could be used to **select appropriate techniques** for the **assessment** and **mitigation** of the effects of collective operational distress, in a **pre-emptive** or **reactive** response that diverts catastrophic operational behaviour before an actual operational state of **systemic failure** becomes unavoidable.
	V.Q4: A1 to A4 from S08.2	d. There is no basis for deciding the regulatory criteria for how **systemic failure** of the GFS will be determined to have materialised, for **pre-emptive** intervention **or reactive mitigation** purposes.	
	VII. Q4:A1 to A4 from S09.4	e. There is no basis for **selecting appropriate techniques** of **systemic** risk of **failure mitigation** for risk management.	

Table 4: Thematic Synthesis of Conjectures

2.3.17.4 Gaps in Explanatory Value

Table 5 summarises associations between individual conjectures and the gap assertions from which they were derived, particular gaps they expose, and the literature search questions they address. Thematic analysis found 10 gaps (I to X in Table 3) in the core literature relevant to the 4 literature review questions (Q1 to Q4), for which 8 conjectures (C1 to C8) were derived from gap assertions (‘a’ to ‘j’).

It shows the 8 conjectures can address all literature review questions, and their derivation from gap assertions confirms an operational perspective is missing in current thinking among relevant insights from a broad range of academic disciplines. They constitute a simple theory, or basic theoretical model, which can be used as the starting point of new theory development, as prescribed in the methodology followed by this thesis (Davis, Eisenhardt and Bingham, 2007). Although detailed articulation of these conjectures is refined in subsequent theorising (see sub-section 4.3), their meaning and derivation is preserved by the numbers allocated to them, so that new theory proposals can be traced back to the gaps in explanatory value they are claimed to address.

Conjectures (from Table 4)	Gap	Q1	Q2	Q3	Q4
C1. If the essential nature of the GFS is represented as a complex system by a model describing the dynamics of all discrete potential operational states the GFS is able to assume, and that model is based on an operational behaviour paradigm, then it could be used for research into an operational perspective on the GFS and its systemic risk of failure. *From assertions a, f and g.*	**I** and **VIII**	✓			
C2. In that model, systemic failure of the GFS could be understood to materialise as: an operational state that defines the system-wide consequence of aggregate distress among system operations exceeding distress tolerance and resilience criteria; producing a sustained inability of the entire system to operate as required. *From assertions c and d*	**III and VI**			✓	
C3. From which, distress in the GFS could be interpreted by the model as: an operational process whereby undesirable effects for system participants arise from participation behaviour in a part of the system; that become unsupportive of overall system operations; generating perceived disincentives or actual barriers to supportive participation in other parts of the system, or perceived incentives for unsupportive participation. *From assertion i*	**VIII**	✓			
C4. This operational interpretation implies that distress propagates from where it arises to other parts of the GFS by: some collective behaviour transmission mechanism that spreads concentrations in unsupportive participation behaviour; increasing the intensity of collective focus on that behaviour; and generating further distress in more parts; to potentially emerge as a shift in the system's actual operational state. *From assertion i*	**IV**			✓	
C5. A succession of such shifts in actual operational states over a period of elapsed time could therefore be used in a theory to represent GFS operational behaviour, such as: catastrophic instability, or total collapse, when those shifts end in an actual operational state of systemic failure. *From assertions a, f and g.*	**I** and **VIII**	✓			
C6. Which suggests that systemic risk of failure could be defined for the GFS as: the probability at a current time that a series of potential operational states of the GFS will manifest an operational behaviour capable of leading to the materialisation of that risk as an actual operational state of systemic failure; by a specified time in the future; in the absence of new efforts to mitigate that risk; through some process of distress generation and propagation; to emerge in the economic environment as a financial crisis. *From assertion h.*	**IX**		✓		
C7. A model based on this definition could be used to select appropriate techniques for the assessment and mitigation of the effects of collective operational distress, in a pre-emptive or reactive response that diverts catastrophic operational behaviour before an actual operational state of systemic failure becomes unavoidable. *From assertions b, d and e.*	**II V and VII**				✓
C8. The GFS could therefore be shown to interact with its economic environment by a two-way process of transformation between its endogenous operational behaviour and exogenous macro-economic circumstances. *From assertion j.*	**X**	✓			

Table 5: Addressing Gaps in Explanatory Value

2.3.17.5 Answering the Literature Review Questions

In contrast to the critical assessment of core literature in sub-section 2.3.16, and the exposure of gaps in explanatory value for answering literature review questions in Table 3, this sub-section summarises what is currently known in that literature (see Table 6). A suitable overall research question is then proposed from these findings and the conjectures about a new operational explanation synthesised in Table 4, which together become the focus of theory development, testing and validation in the remainder of this thesis.

Answer Themes	Literature Questions (cells contain Answer Theme text for column, and applied LoT Counts				Answer Totals (applied LoT count)
	Q1 Nature	Q2 Meaning	Q3 Materialization	Q4 Mitigation	
A1	Systemic 21	Causes 2	Behaviour 34	Behaviour 19	76
A2	Critical 14	Consequences 1	Participation 23	Participation 17	55
A3	Global 12	Combined 2	Infrastructure 28	Infrastructure 22	64
A4	Financial 19	Similar terms 1	Economic Environment 18	Economic Environment 15	53
A5	Structural 11	-	-	-	11
Question Totals (applied LoT count)	**77**	**6**	**103**	**73**	**Grand Total 259**

Table 6: Answers to Questions from current Lines of Thinking

The source of data summarised in Table 6 is the detailed thematic analysis of core selected literature in Appendix D.5. Its implications for each question are explained as follows.

Q1. What is the nature of catastrophic instability or total collapse of this system?

Interpretive analysis found five answer themes for this question in the core literature, which were used in the detail thematic analysis to identify 207 insights for this question from 35 contributions to the core literature of 77 applied lines of thinking (summarized in the Q1 row in Table 31, and the Q1 column in Table 6).

However, Table 30 suggests there is little consensus about the nature of the GFS itself, and that is reflected in how catastrophic instability or total collapse is perceived. Conversations S04 and S06 show that most contributions subscribe to the 'Financial' view that the GFS is a system in which the fundamental nature of its catastrophes are financial. Mishkin (1992) and Minsky (1993) are the earliest proponents of this point of view in the core literature. Mishkin describes crisis conditions as an inability of financial markets to channel funds efficiently, while Minsky refers to the GFS as a complex, sophisticated financial system spinning out of control through financial instability, exhibiting extremes in both inflations and debt-deflations.

Jorda, Schularick and Taylor (2011), in their 140 years of lessons across 14 developed countries, identify five episodes of global financial instability over that time. Their view is that credit growth is the single best predictor of financial instability, among other financial imbalances in macroeconomic dynamics. Foster and Magdoff (2009) take this view further in their analysis of the recent financial crisis, calling it a *"great calamity of neoliberal capitalism"*, taking the world from a financial explosion to a financial implosion. Whereas Mishkin and Frederic (1999) argue that financial instability arises from financial markets becoming unable to perform essential functions, due to adverse selection and moral hazard by system participants such as banks. Allen and Gale (2007) summarize these different viewpoints nicely in their compendium of lectures on financial crises.

When the answer theme totals for this question in Table 6 are examined, the 'Systemic' and 'Critical' themes also appear to be well supported by LoT in this core literature, although they are not as similar as might first be expected. The 'Systemic' view of catastrophic instability, as represented by this literature, is not just based on theory about generic systems, but includes economic and financial notions. For example, in his theory of systemic fragility, Minsky (1977) refers to the susceptibility of economic disruption as a normal consequence of the fragile financial 'structures' economies tend to develop, creating what he calls the incoherent behaviour of financial crisis. While Acharya (2009) models instability arising from a system of correlated risks operating at a collective level among participants such as banks, and Martinez-Jaramillo et al (2010) favour an operational system of commerce. The only contribution invoking systems theory is Helbing (2010), who refers to the self-organizing, adaptive nature of socio-economic systems in terms of complex systems theory and methods.

In contrast, the 'Critical' view of instability or total collapse uses notions from theories about complexity, catastrophe and evolutionary systems, such as the notions of Yang, Mu and Yao (2009) about how a financial system's brittleness can trigger catastrophe. Zeidan and Richardson (2010) and Allen and Snyder (2009) also consider a range of such models in their reviews of the literatures from disciplines such as econophysics and evolutionary biology, using a complexity-theory lens.

The 'Global' and 'Structural' answer themes in Table 6 also appear to have some support from the core literature LoTs. From his global perspective, Stiglitz (1999) calls for reforms to 'economic architecture' to deal with disastrous short-term capital flows during crises; and the structural perspectives of Gramlich and Oet (2011) and Boyd, DeNicola and Smith (2004) suggest that structural fragility has a key role during crises, in both competitive and monopolistic systems.

Q2. What is meant by the risk of such an occurrence?

Interpretive analysis found four answer themes for this question in the core literature, which were used in the detail thematic analysis to identify 21 insights for this question from 16 contributions in the core literature of 6 applied lines of thinking (summarized in the Q2 row in Table 31, and the Q2 column in Table 6).

Table 30 also suggests there is no consensus within conversation S05 on the meaning or definition of systemic risk, which seems to be confirmed by Table 6.

Systemic risk, and associated terms, are usually defined or explained by contributions to this selected literature from some other research agenda, without much regard for rigour. For example, from the 'Causes' answer theme, Acharya (2009) defines it as a collective risk-shifting phenomenon in which one bank's failure propagates as a contagion, causing the failure of many banks. In the 'Consequences' answer theme, Huang, Zhou and Zhu (2009) define systemic risk as multiple simultaneous defaults of large financial institutions in their contribution of a way to measure that risk of a financial system. Similarly, from the 'Combined' answer theme, Martinez-Jaramillo et al (2010) refer to a general acknowledgement that it is a *"risk of the occurrence of an event that threatens the well functioning of the system of interest (financial, payments, banking, etc.) sometimes to the point of making its operation impossible"*.

In their review of systemic risk in the financial sphere, Govtvan and Mansurov (2011) confirm there is no established definition of systemic risk, and conclude it is *"... the most complicated and poorly studied macro-level risk effect"*.

Q3. How does that risk materialize?

Interpretive analysis found four answer themes for this question in the core literature, which were used in the detail thematic analysis to identify 544 insights for this question from 50 contributions in the core literature of 103 applied lines of thinking (summarized in the Q3 row in Table 31, and the Q3 column in Table 6).

Among the contributions supporting the 'Behaviour' answer theme for this question, a wide range of behaviours is blamed for materializing systemic risk. They include panics (Uhlig, 2010), concentrations of collective actions (Acharya, 2009), competition (Berger, Klapper and Turk-Ariss, 2009), bounded rationality (Rotheli, 2010), diversification (Wagner, 2006), moral hazard (Wolf, 1999), intellectual hazard (Miller and Rosenfeld, 2010), and operational policies and practices (Eisenbeis, Frame and Wall, 2007; Hart, 2009; Duffie, 2010).

There is less support from contributions in this literature for the answer themes of 'Economic Environment', and 'Financial Services'. Bikker and Metzemakers (2005) offer the best explanation of how provisioning behaviour and procyclicality interact with the economic environment, while Karras (2009) gives the best explanation of how financial services in the form of credit derivatives precipitated the sub-prime credit disaster leading to the current financial crisis.

Finally, the answer theme of 'Infrastructure' found support from those who attribute the materialization of systemic risk to regulatory and central bank intervention (Brunetti, Di Filippo and Harris, 2011; Espenilla Jr., 2009; Kaufman and Scott, 2003). While accounting rules were offered as a mechanism of confusion by Magnan (2009).

Q4. What can be done to mitigate that risk?

Interpretive analysis found four answer themes for this question in the core literature, which were used in the detail thematic analysis to identify 291 insights for this question from 43 contributions in the core literature of 73 applied lines of thinking (summarized in the Q4 row in Table 31, and the Q4 column in Table 6).

The structure of answer themes for this answer matched their equivalent themes from the previous question. The difference was introduced by swapping the word 'Through' with 'Modify' in the full versions of these answer theme titles. For that reason, contributions about what could be done to mitigate systemic risk were seen to support a similar pattern of answers to the question of how that risk materializes.

Modifying behaviour was supported by such contributions as Panageas (2010), who counselled caution in the way bailouts were provided, to ensure there were incentives to manage risk better in the future. Improved prudential regulation was argued to be the key by Acharya (2009).

Early warning systems (Davis and Karim, 2008) and macro-prudential leading indicators (Bhattacharyay, 2003) were favoured by the 'Modify Interactions' literature. Although the rebalancing of policies (Freedman et al., 2010) and reforming of the global economic architecture (Stiglitz, 1999) gained equal support in this literature.

Among the literature from the answer theme advocating modifications to systemically important services, credit-related services received all the attention. Karras (2009) argues that use of credit derivatives can have multiple effects on bank behaviour, and can lead to a reduction in their capital reserves. While better regulation of credit agencies holds the answer for Sy (2009).

Finally, the answer theme suggesting modification of external interventions was favoured by Honohan (2008) and Blankart and Fasten (2009). They both advocate containment and resolution practices, but the former suggests that instability was the result of them being applied in a way he characterized as *"too little too late"*.

2.3.18 Conclusions

2.3.18.1 Findings

A gap in theory and knowledge about practice has been found in the evidence-base of primary research that is presented and discussed in this systematic review, by the techniques of descriptive and interpretive analysis applied during thematic synthesis. It confirms that a unifying thesis capable of fully answering the literature review questions is indeed necessary and missing, and appears to be feasible if approached from a multi-disciplinary perspective.

Eight conjectures were synthesised from ten thematic gaps in the explanations provided for literature review questions by relevant lines of thinking in the core literature (see Table 4). Each gap represents where there is unfulfilled potential for making contributions to answering four literature questions derived from this review's initial research problem. When considered together with the analysis of answers found in the literature (see sub-section 2.3.17.5), they suggest that a plausible opportunity exists for developing a unifying thesis about systemic risk and its mitigation for the global financial system, based on notions of complexity and operational behaviour, which can also inform a contribution to regulatory practice. A theory of this type could explain specific phenomena that emerge when the system is close to operational catastrophe, and provide a neutral framework for interpreting how other contributions interrelate in this fragmented and disparate literature.

2.3.18.2 Limitations

The findings of this review are based on results from a qualitative method of synthesis, exposing it to challenges of lacking rigour. However, there is currently no quantitative synthesis method suitable for the project's stated objective of identifying theory development opportunities from a disparate multidisciplinary literature (see synthesis aims in Appendix C.9, and the discussion about qualitative methods in sub-section 2.1). To some extent, that limitation has been addressed by ensuring transparency through providing an audit-trail of all literature collected, in the form of complete lists of categorized references in soft-copy (see supporting evidence and materials in Appendix I).

Another way of improving that qualitative synthesis rigour could have been automation of interpretive analysis and synthesis rules, to ensure greater consistency in their application. This would also have enabled the synthesis process to be more replicable. However, to implement that improvement it would have been necessary to introduce another software application for rules automation into the systematic review tools environment. Nvivo9 does not have sufficient functionality to do this. The additional cost in terms of money and time required would have been prohibitive, so the 'full audit trail' solution was adopted as the quickest and simplest way to achieve adequate transparency and replicability.

Finally, a smaller evidence-base could have been scoped by reducing the range of terms considered equivalent to 'systemic risk' and its related terms in economics and finance. However, it would have made any argument that a truly multi-disciplinary assessment of current understanding had been achieved by this review less credible.

2.4 Exploratory Search

During project 2 in the research methodology (see Figure 4), before an outline of theory was developed in step 6, step 5 called for a more focused exploratory search of both in-scope and alternative literature to find more insights directly applicable to the research problem. Its findings are discussed here within the literature review section of this thesis, so that a combined review and assessment of the extended core literature can follow in sub-sections 2.5 to 2.8, even though the two reviews were not executed consecutively.

First, a return to the literature sources of project 1 used the same search strings to look for new insights about the identified gap in theory published since the systematic review extraction date of 16/17th August 2011, and found no new 'exemplar' contributions to add to the core literature. Then attention turned to what may be known in alternative literature sources about three new literature review questions (see Figure 10), derived from the gap assertions, aimed at finding insights that could test, validate and refine the outlined theory.

Q1.	What is known about disorder and related topics?
Q2.	How may the operational behaviour of a complex system be modeled?
Q3.	What are the implications of answers to Q1 and Q2 for making a contribution to theory and policy or practice?

Figure 10: Exploratory Literature Review Questions

Finally, by following references in the bibliographies of the 194 selected contributions that cite potentially relevant literature not scoped into the initial systematic review, and continuing to follow the citation trails of applicable lines of thinking, 156 new exemplar contributions were revealed and added to the core literature (see underlined entries in the References section). This created a more diverse collection of relevant insights in an extended core literature. A picture began to emerge of latest research in a number of apparently unrelated academic fields, which suggested improvements to the systematic review conjectures for theory development, from which a research question is derived in sub-section 2.9.

2.5 Theory in Economics

2.5.1 Map

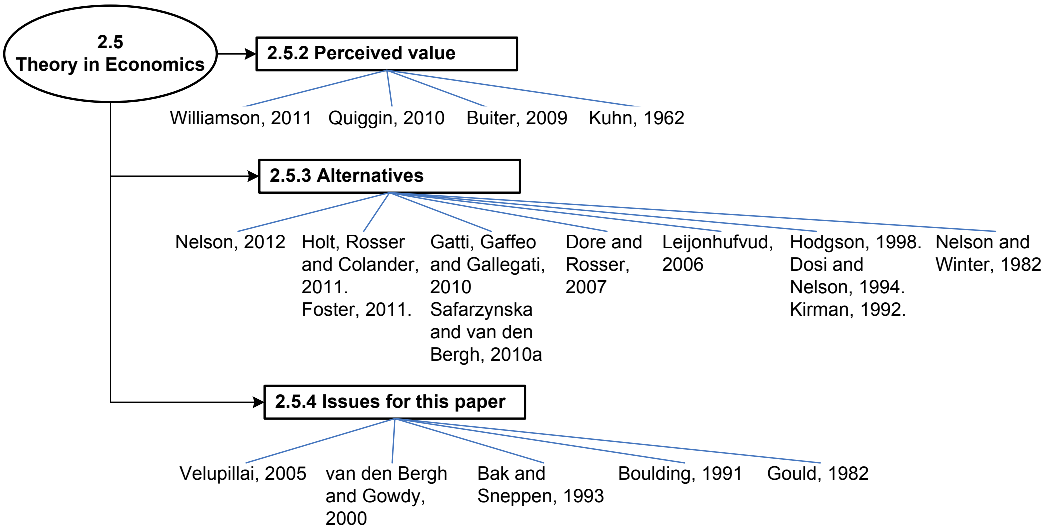


Figure 11: Literature Review Map, sub-section 2.5.

2.5.2 Perceived value

Willem H. Buiter, Chief Economist at Citigroup, expressed a popularly endorsed opinion of the economics practitioner community by writing in the Financial Times on the 6th March, 2009, about “The unfortunate uselessness of most ‘state of the art’ academic monetary economics”. He wrote:

> *“Standard macroeconomic theory did not help to foresee the crisis, nor has it helped understand it or craft solutions. This column argues that both the New Classical and New Keynesian complete markets macroeconomic theories not only did not allow the key questions about insolvency and illiquidity to be answered. They did not allow such questions to be asked. A new paradigm is needed.”*

(Buiter, 2009)

At first glance this appears to be an extreme statement by a senior practitioner who may be attempting to deflect attention away from poor decisions made by many in the banking industry. However, there is a surprising degree of support for this view growing in recent academic literature, although the aforementioned schools of economic thought continue to be endorsed in academic courses on that discipline.

When Buiter calls for a new paradigm, he is invoking the notion proposed by Thomas Kuhn (1962) to describe what happens when scientists within an academic discipline encounter anomalies they cannot explain by their current mode of thinking, assumptions and generally accepted understanding. According to Kuhn, when a sufficiently large body of new findings challenges that thinking in ways that cannot be disregarded as being due to errors of some kind in the research process, the discipline enters a state of crisis. A revolution follows in which intellectual conflict eventually leads to a new mode of thinking becoming dominant. He characterizes this process as a shift from one paradigm to another. Therefore, what Buiter is calling for is no less than an intellectual revolution in macroeconomics.

A glance at the academic literature shows that the entire field of economics has indeed been going through the trauma of a paradigm shift for some time now. On the revolutionary side, Quiggin's (2010) book titled 'Zombie Economics' offers a well-received exposition of "*how dead ideas still walk among us*" from a distinguished, award-winning academic. Counter-arguments are provided from the establishment by Williamson's (2011) critique of Quiggin's critique in his review essay 'A Defence of Contemporary Economics'. Both are credible representations of the arguments offered by the growing literature from their side in this debate.

Essentially, five ideas are being challenged and defended:

i. The Great Moderation;
ii. The Efficient Markets Hypothesis;
iii. Dynamic Stochastic General Equilibrium (DSGE);
iv. Trickle-down Economics;
v. Privatization.

Although the debates around all of these ideas are fascinating, for the purposes of this thesis only idea iii above will be examined further. Given the advantage enjoyed by so-called contemporary economics as custodian of the incumbent paradigm, and the potential offered by its critics for contributing to a new paradigm of economics, this thesis will focus on issues of alleged weaknesses that are relevant to the project 2 research problem.

2.5.3 Alternatives

The theme of a Kuhnian crisis in economics is summarised in a recent article (Holt, Rosser Jr and Colander, 2011) in which the authors argue that the neoclassical era in economics has already ended, and is being replaced by the '*complexity era*'. However, they describe that process as not being revolutionary, but evolving out of a combination of neoclassical and other less orthodox work.

2.5.3.1 New Opportunities

In their assessment of the future of economics, the traditional role of models based on *a priori* assumptions will diminish, and empirically driven models and assumptions will eventually replace them. Answering grand questions will become less important than learning how to develop a better understanding of economic complexity that cannot be explained by models of the aggregate economy using analytically solvable equations. To do this, they suggest the economics profession has to *"go into the trenches, and base our analysis on experimental and empirical data"*, using behavioural approaches, and by adopting a complexity vision (see sub-section 2.7.2 for a further discussion on complexity).

Their assessment is based on a rising tide of opinion, illustrated by an earlier paper which directly addresses the paradigm-shift question (Dore and Rosser Jr, 2007). It concludes that neoclassical economics has already been transcended by a considerable body of empirical analysis and econometric work of an explicitly dynamic nature. Anomalies in that data are described as being inconsistent with the neoclassical model, finding chaotic dynamics and complexity to be rife in everyday reality, and indicating nonlinearities that could not be explained by traditional notions such as general equilibrium.

Dynamic Stochastic General Equilibrium (DSGE) is an attempt by the neoclassical perspective to accommodate this dynamic behaviour of the economy as it changes over time. However, Gatti, Gaffeo and Gallegati (2010) argue there is a reductionist approach at the heart of mainstream DSGE models which wrongly assumes all macroeconomic phenomena can be reduced to the collective effects of individual microeconomic behaviours, and so there is no macroeconomics worth preserving as an autonomous field. This approach is described as making an epistemological fallacy of composition, in which a property is assumed to be true for the whole when it is true for its constituent parts. Furthermore, they point out that in sciences such as statistical physics a hierarchical reductionist approach of that type is allowed if and only if the interaction between elementary units is linear. On the basis of that criterion, the practice of using DSGE to model dynamic economic behaviour that is non-linear must be discarded. Consequently, they suggest there is now a compelling need for a meaningful reconstruction of economic theory. They argue that macroeconomics needs a new scientific paradigm based on notions of complexity, with new tools and a new research agenda, to develop theories capable of explaining *"how a cluster of interacting agents succeed in coordinating themselves without any central authority, and how they suddenly fail to do so from time to time"*. One way of achieving that objective, they observe, is by the cross-fertilization of ideas when '*contaminations*' with other scientific fields have *"allowed the emergence of brand new questions never asked systematically before"*.

2.5.3.2 The Agent-Based Approach

Leijonhufvud (2006) offers a good example of this vision in his discussion of macroeconomics and the potential of agent-based process analysis for explaining the self-regulating adaptive capabilities of a capitalist economy. He describes the first responsibility of a macroeconomist as working towards an understanding of major economic disasters, but confirms there has been a general failure to throw light on that subject. Although an economy is known to be an evolving, complex, adaptive dynamical system, he observes that the progress made in studying such systems over recent years in many other fields has not been matched by economics. He speculates this may be because the central concepts of complex systems theory that are generating excitement in other fields are old themes in economics; such as emergent order, and multiple-layered hierarchical structures of systems with embedded systems, comprised of simple interrelated components, sometimes interacting and operating on different timescales. The problem, he suggests, is those old themes belong to an earlier form of neoclassicism, from before the 1950's.

The DSGE framework of modern macroeconomics has no place for most of these concepts, preferring alternative notions such as the representative agent model (see Kirman, 1992, for a discussion of this model), which uses a single highly-rational agent to displace the natural idea of multiple heterogeneous agents with bounded rationality interacting in ways that can be interpreted as creating such market forces as supply and demand. Leijonhufvud concludes that although the theories of Marshall and Keynes from that earlier form of neoclassicism were flawed, agent-based methods could tap into the older tradition in ways that are capable of advancing our understanding of the adaptive dynamics of actual economies and their systems.

2.5.3.3 An Evolutionary Perspective

Nelson and Winter (1982) conclude that the ideas of orthodox microeconomic theory from the 1950's onwards, exemplified by neoclassical growth theory, were obscuring the essential features of the processes of economic change, and taking understanding *"down a smooth road to a dead end"*. They recognized the need for an evolutionary approach to growth theory, and developed a model in their seminal work on 'An Evolutionary Theory of Economic Change' which combined their notion of selection equilibrium with existing ideas about evolutionary economics (see reviews in: Dosi and Nelson, 1994; and Hodgson, 1998), to explain how profitable expansion in firms is related to the decision rules they use when engaged in searching for how to evolve the way they do things in response to change. The authors chose to embody this evolutionary model of economic growth in a computer simulation, and ran a series of experiments which varied key parameter values to produce an account of economic growth in technical change that encompasses economic phenomena at both micro and macro levels derived from firm-level microeconomics. Their main intention was to develop a general evolutionary approach to theorising about economic change, not to construct and explore particular economic models or arguments through simulation. However, they observed that a combination of evolutionary theorising and simulation permits greater complexity to be modelled, enabling a better understanding of intrinsically dynamic phenomena.

Considerable research effort followed that early attempt to escape the limitations of neoclassical economics. A survey of the methods and building blocks of formal evolutionary economic modelling by Safarzynska and van den Bergh (2010a) provides three broad classifications of latest thinking in this area of research: game theory and selection dynamics, computation, and multi-agent models; with a comparison between their methods. In his article on evolutionary macroeconomics, Foster (2011) adds to that thinking by offering a new research agenda with an analytical framework for macroeconomics using a 'micro-meso-macro' approach to economic evolution, focused on the stocks and flows of energy and knowledge in complex economic systems. This addresses the challenge of how a more balanced and coherent evolutionary macroeconomic approach to economic growth could be devised around discovered '*meso-rules*' used by '*meso-agents*' who represent diversity in microeconomic behaviour, built on the insights of Keynes and Schumpeter rather than neoclassical principles.

Finally, Nelson's (2012) recent interpretation of neoclassical price theory is a particular example of a new trend in evolutionary economics which considers the effects of shifts in demand or supply that may have special relevance to this programme of research.

2.5.4 Issues for this thesis

From the narrower perspective of this thesis, Boulding (1991) touches on the main deficiency of economic thinking summarised in sub-section 2.5.2. Evolution is not a continuous process as Darwin supposed, it is interrupted by catastrophes and other improbable events (Gould, 1982). With so much emphasis on theories of growth in mainstream economic literature, scant attention has been given to the implications of theories on punctuated equilibrium and criticality in evolution, as in self-organization into a critical steady state with intermittent coevolutionary avalanches (Bak and Sneppen, 1993; van den Bergh and Gowdy, 2000). Insights from evolutionary economics capable of explaining discontinuities using notions of that type from biology and physics could potentially be used to make significant contributions to the systemic risk and financial crisis literature, by informing theory development from the conjectures of project 1.

The other deficiency of this literature is more fundamental. The value of mathematical formalizations in many of its contributions is challenged by Velupillai (2005), who exposes *"the unreasonable ineffectiveness of mathematics in economics"*. He argues it is often *"unreasonable, because the assumptions are economically unwarranted;* [and] *ineffective because the formalizations imply non-constructive and incomputable structures"*. For example, the common practice of axiomatic encapsulation and compression of unrealistic fundamentals into precise mathematical theorems suggesting proof is shown to be misleading and irrelevant, because it cannot explain the proven mathematical intractability, insolvability and undecidability of solutions capable of experimentally demonstrating the true dynamical and complex nature of observed economic phenomena. His conclusion is that these undecidabilities and incomputabilities can be more reasonably explored with simpler Diophantine formalisms, allowing variables to take only integer values, in alternative mathematical structures underpinning freer experimental methodologies such as cellular automata.

That insight offers useful criteria for selecting an appropriate overall research philosophy for theory development, and suitable methods for addressing the conjectures of project 1.

2.6 Financial Crises and Systemic Risk of Failure

2.6.1 Map

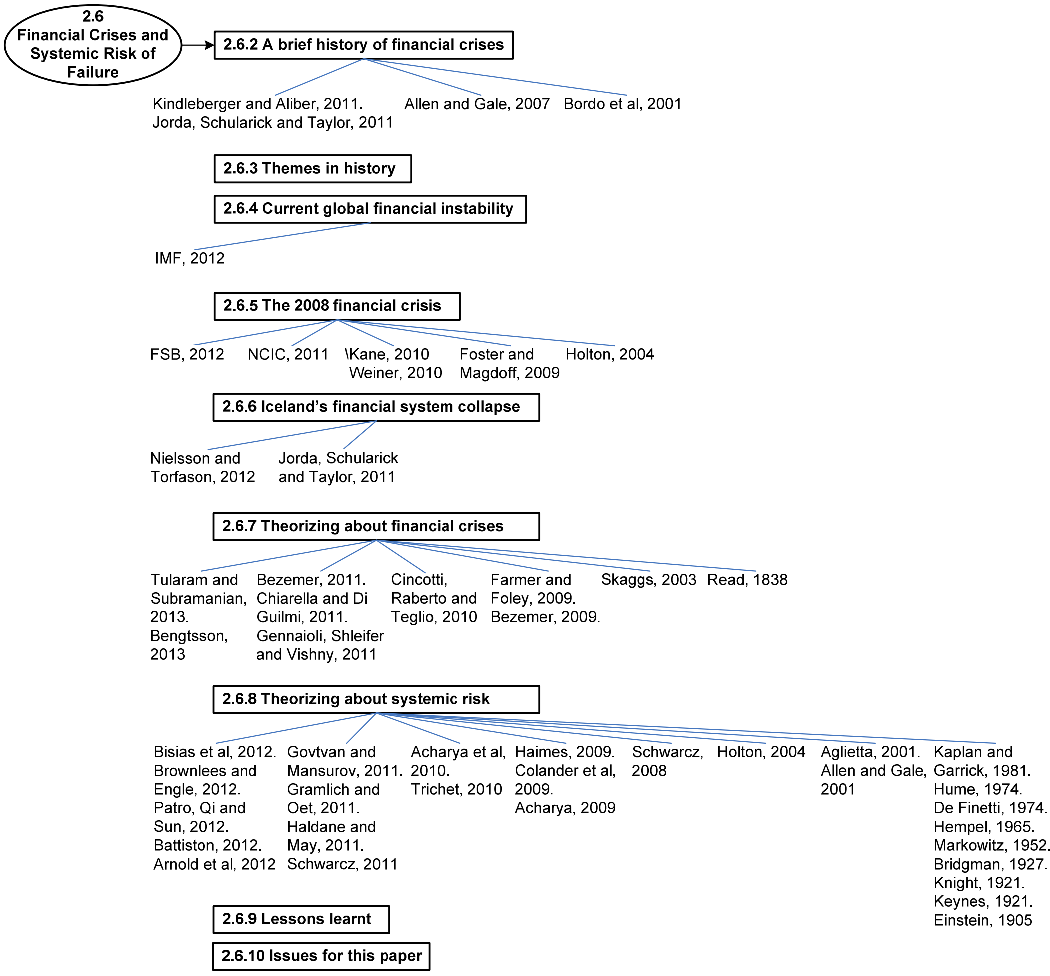


Figure 12: Literature Review Map, sub-section 2.6.

2.6.2 A brief history of financial crises

In their compilation of material from a series of lectures, Allen and Gale (2007) begin by describing financial crises as complex events. A brief analysis of crisis history is then provided in chapter 1, in which they examine the relationships between various historical events and the crisis phenomena that accompanied them, illustrated with references to findings from key contributions to the financial crisis literature. By considering a time period that ranges from the establishment of the first central bank in Sweden over 300 years ago in 1668, to the Argentine crisis of 2001-2002, Allen and Gale show how we arrived at the crisis situations of modern times. Among the many conclusions they draw, perhaps the most relevant to this thesis is the observation that *"crises are not everywhere and always bad"*. Sometimes financial crises stimulate increases in effective contingencies, and generate improvements in the allocation of resources. But in general, increased financial fragility occurs because markets are incomplete, and it tends to have undesirable effects on economic welfare. It is therefore argued that an ability to identify the circumstances under which market failures can lead to such effects should be a priority for policy makers. Potential changes in the regulation of bank capital and liquidity are cited as practical ways of doing that. However, delivering more stability in overall economic welfare would require a better understanding of the complexities of financial crises, and the global financial system in general.

Although there is a significant empirical literature on financial crises, Allen and Gale argue that theory is at a relatively early stage of development and much work remains to be done. They go on to summarize the state of financial crisis theory and develop an improved theoretical approach to analysing financial crises in subsequent chapters, after first providing an account of what has been found in the data so far.

That account includes the empirical work of Bordo et al (2001), who analyse the macroeconomics of financial crises found in the data from a sample of 21 countries over the years 1880 to 1997, and in further data from a larger sample of 56 economies over the years 1973 to 1997. Four distinct periods were identified:

i. Gold Standard Era, 1880-1913;
ii. Interwar Years, 1919-1939;
iii. Bretton Woods Period, 1945-1971;
iv. Recent Period, 1973-1997.

The results showed crisis frequency since 1973 has doubled that of the Bretton Woods and Gold Standard periods, and resembles the crisis-ridden Interwar Years, but crises have not become discernibly more severe in depth or duration. Unsurprisingly, recessions that occur with crises were found to be more severe than recessions at other times, lasting on average from 2 to 3 years and costing 5 to 10 per cent of GDP. However, the various monetary and regulatory regimes in effect over the four periods analysed seemed to suggest their differences of approach had little effect on preventing such crises, even when banking, currency and twin crises (banking and currency) were considered separately. A notable exception is the lack of banking crises during the Bretton Woods Period, which is often attributed to severe banking regulations and state controls introduced after the Great Depression.

More recently, Kindleberger and Aliber (2011) provide an updated edition of their history of manias, panics and crashes, in which they analyse the stages of financial crises over a 400 year period from before 'The Dutch Tulip Bulb Bubble' bursting in 1636 to this current 'Great Recession'. They describe how financial crises often follow bubbles in credit supply that stimulate economic booms until unsustainable bubbles in asset prices result in their collapse. Four recent waves of financial crises make the last forty years particularly unique, because the bubbles in those waves involved many countries simultaneously, and money flows associated with the implosion of bubbles in each wave probably contributed to the next wave.

Other circumstances, such as banking and currency crises, are described in the context of financial crises and the links between them. A key feature of those links in the twentieth century, and financial crises generally according to Kindleberger and Aliber, is that central banks had to choose at those times between giving priority to maintaining the value of their currency or supporting their domestic economic stability. The crisis contagion effects in the 1930s triggered by fluctuations in those priorities after the Great Depression led central banks to conclude that the economic costs of business failures and unemployment from maintaining their currency exchange rate parity were too high, and certainly greater than the economic benefits. The key lessons learnt at that time, and revisited in the 1990s, are that: cross-border flows of money induced by central bank manipulation of currency rates often distort national competitiveness for a few years, with undesirable effects; and, free-floating currencies tend to 'overshoot' or 'undershoot' their long run values, a behaviour which is exacerbated if central banks intermittently try to maintain exchange rate parity at times of crisis.

In terms of the number, scope and severity of country-level financial crises, the period since the 1980s is cited as the most 'tumultuous' in history (Kindleberger and Aliber, 2011: page 278). More national banking systems have collapsed in this period, and there have been more credit and asset-price bubbles, than in any other comparable period, with a resultant cost to taxpayers in some countries amounting to losses of 15 to 20 per cent of their GDP. One emerging pattern indicates that financial crises in this period follow two or three years after sudden reversals in the normal directions of cross-border money flows, when movements of money slow or dry up, causing the prices of key assets to fall and a depreciation of the affected currency. Another observation from this period indicates that the indebtedness usually comes to rest in a large group of system participants, such as home owners or large government institutions. It is usually not spread more widely throughout the financial system.

A recent article documenting new research from a more world-wide perspective by Jorda, Schularick and Taylor (2011) found five episodes of global financial instability appearing as temporal and spatial patterns among country-level financial crises, credit booms and external imbalances of 14 developed countries in a long-run data set covering 140 years (1870-2008). They also observed that the macroeconomic dynamics preceding global financial crises, when crises are 'synchronized' across many countries, tended to exhibit higher credit growth and more depressed short-term interest rates relative to isolated national crises; while the recessionary aftermath of global crises had deeper slumps and stronger turnarounds in general than recessions following other circumstances. However, external imbalances in long-run current and capital account data for economies involved did not seem to play a large role in creating financial instability over the period since World War II. They concede that the patterns identified were complex and not sufficiently clear to enable them to entirely reject the notion that *"crises occur by and large randomly"*. Although, they found the data concerning pre-crisis and post crisis macroeconomic dynamics clearly shows that excessive credit growth poses the key stability risk, and it suggests the rationale behind policy proposals on limiting financial fragility by restricting current account imbalances is not supported by empirical evidence.

2.6.3 Themes in history

The common themes among this literature of relevance to this thesis can be organized into 5 observations about financial crises:

i. They are complex phenomena.
ii. They are not always bad for economic welfare.
iii. They occur as concentrations in the behaviour of financial system participants and system responses.
iv. They are usually induced by some initial stimulus;
v. They escalate by some coordination process.

2.6.4 Current global financial instability

The IMF's Global Financial Stability Report (Brockmeijer et al., 2012: October issue) is a biannual economic and financial survey of the world economy, published for the purpose of:

> [providing an informed assessment of] *"... key risks facing the global financial system. In normal times, the report seeks to play a role in preventing crises by highlighting policies that may mitigate systemic risks, thereby contributing to global financial stability and the sustained growth of the IMF's member countries".*

It provides the latest official view of the state of global financial system at the time of writing this thesis, and makes observations which can inform a solution to the research problem.

2.6.4.1 IMF Assessment

The overall assessment is that risks to financial stability have increased since the April 2012 issue of this report, and confidence has become very fragile. The principal concern is the euro-area crisis, with possible currency redenomination fuelling retrenchments against exposures to the euro-periphery, resulting in capital flight and increasing market fragmentation. This sentiment in financial markets is generating contractions in projected credit supply which are expected to increase financial burdens on the corporate sector in the euro-area periphery, as funding becomes even more difficult to obtain at a time when banks in the region are deleveraging and sovereign stress is generating a difficult economic climate.

The report urges national policymakers to *"build on improvements and avoid fresh setbacks"*, by: reversing capital flight and reintegrating the euro zone through growth-friendly fiscal consolidations; reducing external imbalances through structural reforms; and resolving outstanding issues with the capital, structure and viability of their banks.

At the euro zone level, the report calls for sufficient funding to be made available to banks through the European Central Bank's (ECB's) liquidity framework, and for 'concrete progress' towards establishing a banking union in the euro zone. A successful banking union is described as one with sufficient resources over the longer term to maintain a credible bank resolution authority and a joint deposit insurance fund.

Meanwhile, flows of capital out of the euro zone to perceived safe-havens in other jurisdictions, notably the United States and Japan, are described as a flight towards unsustainable debt dynamics and growing local interdependencies between banks and sovereigns, where necessary steps towards fiscal adjustment are yet to be taken. The report hints at the flight of capital dangers of that lack of action, arising from the suspected role of external imbalances in creating financial instability indicated by long-run current and capital account data for economies (see historical discussion in sub-section 2.6.2), by highlighting: *"The key lesson of the past few years is that imbalances need to be addressed well before markets start flagging credit concerns"*.

2.6.4.2 Recommendations

On the topic of regulatory reforms, the report compares progress with a benchmark set of desirable features, categorized by: more transparency; less complexity; and less leverage. Analysis suggests that financial systems around the world are still overly complex, interconnected and concentrated, with many outstanding concerns such as 'too-important-to-fail' resolution issues. To some extent that is attributed to on-going crisis intervention measures delaying reforms. The areas still requiring attention are given as: a decision on the desirability or otherwise of intervention by direct restrictions on certain business activities; consideration of how to deal with potential systemic risks of the nonbank system (i.e. shadow banking); and more progress in planning for how to recover from large institution failures, or their collapse resolution.

Operational issues are hinted at in the report when it recommends by what it calls the desirable 'structural features' of a more stable financial system, citing notions such as *"non-traditional bank intermediation"*, and *"cross-border connections* ... [acting] *as conduits to transmit destabilizing shocks"*, or by statements such as *"*[banking] *global interconnectivity needs to be managed"*, that convey more than structural meaning. However, explicit recommendations about global financial system operations are not made, even though detailed worked examples are provided throughout the report to explain how operational effects occur (e.g. bank deleveraging simulations). This omission may be explained by the declared purpose of the report, which is to *"*[prevent] *crises by highlighting policies",* as quoted at the beginning of this sub-section. But, when it makes assertions about a more stable financial system, policy suggestions regarding how they could be successfully operationalised would be helpful. As always, the devil is in the details.

2.6.4.3 Systemic risk

Finally, use of the term 'systemic risk' appears in different contexts, with implied meanings that are incompatible and potentially confusing. For example, many references are made to 'systemic risks', in the plural, whereas at other times a meaning of overall risk is implied by the use of a singular reference. Furthermore, in the singular, the systemic risk of a sub-systemic phenomenon is sometimes discussed, and in the plural, various causes and effects are referred to as systemic risks. Clarity is needed about the risk incurred and its causes, effects and subordinate risks.

2.6.4.4 Relevant conclusions

The main findings and recommendations of the report relevant to this thesis are: the global financial system continues to approach deeper levels of instability; and, complexity and concentrations in the financial system need to be addressed. Two further observations arise from a critical assessment of its contents. The first concerns a missed opportunity to directly address the operational implications of findings, even for the purpose of making broad policy recommendations. For example, what policies should be applied when making decisions about reducing operational complexity, or when improving the operational visibility of systemically important nonbank institutions (i.e. shadow banking)? Secondly, systemic risk remains a confused notion that suffers from the lack of a precise definition and consequent inadequate analysis.

2.6.5 The 2008 financial crisis

To help explain how the global financial system got into the state described by the previous sub-section, this thesis turns to the final report of The National Crisis Inquiry Commission on the causes of the financial and economic crisis in the United States (Commission, 2011). Although Congress did not ask the Commission to offer policy recommendations, their report does provide a well-researched analysis of how the greatest financial and economic upheaval since the Great Depression occurred. The Commission's perspective was focused on the United States, but the report's findings are generally relevant to the entire global financial system. Their declared mission was to ask and answer the central question:

> *"How did it come to pass that in 2008 our nation was forced to choose between two stark and painful alternatives – either risk the total collapse of our financial system and economy or inject trillions of taxpayer dollars into the financial system and an array of companies, as millions of Americans still lost their jobs, their savings, and their homes?"*

2.6.5.1 Inquiry Assessment

The major findings of that inquiry resulted in the following conclusions, offered in the hope that lessons may be learned to help avoid future catastrophe.

i. This financial crisis was avoidable.
ii. Widespread failures in the financial regulation and supervision proved devastating to the stability of the nation's financial markets.

iii. Dramatic failures of corporate governance and risk management at many systemically important financial institutions were a key cause of this crisis.
iv. A combination of excessive borrowing, risky investments, and lack of transparency put the financial system on a collision course with crisis.
v. The government was ill prepared for the crisis, and its inconsistent response added to the uncertainty and panic in the financial markets.
vi. There was a systemic breakdown in accountability and ethics.
vii. Collapsing mortgage-lending standards and the mortgage securitization pipeline lit and spread the flame of contagion and crisis.
viii. Over-the-counter derivatives contributed significantly to this crisis.
ix. The failures of credit rating agencies were essential cogs in the wheel of financial destruction.

Perhaps the most poignant comments are made at the end of the conclusions section of this report:

"While we have not been charged with making policy recommendations, the very purpose of our report has been to take stock of what happened so we can plot a new course. In our inquiry, we found dramatic breakdowns of corporate governance, profound lapses in regulatory oversight, and near fatal flaws in our financial system. We also found a series of choices and actions led us toward a catastrophe for which we were ill prepared. These are serious matters that must be addressed and resolved to restore faith in our financial markets, to avoid the next crisis, and to rebuild a system of capital that provides the foundation for a new era of broadly shared prosperity.

The greater tragedy would be to accept the refrain that no one could have seen this coming and thus nothing could have been done. If we accept this notion, it will happen again.

This report should not be viewed as the end of the nation's examination of this crisis. There is still much to learn, much to investigate, and much to fix.

This is our collective responsibility. It falls to us to make different choices if we want different results."

Apart from the valuable conclusions (i to ix) mentioned above, which serve as examples of the factors that can conspire to give rise to catastrophic failure of the global financial system, two other issues presented in the report have special relevance for this thesis.

2.6.5.2 Recommendations

The first is the issue of shadow banking discussed in chapter two of the report, also referred to as the 'nonbank system' in the Global Financial Stability Report reviewed in sub-section 2.6.4. This is closely related to the shadow market described by Weiner (2010), but takes a narrower view which defines it as the banking sub-system comprised of:

"... financial institutions and activities that in some respects parallel banking activities but are subject to less regulation than commercial banks. Institutions include mutual funds, investment banks, and hedge funds".

Another definition is provided by the latest Global Shadow Banking Monitoring Report from the Financial Stability Board (FSB, 2012), which offers a functional interpretation in which there is:

"... credit intermediation involving entities and activities outside the regular banking system".

The key point raised in chapter 2 is that shadow banking was, and continues to be, an essentially unregulated sub-system of the global financial system involved in activities that create concentrations of counterparty credit and operational risks in a very few firms. As of June 30^{th}, 2008, the report cites examples of enormous OTC derivatives positions for JP Morgan of \$94.5 trillion, \$37.7 trillion for Bank of America, and \$35.8 trillion for Citigroup. Through their interconnections with other financial institutions, these holding companies and investment banks clearly posed unacceptable levels of systemic risk to the entire global financial system. The aggregate size of the shadow banking system reached approximately half the size of total banking system assets in 2011, making it equivalent to 111% of the aggregate GDP of all 26 jurisdictions monitored by the Global Shadow Banking Report (FSB, 2012). Consequently, by asset size, more than half of the banking system remains essentially unregulated but able to expose the entire system to concentrations in risk.

There are others, however, who point out that the blame for current crisis circumstances should not be laid exclusively at bankers' feet. While the banking industry has clearly played a central role in this economic catastrophe, some economists argue that the roots of fiscal problems went much deeper (Foster and Magdoff, 2009), mainly due to stagnation tendencies in the underlying economy giving rise to the phenomenon of capital seeking to 'leverage' speculative profits by expanding national debt. For example, over the period from 1959 to 2007 in the US, total debt (including non-financial business debt and government debt) as a percentage of GDP rose from 151 per cent to 373 per cent.

2.6.5.3 Relevant conclusions

This thesis examines how concentrations of various types give rise to systemic risk, and takes care to include relevant 'nonbanking' activities and institutions in its definition of the global financial system, to ensure that sufficient attention is given to contributing factors of systemic risk that do not currently appear on the regulatory radar.

The other issue is more implicit and pervasive throughout the report; namely, it's interpretation of the nature of systemic risk. As usual in both academic and practitioner literature, the meaning of this term is allowed to remain vague. Even though a token attempt is made to define it in the glossary section of this report, readers are left none the wiser. The glossary suggests: *"Systemic Risk - In financial terms, [is] that which poses a threat to the financial system"*.

In an otherwise excellent report, this is perhaps the single most glaring inadequacy. It is partly excusable because, as mentioned above, the Commission was not asked to make recommendations. However, even a non-technical explanation of what occurred still demands clarity about such a central notion. As Kane (2010) argues, official definitions of this type lead to an incomplete diagnosis of the roots of systemic risk, and misguided strategies of regulatory reform. It is simply not a definition of a risk, in the sense given in the Oxford English Dictionary, as *"a chance or possibility of danger, loss, injury, or other adverse consequences"*, which is usually quantified by a probability. Instead, the report's definition merely offers an allusion to some indeterminate cause of systemic risk. Unfortunately, neither the academic nor the practitioner literatures are free from dispute over the correct general definition of the term 'risk' (Holton, 2004), or 'systemic risk' in particular. Sub-section 2.6.8 of this thesis reviews the current debate about both terms, and later sub-sections contribute a new operational perspective.

2.6.6 Iceland's financial system collapse

Any attempt at a meaningful definition of the term 'systemic risk' in a new theory would be required to specify the phenomenon at risk of being manifested. This thesis explores the implications when 'systemic failure' is taken to be that phenomenon, from which the term 'systemic risk' is assumed to mean 'systemic risk of failure'. Consequently, the term 'failure' also requires definition, as either a complete collapse or some lesser breach of performance criteria, along with some way of identifying when it has occurred.

With definitions established for these terms, as proposed later in this thesis, a programme of research into the nature of systemic risk is well placed for its findings to be validated by real occurrences of global financial system failure. However, although it would be easy to identify, there has never been a manifestation of the 'complete collapse' interpretation of that failure in modern economic history, and therefore it would be impossible to empirically validate a theory directly for such cases. Even during The Great Depression the global financial system continued to limp along, and the only complete collapse of a sub-global financial system at national level was that of Iceland in the fall of 2008 (Nielsson and Torfason, 2012).

At first glance, the alternative 'breach of performance criteria' interpretation of systemic failure seems to offer more potential for theory validation, because there have been at least five suitable examples of that type of failure in modern economic history (Jorda , Schularick and Taylor, 2011). However, a greater exposure to the risk of confirmation bias arises in such cases, inherent in the choice of performance criteria for their identification. Besides, most historical accounts of either interpretation of systemic failure focus on the causes and effects of instability or collapse, not on the research interests of this thesis concerning how stability of the global financial system deteriorates and becomes operationally catastrophic.

On closer examination, Iceland's financial crisis is arguably the best option for assessing the plausibility of a systemic risk theory, by serving as a proxy for similar collapse events of the entire global financial system. In that option, speculations about causes and effects attributed to that crisis would be less relevant than the available raw data, which may be usable for proposition and hypothesis validation, followed by further inductive theorising. With that intention in mind, the protocol for project 3 will propose a review of empirical academic articles about the Icelandic financial system collapse, along with government reports and relevant financial databases, specifically to look for clues in the data about how it occurred or became operationalised.

From those observations, a pattern of key contributing factors may begin to form that could help to either confirm or refute theoretical notions proposed in this thesis. Subsequent theory testing, validation and refinement would then build on any general findings to explore the implications for specific propositions and hypotheses.

2.6.7 Theorising about financial crises

Recent contributions to the financial crisis literature relevant to this thesis have appeared within two distinct strands of theorising. The first is about improvements in modelling financial crises, whereas the second addresses a greater understanding of the impact of shadow banking on financial stability. Examples from both of these strands of literature are discussed in this sub-section, to establish an appreciation of latest thinking about financial crises and the key issues involved in explaining them.

2.6.7.1 Models

In their mathematical and critical-reflective analysis of the literature on financial and currency crisis models, Tularam and Subramanian (2013) find current approaches are not sufficiently *"visionary or systematic"*. While being highly adapted to specific past situations, these approaches are unable to explain what is generally happening at such times, or predict their occurrence. The authors categorize and review four generations of crisis models to assess what they describe as a *"patchwork-like approach"* to this area of research in the literature. Their results are summarised in a table of the main variables, important features and issues of each model generation, and its list of pioneer authors. Although a recent increase is identified in the range of contributions to nonlinear behavioural models in the fourth generation, real behaviour is not represented well and little new work is evident. Agent-based simulations are mentioned as being particularly well-suited to simulating the complex and nonlinear behaviour of the economy, but the overall assessment confirms the general view that this type of modelling is not sufficiently developed in economics (Farmer and Foley, 2009). In conclusion, the authors call for more research in this area incorporating new ways of thinking about these crises.

2.6.7.2 Predictions

Bezemer (2009) debunks the popular myth about the current global crisis that suggests *"no one saw this coming"* in his paper on understanding financial crises through accounting models. He does this by citing nine economists and three investment commentators, along with their accurate forecast quotes and dates, with some discussion of their rationale and models. Then he describes the crisis and its ensuing recession as a *"natural experiment in the validity of economic models"*, by reviewing the gross inadequacy of the general equilibrium models widely used in conventional analysis, to show by a systematic comparison of underlying assumptions and theoretical pedigrees how those who did see the crisis coming had used alternative flow-of-fund or 'accounting' models of the macro-economy that are able to anticipate breakpoints in economic development. His conclusion echoes a quote he attributes to Keynes, which is actually paraphrased from an original quote by Read (1838): *"it is better to be roughly right than precisely wrong"*.

2.6.7.3 An alternative approach

More recently, Bezemer (2011) expands on his theme of an accounting approach to economics, based on the ideas of Skaggs (2003) and others, by demonstrating how financial instability can be explicitly modelled as residing in the financial structure of the economy, not only in the behaviour of its agents. This is explained as an alternative and more realistic approach to the *"methodological individualism with optimization"* inherent in the exclusive focus on individual behaviour in the micro foundations of neoclassical economics. Then he shows how financial structure, based on a simplified balance-sheet interpretation that does not need to invoke the behavioural effects of micro foundations, can also be a source of the economy's dynamical, complex-system behaviour, in a simulation of how leverage is key to understanding finance-induced instability. Having demonstrated in this way how traditional macroeconomics has failed to meaningfully include finance in its models, he suggests that a promising avenue of future research could be to combine micro foundational behaviour with a balance-sheet structure in developing a more comprehensive, financially credible agent-based simulation model for instability scenario analysis. The intentions of this thesis are broadly consistent with this suggestion, and will be explored further in later sections.

A rare example of an agent-based simulation using a rigorous balance-sheet approach shows the emergence of endogenous business cycles from the interplay between real economic activity and it's financing from various sources (Cincotti, Raberto and Teglio, 2010). Meanwhile, other agent-based research is now surfacing that takes a non-balance-sheet financial approach, such as the development of a consistent micro foundation for Minsky's hypothesis (Chiarella and Di Guilmi, 2011) for exploring the mechanism of shock transmission from the financial sector to the real economy.

2.6.7.4 Non-bank intermediation

Regarding the second issue mentioned at the beginning of this sub-section, the relationship between shadow banking and financial stability is described in a recent article by Bengtsson (2013) from the perspective of money market funds. Although, an earlier contribution from the US National Bureau of Economic Research (Gennaioli, Shleifer and Vishny, 2011) provides a more comprehensive model of how financial intermediaries originate and trade loans, assemble them into diversified portfolios, and attempt to finance the portfolios externally as riskless debt. From the perspective of this thesis, these contributions help to explain how concentrations of risks arise among non-bank intermediaries, generating financial fragility and fluctuations in liquidity system-wide over time.

2.6.8 Theorising about systemic risk

As mentioned earlier, understanding how the literature on 'systemic risk' has arrived at its current confused state requires an appreciation of the fundamental concept of 'risk' from which it should be derived. A brief review of relevant debates about both terms is provided in this sub-section to establish if they are related, with a summary of latest research, to set the scene for new contributions later in this thesis.

2.6.8.1 Risk

Haimes (2009) expresses the consensus view that *"a universally agreed-upon succinct definition of risk has been difficult to develop* ... [because] *it is multidimensional and nuanced"*. He explains how over time, increasing fuzziness in proposed interpretations from different perspectives within the academic and practitioner literatures has led to general confusion. In their contribution of a quantitative definition of risk, Kaplan and Garrick (1981) refer to this issue as a need to *"greatly diminish the confusion and controversy that often swirls around public decision making involving risk"*. Holton (2004) agrees, finding there is a lot of discussion about risk in the literature but explicit definitions are rarely offered. In a common understanding of the term, risk is thought to entail both uncertainty and exposure regarding possible consequences, whereas formal interpretations are far less concise. Holton traces the latter back to the empiricism of Hume (1974), which is currently represented by the 'probability' and 'operationalism' lines of thinking in the risk literature.

The key example Holton gives from the first line of thinking comes from the debate on subjective versus objective interpretations of probability. He cites a well-known contribution to the objectivist view that refers to risk as a real, measureable uncertainty relating to a probability intrinsic to some formally-expressed logical proposition, whereas an unmeasureable uncertainty is simply an estimate (Knight, 1921). Another contribution from that debate cited by Holton also refers to this distinction between risk and uncertainty (Keynes, 1921), but holds that an objective probability is a relationship between two propositions, one of which is known to be true while the other can be rationally determined as evidence of the first by a statement of mathematical logic. Risk by these objectivist interpretations of probability may therefore be methodically evaluated through statistical analysis, or discovered by logic. Subjectivist interpretations, however, hold that probability is a characterization of uncertainty akin to a belief (de Finetti, 1974), and not intrinsic to nature. By that interpretation risk cannot therefore be rationally determined. Although this suggests an objectivist approach to defining risk may be the way to go, deep philosophical objections have been raised involving such inconsistencies as the relativity of risk (Kaplan and Garrick, 1981). This is reminiscent of Einstein's theory of the relativity of space and time (Einstein, 1905), in which time is argued to be relative to the perception of observers. Further consideration of criticisms and counter-criticisms leads Holton to conclude that, at best, probability quantifies '*perceived*' uncertainty. Therefore, he tentatively defines risk as a condition of self-aware individuals who perceive *"… exposure to a proposition of which one is uncertain"*. An interesting implication of that narrow definition is that entities such as organizations, companies and governments are considered incapable of being at risk in a way that is independent of a self-aware perception of uncertainty about some proposition. They are simply conduits through which self-aware individuals can relate to risk. Holton's definition is intended to clarify common usage, and raise new insights, but he acknowledges it is flawed because it depends on the notions of 'exposure' and 'uncertainty', which are also inherently vulnerable to philosophical inconsistencies.

However, the second line of thinking Holton identifies for understanding the term risk, based on the philosophy of operationalism (Bridgman, 1927), has the potential to overcome these inconsistencies. If knowledge of the world stems from our experiences, as relativity would imply, then a formal definition of a concept must refer to experiences. Operationalism proposes a way to achieve that by specifying: *"the concept is synonymous with the corresponding set of operations* [through which that concept is experienced]*"*. Holton gives an example, by reconsidering the traditional view of making a best estimate by taking a measure m of a quantity q that satisfies the equation: $m = q + e$, where e is the error in that measurement. According to operationalism, all that exists is the measurement m, defined by the operations through which it is obtained. The quantities q and e do not exist independently, because they are only perceived through m and its defining operations.

The philosophical roots of operationalism can be traced back to the empiricism of David Hume by its similarities to logical positivism of the Vienna Circle (Hempel, 1965), one of the most influential philosophical movements of the 20th century. They wrote primarily for philosophers, whereas Bridgman wrote for scientists. When that philosophy is applied in finance, Holton finds the term risk is an exception to the general rule that most intuitively understood financial terms can be operationally defined if necessary. Operationalism maintains that operational definitions apply only to that which can be perceived. Therefore, Holton asserts there can be no true or absolute risk in finance, because a philosophically valid definition is likely to require the inclusion of more than what is perceived of risk by a self-aware entity. Instead, finance applies the common understanding of risk, entailing both uncertainty and exposure regarding possible consequences, for interpreting some aspect of perceived risk whereby subjective probabilities are used to operationally define perceived uncertainty, and where utility or state preferences are used to define perceived exposure. But aspects of perceived risk can take many forms. Holton observes finance addresses that issue by following Markowitz's lead (Markowitz, 1952), in adopting one or more specific risk metrics, such as variance of return or maximum likely credit exposure, to represent a specific aspect of perceived risk. However, this approach introduces another debate about whether adopted risk metrics are appropriate for a particular purpose, such as setting limits or performance-based compensation.

In conclusion, Holton's argument implies that it is meaningless to ask how absolute risk may be traditionally defined and measured, but it is useful to ask if a metric assigned to some operationally defined aspect of perceived risk captures that risk adequately for a purpose. That insight, and its application of the philosophy of operationalism, is explored further in a systemic risk context in later sections of this thesis.

2.6.8.2 Derivative Concepts of Risk

Given this lack of philosophical and practical consensus in the literature regarding the fundamental concept of risk, it is perhaps reasonable to expect that a similar situation exists in the complex systems and economics domains of literature, where logically derivative concepts are explored. However, evidence of attempts to derive new insights from that existing fundamental body of knowledge about risk is much stronger in the field of complex systems than in economics. This difference is attributed to the well-documented insular attitude of economics towards ideas 'not invented here' from other disciplines (Colander et al., 2009). Nonetheless a similar home-grown lack of consensus can be found in economics over derivative concepts such as systemic risk.

2.6.8.3 Systemic Risk

Project 1 reviewed example definitions of systemic risk and similar terms selected from the interpretations found in the literature, and categorized them as 'causal', 'consequential' or 'combined'. After further analysis, the assessment reached in sub-section 2.3.17.5 Q2 was in general agreement with Govtvan and Mansurov (2011), who confirm that there is no unique, established definition of systemic risk, and conclude it is *"... the most poorly studied macro-level risk effect"*.

Since then, up to the time of writing this thesis, there has been further progress in the development of detailed analytical models of various systemic phenomena in the economy, but a consensus on the fundamental meaning of this macro-level risk remains out of reach. Preliminary findings from a recent survey of systemic risk analytics (Bisias et al., 2012) disseminated in a working paper published by the Office of Financial Research (OFR) of the US Treasury, in collaboration with MIT Sloan School of Management and MIT Laboratory of Financial Engineering, confirm there is much that is still not understood. Although, the authors remain agnostic at this stage about what is ultimately knowable. Their stated intention is to encourage research and development in this area, and to provide the broadest possible audience with a sense of the boundaries of current knowledge, without introducing too many of their own preconceptions and opinions. The survey is currently only available as a working paper, but the authority and academic credibility of its sponsor and contributors is undeniable, and fully justifies its use as a key citation in this sub-section.

The OFR was created by the Dodd Frank Act, the most comprehensive financial reform bill in the US since the 1930s, with three broad mandates:

i. To identify risks to financial stability arising from events or activities of large financial firms or elsewhere;
ii. To promote market discipline by eliminating participants' expectations of possible government bailouts; and
iii. To respond to emerging threats to the stability of the financial system.

Before any of these mandates can be addressed, however, the OFR acknowledges there is a need to identify an *"accurate and timely measure of systemic risk"*, which in turn demands a practical definition of what is to be measured. However, this working paper pithily observes that regulatory and research communities working on financial instability have a tendency of delving straight into the details of complex analytics without having established fundamental concepts, assuming it is sufficient to paraphrase Justice Potter Stewart's definition of pornography: *"systemic risk may be hard to define, but I know it when I see it"*.

Therefore, the survey's stated intention is to become a perpetual working paper or living document that will evolve into a comprehensive library of systemic risk research, providing a categorized knowledgebase which can be used to expose such blind spots in current thinking, and stimulate innovative new ideas and approaches. Although the authors admit the survey does not attempt to be exhaustive in breadth, as a typical academic survey might be, and its focus is the needs of regulators and policymakers not academic conjectures; from the perspective of this thesis, it provides a timely summary of the somewhat incomplete state of knowledge in practice. For that reason, it may also become the primary target for the contribution to practice of this overall programme of research, if an identified gap in knowledge about practice can be addressed.

2.6.8.4 A Review of Latest Research

Returning to the recent article by Govtvan and Mansurov (2011), in which they review approaches to the regulation and estimation of systemic risk in the financial sphere, the same mistake found throughout this literature of referring to 'systemic risks' in the plural can be found repeated in their first paragraph. Although this is otherwise a timely review of a broad range of issues, it is extremely light on references to the literature, and the useful observations it makes are diminished by its lack of clarity about the nature of systemic risk.

After confirming that knowledge of such risks and the ability to identify them is widely recognized as being crucial to financial stability in the private and public spheres, the authors attribute a continuing lack of consensus about them in the literature to *"the insufficient development of many theoretical and practical matters connected with this problem"*. Sadly, their working definition of systemic risk, on which subsequent comments are based, is then given as: *"... a potential danger of the occurrence of situations in which the individual response of economic agents to risks leads to an increase in general insecurity rather than to their better division and diversification"*. In terms of the project 1 categorization of such definitions mentioned earlier, this is a 'combined' causal and consequential definition based on the work of Aglietta (2001) and others more than ten years ago. It is also extremely vague, and serves little purpose either for practical reference or serious academic research. Various useful ideas are discussed, but they are often without reference to their original contributors, which is surprising considering the article is published through the Russian Academy of Sciences. However, it does present a credible summary of many issues pertinent to this thesis, and fairly represents the neutral and unprovocative flavour of recent reviews.

For more incisive discussions of latest academic research in the field of systemic risk it is necessary to look at that field by individual topics of focus. The remainder of this sub-section reviews examples from the topics that feature prominently among recent contributions.

2.6.8.5 Measurement

Systemic risk measurement is represented by an empirical methodology for that purpose from a working paper by Brownlees and Engle (2012) related to research out of Stern School of Business, New York University. It is based on a theoretical model for the measurement of systemic risk by Acharya et al (2010), which takes a different perspective to the theory of systemic risk from his PhD dissertation[1] (Acharya, 2009). The latter contribution was evaluated in the project 1 as: *"... the most explicit claim to be a theory of systemic risk* [in the literature] ... *based on the dominant equilibrium paradigm of economics ... and uses a balance-sheet perspective in its model. This is a well-structured contribution of theory containing useful insights, but does not offer a general theory capable of addressing most potential crises. It focuses on specific financial aspects and risk-shifting phenomena of the current systemic crisis, implicating recent innovations and practices, but cannot explain other observed phenomena of past crises or their potential future variations"*. As a conceptual paper, it stands purely on proofs for the mathematical expressions of its propositions, without demonstrating that those expressions do in fact describe reality. In Acharya et al (2010) he explains his departure from this previous theory by saying: *"It is of course difficult, if not impossible, to find a systemic risk measure that is at the same time practically relevant and completely justified by a general equilibrium model. In fact, the gap between theoretical models and the practical needs of regulators has been so wide that inappropriate measures ... have persisted in assessing risks of the financial system as a whole"*. His observation resonates with the misgivings expressed by others, quoted in sub-section 2.5.3 of this thesis. Nonetheless, Acharya's research is deservedly highly rated, representing the most coherent theorising about systemic risk from that economics tradition to date.

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[1] Interestingly, when Acharya cites this paper he reverts to the original unabridged working paper published in 2001.

The methodology Brownlees and Engle propose, therefore, uses Acharya's measure of systemic risk associated with his new model of the systemic expected shortfall (SES) of financial institutions, developed using less contentious statistical measures of risk. SES is defined in terms of undercapitalization and the exacerbating effects of leverage as an institution-level contribution to systemic risk through each institution's expected loss in the tail of the system's loss distribution (i.e., the institution-level marginal expected shortfall, MES), and shown to be particularly significant at times when the system as a whole is undercapitalized. By introducing the SRISK index, representing the expected capital shorfall of a firm conditional on a substantial market decline as a function of its degree of leverage, size, and MES, Brownlees and Engle are able to construct an aggregate SRISK of the whole financial system which can provide early warning signals of distress in the real economy.

2.6.8.6 Indications

Other recent contributions to indicators and early warning signals for systemic risk include a simple indicator using stock return correlations among financial institutions (Patro, Qi and Sun, 2012), and an analysis of the modelling implications for how to integrate structural fragility within a systemic risk framework to enable a more comprehensive and consistent assessment of its role as a cause of systemic distress (Gramlich and Oet, 2011). The former article is particularly interesting for its approach to disaggregating stock returns into systematic (i.e., market-driven) and idiosyncratic components. It finds that stock return correlations among banks are largely driven by their idiosyncratic risk correlations, which the authors associate with increasing systemic risk. The latter article was included in project 1, but is revisited here for its review of concentration effects found among the elements of structural fragility, particularly relating to behavioural factors and the destabilizing effects of feedback loops on the system.

2.6.8.7 Connectivity

Meanwhile, connectivity remains a popular topic of research in the systemic risk field, illustrated by two recent articles. Battiston et al (2012) use the notion of 'financial acceleration', about positive feedback of financial robustness on itself, to explain the surprising effects of risk diversification in a financial network. The authors report on a very recent stream of work showing that full risk diversification is not an optimal approach for ensuring the resilience of financial networks. They introduce a dynamic model for the evolution of financial robustness, and show that a financial network is most resilient at an intermediate level of connectivity. This is contrary to the generally accepted view that greater diversification and integration equates to more resilience (Allen and Gale, 2001). In the other connectivity article, Haldane and May (2011) reach a similar conclusion when they explore the interplay between complexity and stability in financial network models that draw analogies from the dynamics of ecological food webs and the propagation patterns of infectious diseases. They find that in the pursuit of individual diversification in such things as balance sheet composition, funding sources and risk management systems, banks collectively reduce diversity in these areas as homogeneity breeds fragility across the system, increasing systemic risk. In other words, when banks individually attempted to do more things differently, they collectively ended up doing many things the same way, thereby increasing systemic risk.

2.6.8.8 Other Insights

The final two articles address the twin topics of legal and regulatory insights. A legal assessment of progress made in identifying and managing systemic risk is contributed by the first article (Schwarcz, 2011). Schwarcz was criticized in the Project 1 for his 'combined' definition of systemic risk in his testimony on October 2nd 2007, before the US House of Representatives Committee on Financial Services (Schwarcz, 2008). He offered a working definition that holds systemic risk to be: *"the risk that an economic shock such as a market or institutional failure triggers (through panic or otherwise) either a failure of a chain of markets or institutions, or a chain of significant losses to financial institutions, resulting in increases in the cost of capital or decreases in its availability, often evidenced by substantial financial-market price volatility"*. This was considered by project 2 to contain too many embedded assumptions, therefore having little practical value for either academic or regulatory purposes. However, it was a credible attempt at the time by a respected lawyer to inform politicians about a concept for which the academic literature had completely failed to offer a better alternative. In his latest paper, Schwarcz takes a wider look at the on-going trend towards disintermediation. This enables firms in general to access new sources of funds without using banking services as intermediaries. He argues this trend is shifting the focus of systemic risk to financial markets. In his conclusions he then calls for regulations, such as the new Dodd-Frank Act, to move beyond politically targeted responses to: *"situate financial regulation within an analytical framework that realistically explains how systemic risk is transmitted and why free-market factors do not limit that transmission"*. His use of the word 'how' in that statement regarding systemic risk transmission echoes the research problem of this thesis. Although, it is maintained here that explaining how it is transmitted should be developed from a clear definition and an understanding of how it arises, not its causes and effects.

In the final article of this sub-section, Arnold et al (2012) contribute another progress review. At a time of significant policy reform, they discuss various macroprudential and regulatory issues in a contribution that covers enough ground to fill four articles. Although they offer a well-informed overview of research in this area, many of the issues covered are not directly relevant to the research problem of this thesis. However, three issues stand out as being worthy of special note. The first is their confirmation that there is still *"no universally accepted definition"* of systemic risk, citing as an example a recent attempt by the President of the European Central Bank in Trichet (2010), who defines it as: *"... financial instability so widespread that it impairs the functioning of a financial system to the point where economic growth and welfare suffer materially"*. Secondly they point out the reasons why systemic risk measures that work well in the United States may not work so well elsewhere, as in Europe. Then, finally, they mention the normal exclusion of systemic risk associated with non-bank financial players in classic studies of financial crises, calling for future research in this area.

2.6.9 Lessons learnt

A number of important observations can be summarised from the literature on financial crises and systemic risk of failure reviewed in sub-section 2.6 as follows:

Financial crises:

i. are complex phenomena;
ii. are not always bad for economic welfare;
iii. seem to entail concentrations in the behaviour of financial system participants, and responses by the system;
iv. produce concentrations such as: unsustainable asset-price bubbles; currency exchange rate movements; the directions and destinations of money flows; focus on a reducing number of key financial institutions; similarity in operational practices in functional areas such as risk and treasury management; indebtedness coming to rest in particular groups of system participants, e.g. home owners, government institutions, etc.;
v. are usually induced by some initial stimulus;
vi. require some kind of synchronization;
vii. are escalating in frequency, scope and severity;
viii. have increasingly involved multiple countries on a global basis over the past forty years.

The current crisis:

ix. was predicted by credible economists and investors;
x. could have been avoided;
xi. is attributed to banking malpractices;
xii. continues to be aggravated by nonbanking or shadow banking activities;
xiii. was severely exacerbated by widespread failures in financial regulation and supervision.

Current theory about financial crises:

xiv. is at a relatively early stage of development and much work remains to be done;
xv. is not sufficiently visionary or systematic.

Systemic risk:

xvi. calls for a new way of thinking about financial crises;

xvii. has only materialised as a complete failure once in modern economic history, on a non-global scale, as the collapse of Iceland's financial system in the fall of 2008;

xviii. remains a confused notion that suffers from the lack of a precise definition;

xix. literature could apply some operationally defined aspect of systemic risk from the financial risk literature to gain useful insights that have not yet been explored;

xx. literature could also use recent contributions to the accounting and behavioural economics literatures to develop a potential new theoretical explanation that is broadly operational.

2.6.10 Issues for this thesis

The phenomena of interest are complex in nature and global in scope, suggesting some role for the complexity sciences in potential solutions for the research problem. However, the relatively early stage of theory development in such a long established problem domain indicates that a more radical approach may be necessary to introduce a paradigmatic shift in current thinking. The philosophy of operationalism does not appear to have a central role to play in any such approach, but some operationally defined aspect of risk may prove more useful. With supporting contributions from notions of concentration in financial system participation, derivation of a more precise definition for systemic risk may be possible. However, any such solution for the research problem would need to account for all aspects of the financial system, including unregulated and otherwise hidden parts such as shadow banking, and it should be presented in a form that can make a contribution to regulatory and banking compliance practice.

2.7 Disorder in Financial Systems

References to systemic risk in economics usually have financial or economic loss in mind for what is ultimately being risked, with little concept of systemic failure other than some passing reference. For a more comprehensive understanding of disorder in financial systems, the return to literature included the literatures of other disciplines, to find recent contributions and related landmark research offering useful insights about similar notions. This sub-section reviews the results of that search, and sets the scene for later discussions in this thesis by explaining the meaning intended when various non-economic terms are used, and establishes its alignment to relevant on-going debates.

2.7.1 Map

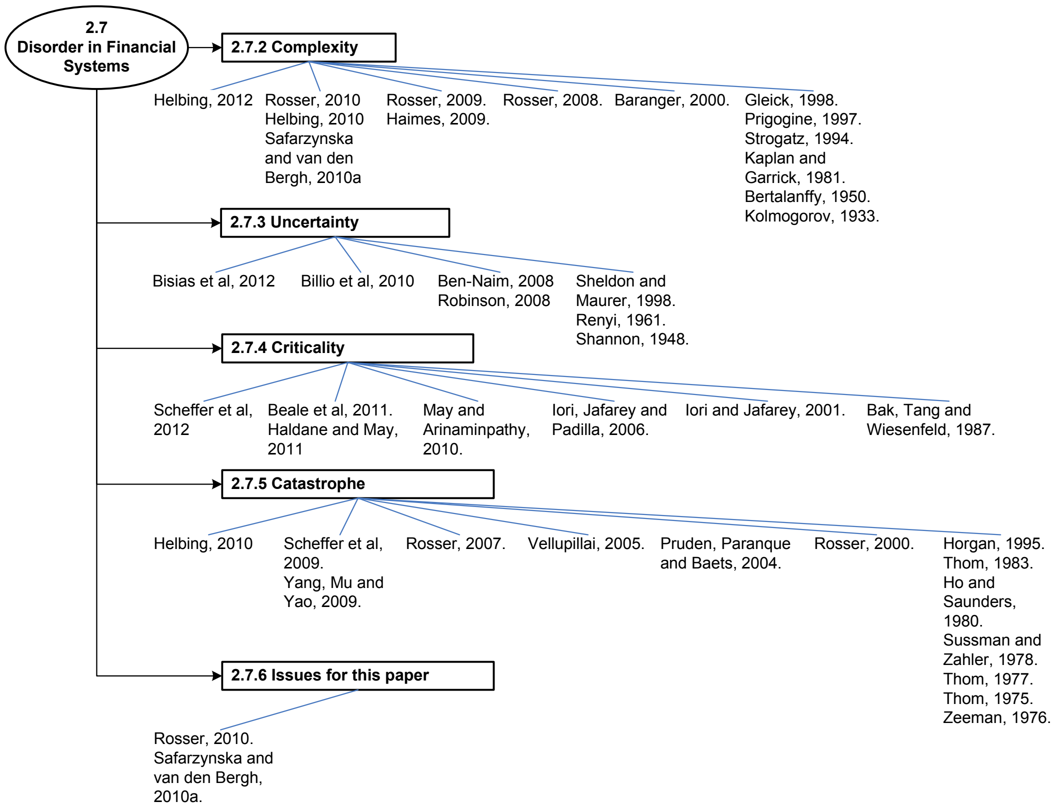


Figure 13: Literature Review Map, sub-section 2.7.

2.7.2 Complexity

2.7.2.1 Chaos and Economic Complexity

Chaos has been described as a science of the global nature of systems, *"a science of becoming rather than being …* [eliminating] *the Laplacian fantasy of deterministic probability"* (Gleick, 1998). It observes that even the simplest of systems can present extraordinarily difficult problems of predictability through their irregular chaotic behaviour, while they also remain capable of spontaneously giving rise to order. As part of the wider subject area known as dynamics, chaos is about system phenomena in which responses can be out of proportion to their stimuli; whereas, dynamics is more generally about '*dynamical systems*' capable of changing their configuration over time. They are both further related to the much broader field of complexity, which involves interplay between chaos and non-chaos (Strogatz, 1994; Baranger, 2000), and the nature of change in all three is known to be mostly nonlinear (Prigogine, 1997). However, complexity does not require the occurrence of chaos even though nonlinearity tends to be irregularly chaotic, and chaos does not confirm the existence of complexity because very simple systems can behave chaotically. Any research involving these domains of knowledge must appreciate the subtle interplay between such concepts, and must be thoughtfully aligned with the academic debates in progress.

2.7.2.2 Complex Systems

This thesis takes an interest in both complexity and chaos through the type of dynamical systems known as complex systems, or more specifically their sub-set of complex adaptive systems, which are generally considered to be a plausible way of modelling a financial system. Apart from a general consensus on their dynamical nature, the precise definition of a complex system is still being debated. The following are some of their most typically accepted properties (Baranger, 2000):

i. They contain many constituents interacting nonlinearly.
ii. Their constituents are interdependent.
iii. They have overall structures spanning several scales.
iv. They are capable of emergent behaviour.
v. Their complexity involves interplay between chaos and non-chaos.
vi. They have constituents that mutually adapt to each other through their interactions (in the special case of complex adaptive systems).
vii. The behaviour of their constituents involves interplay between cooperation and competition.

Essentially, complex systems can be represented by nonlinear mathematical models consisting of a set of state variables to define things that can change over time, and dynamical 'equations of motion' describing how that change occurs. What makes them distinct from other mathematical models of a similar type is the further requirement for their state variables to be chosen so that a complete set of data for those variables uniquely determines the overall state of the system in relationship with time; such that the system will always evolve identically after any time when the overall system state is defined by the same variable data. In other words, it will evolve deterministically in the absence of random or noisy input parameters, and any irregular behaviour will arise from the system's nonlinearity driven by the state variables, not by any other forces (Strogatz, 1994: page 324).

The set of all possible states of a complex system is known as the 'phase space', in which the present overall state is a point that moves over time according to the system's equations of motion. A future trajectory of this state is calculated from the initial conditions of its state variables at some present point in the phase space, and can generally be solved as a nonlinear expression of the equations of motion. However, finding a solution is usually a non-trivial problem, due to the interplay between endogenously generated chaos and non-chaos in such systems. This is further exacerbated in social systems by the difficulties of developing deterministic models of systems defined by human behaviour. Although they exhibit many of the accepted properties of complex systems familiar to other disciplines, as in the physical sciences, social systems have an irreducible degree of randomness and other endogenous or exogenous factors affecting their behaviour (Helbing, 2012). Therefore, a more probabilistic interpretation is required for understanding the complex socio-economic systems of this thesis. An acknowledged alternative approach to modelling the nonlinearity of such systems by purely mathematical methods is to apply agent-based simulation techniques (Rosser Jr, 2010), which is the constructivist approach favoured by this thesis.

2.7.2.3 The Structure of Complex Systems

Baranger explains how perhaps the most striking difference between chaos and complexity is one of scales. As property iii implies, a complex system always has multiple scales, or layers of detail; such that chaos may reign in one layer, whereas the next layer may be self-organizing or non-chaotic. The most confusing effect of chaotic complexity is probably something called *"sensitivity to initial conditions"*. This holds that, when a complex system's nonlinear equations of motion are applied to determining how it will change, similar conditions in the state variables of two initially close overall system states will quickly produce divergent trajectories through phase space as the parameter of time is increased. Even though complex systems are deterministic, however accurately initial conditions are specified, irregular behaviour arising from the system's nonlinearity, and its sensitivity to initial conditions, will make predictability of the system's behaviour decay quickly over a very short period into the future. Strogatz describes this implication more generally as a characteristic of chaos, *"in which a deterministic system exhibits aperiodic behaviour that depends sensitively on the initial conditions* [of its state variables], *thereby rendering long term prediction impossible"*. Chaos is seen as destroying the reductionist dream in which phenomena in higher scales of complex systems can be explained by comprehensive knowledge about what happens in more detailed scales over useful timeframes. That observation has special relevance for the ability to describe how and when certain macro-level phenomena arise in a financial system from knowledge of the interactions of its participants, in attempts to explain systemic risk of failure.

2.7.2.4 Constructivism versus Formalism

In a recent article, Rosser Jr (2010) adopts a hierarchical view of the different meanings of complexity found in the literature, with three categories: 'small-tent' complexity; 'big tent' complexity; and 'meta' complexity. This thesis uses the big-tent meaning, which encompasses cybernetics, catastrophe theory and chaos theory in what Rosser calls a dynamic definition of complexity. An earlier article he wrote on this subject (Rosser Jr, 2009) compares this dynamic definition with a more rigorous computational conceptualization based on notions involving the theories of probability, information and computability. He concludes that although adherents to the computational approach would not be impressed with the non-axiomatic foundations of dynamic complexity, the latter line of thinking does provide insights suitable for constructivist research into the special problem of emergent phenomena in economics. However, when emergence is associated with evolution (as in complex adaptive systems), Rosser (2008) argues it becomes desirable to attempt some reconciliation of these contradictory approaches to complexity. He calls this the struggle between constructivism and formalism. Rather than joining that struggle, this thesis intends to achieve a similar reconciliation effect by exploring the phenomenon of emergence by using the building blocks of evolutionary economics and its models (Safarzynska and van den Bergh, 2010a) in a constructivist context.

2.7.2.5 Systemic Risk in Complex Socio-economic Systems

If financial crises are complex phenomena that occur within a socio-economic system context, as the literature suggests, then it should also be possible to apply systems theory (Bertalanffy, 1950) to understanding how disorder may become catastrophic when they occur. In particular, new research in the fields of complex adaptive systems and chaotic systems contributed from other disciplines offers economics potential insights worth exploring.

Established notions from these fields, such as the state of a system (e.g. stationary, steady and critical states), open or closed systems, equifinality, self-organization, emergence, bifurcations and tipping points, are already being used to explain the complexity of financial system behaviour during times of crisis. When a more trans-disciplinary perspective is taken on that complexity (Rosser Jr, 2009) further explanatory potential is revealed. This sub-section reviews two recent contributions to the literature on complexity and complex systems that are relevant to addressing the research problem of this thesis.

Helbing (2010) reviews what is known in a wide scope of literature about complexity and the emergence of systemic risks that can be applied to socio-economic systems, and concludes that large-scale disasters are generally induced by cascading effects arising from non-linear or network interactions, or both. He then describes how methods derived from an understanding of complex systems are able to mitigate systemic risks arising from these effects; whereas alternative linear, experience-based, or intuitive approaches create the illusion of control, and introduce a dangerous ‘logic of failure’ that tends to engender paradoxical system behaviours, unwanted side effects, and sudden regime shifts.

Among the explanations for systemic risk arising from complex systems behaviour cited by Helbing from the literature, there are a few notable observations relevant to a constructivist perspective. They are paraphrased in italics as follows (with relevance comments in regular font):

i. *"Complex systems are mostly characterised by non-linear interactions among their constituent elements or entities"*. Therefore a realistic model of financial system behaviour must reflect these non-linear characteristics.

ii. *"Non-linear interactions typically occur among elements of a complex system that mutually adapt to, and have an impact on, each other and their environment"*. This is consistent with how participants in a financial system behave, and suggests a realistic model should show how this mutual adaptation is operationalised, at least in some simple way.

iii. *"Non-linear causes and effects can be grossly disproportional to each other, and may be unresponsive to control attempts or show sudden regime shifts when a tipping point is crossed"*. This needs to be considered when recommending a contribution to practice for risk mitigation, or an intervention policy for financial system regulation.

iv. *"When system elements tend to have strong interactions, this implies extreme events may occur with greater frequency, because the statistical distributions characterising their behaviour change from normal distributions to so-called heavy-tail distributions"*. Power law relationships may apply. In general, when modelling participant behaviour, care needs to be taken over assumptions about the strength of interactions among participants as elements in a financial system; otherwise the frequency of extreme events will be unrealistic.

v. *"Network interactions are ubiquitous in socio-economic systems, and their non-linearity implies the occurrence of feedback loops, vicious circles and induced side effects, along with a tendency to cascade local failure events (as in chain reactions or domino effects)"*. When modelling the special case of network interactions among financial system participants, care needs to be taken to ensure that their elementary behaviour is not allowed to become spuriously amplified.

vi. *"Systemic failures are usually triggered by: passing over a critical point or tipping point (assuming a graphical representation of the system), beyond which system behaviour becomes catastrophic; or when a metastable system (that is robust to small perturbations) is overcome by a catastrophic perturbation that harms the system's functionality; or when a metastable system is overcome by several interacting perturbations that trigger cascading failure events"*. In a realistic model of participant behaviour, the potential for triggering financial system failure in these ways should be allowed to arise naturally.

vii. *"A critical state can be induced by exogenous or endogenous processes. The latter are called self-induced or self-organized criticality, such as bankruptcy cascades"*. A model capable of showing how critical states arise in a financial system should allow them to be induced by its environment or from within.

viii. *"System phenomena such as turbulence and chaos, and a probabilistic or stochastic dynamic, can render a complex system unpredictable after a certain time period"*. A model of such phenomena in a financial system should have a temporal dimension, and consider the effects of an extended passage of time.

ix. *"Complex systems can also exhibit self-fulfilling or self-destroying prophecy effects, as when stock speculation leads to herding behaviour and consequent bubbles, which later burst"*. This can be modelled as normal participant behaviour in a financial system.

x. *"Critical transitions, or regime shifts, of a complex system can exhibit early warning signals such as: slow relaxation, where perturbations in the system take a long time to dampen out; and critical fluctuations or flickering, were regular perturbations in the system tend to be larger than usual"*. This resonates with the research focus of project 1, which refers to 'understanding the behaviour of the global financial system as it approaches a state of operational crisis'. Therefore, confirmation of the plausibility of a model can be provided by observations of critical transitions exhibiting these phenomena.

xi. *"Complex systems tend to counteract external control attempts, which are obstructed by such effects as irreducible randomness which cannot be eliminated, or delays and anticipation in the behaviour of system elements. This is usually the reason why conventional attempts to control complex systems fail. When initial measures have little or no effect, due to the system's push-back, increasingly intense measures are attempted, until the system undergoes a sudden regime shift. Oscillations of system state can ensue, and in extreme cases can develop into chaotic system dynamics. Such control attempts are described as applying the logic of failure"*. Testing of a financial system model should include external control attempts, the results of which can inform mitigation recommendations.

xii. *"The correct approach to influencing the stability of a complex system is to nurture its self-organization and self-control mechanisms"*. Explanations of how to achieve this nurturing would be a useful contribution to practice.

xiii. *"Among the 12 scientific techniques listed as credible ways to address the challenges of complex systems, agent-based modelling is described as maybe the most prominent"*. Others techniques quoted as popular in financial crisis and systemic risk literature are 'non-linear dynamics and chaos theory', 'systems theory and cybernetics', 'catastrophe theory', and 'the theory of critical phenomena'.

At least some of these observations about complex systems and systemic risk in the literature noted by Helbing should be reflected in a proposed solution to the research problem of this thesis.

In his contribution to the systems engineering literature, Haimes (2009) takes the view that risk, vulnerability and resilience of a system are best understood through a systems-based philosophy and methodology that recognizes the central role of system states. According to this view, risk to a system is: *"inherently and fundamentally a function of the initiating event, the states of the system and of its* *environment, and the time frame".* To define that function, he begins by deconstructing the standard risk management definition of risk, given as the probability and severity of adverse effects, using three assessment questions from the theory of scenario structuring (Kaplan and Garrick, 1981): 'What can go wrong?'; 'What is its likelihood?'; 'What are the consequences?' They lead him to conclude that a definition of risk that uses an abstract concept such as 'probability' introduces conceptual and cognitive challenges (see sub-section 2.6.8 in this thesis for a more comprehensive discussion). Therefore he bases his notion of 'risk to a system' on the objectivist mathematical definition of that term from Kolmogorov's theory of probability (Kolmogorov, 1933), which Haimes describes as being the gold standard used in the field of systems engineering. He then explores the potential for mathematically modelling the complete risk function, and discusses the other concepts and state variables required for describing: the performance capabilities of a system; its vulnerability and resilience; and the consequences of the initiating event.

Interestingly, Haimes does not refer to systemic risk at any point. He simply describes a systems engineering approach to defining 'risk to a system'. He also makes little reference to complexity science in general, although some of the ideas he applies have their origins in that literature. Nonetheless, his view of the central role of system states resonates with the conclusions of this thesis.

2.7.3 Uncertainty

At first glance, the complexity of a financial system, with its inherent tendency towards irregular chaotic behaviour, would seem to imply there may be a connection between some general notion of disorder in the system and the overall risk of its failure. Entropy is a trans-disciplinary concept often interpreted as a measure of disorder, but it is also considered to be a measure of other things such as mixed-upness, disorganization, chaos, uncertainty, ignorance and missing information (Ben-Naim, 2008). The term is attributed to Rudolf Clausius, who coined it in 1865 to describe an idea of dissipative energy-use in thermodynamics based in part on the work of French mathematician Sadi Carnot and Lord Kelvin in 1824. It subsequently became a measure of disorder in the second law of thermodynamics; which states that the entropy of an isolated system never decreases, because isolated systems spontaneously evolve towards thermodynamic equilibrium, which is described as the state of maximum entropy. More general explanations of entropy refer to its increase as a consequence of a tendency for systems to move toward greater confusion over time.

2.7.3.1 Origins of the term

From the experimental research origins of entropy in the mid-19th century, when the sciences of physics and chemistry examined the relationship between ordered and disordered energy in the form of heat, the field of thermodynamics shifted its focus to a more theoretical point of view. The field of statistical dynamics emerged as an attempt to derive the laws of thermodynamics from existing laws of mechanics by statistical analysis. Boltzman's statistical interpretation of entropy in his kinetic theory of gasses found it was proportional to the natural logarithm of the number of possible molecular conditions of a thermodynamic system which could give rise to an overall phenomenon. His expression (engraved on his tombstone in Vienna) for entropy S is:

$$S = k.\log W$$

where k is known as Boltzmann's constant (which is a physical constant relating the energy and temperature of an individual gas particle), and W is a variable representing the possible molecular conditions of position and momentum for a set of identical particles of a thermodynamic system corresponding to an observable overall phenomenon under consideration. The natural base e is used for the logarithm. Essentially, this expression is derived from statistical notions of probability, and uses k to characterize individual particle conditions in a unit of measure for a quantitative representation of an entire system's degree of disorder.

In this original form, entropy is defined in terms that are specific to physical and chemical systems involving heat transfer. However, it also suggests there may be a general relationship between the low-level conditions and overall phenomena of systems, and complex systems in particular, that may help to explain how the specific phenomenon of systemic failure arises, and its relationship to notions about the risk of that failure.

Boltzmann's fundamental insight led to ground-breaking research in various fields of physics, such as quantum mechanics, and has been successfully applied to many other fields of knowledge, and refined in various ways. However, it has also attracted much controversy along the way, involving confusion about what entropy is actually measuring, and the subjective versus objective debate about the nature of probability on which the concept is founded (for further discussion see sub-section 2.6.8, and Ben-Naim, 2008).

2.7.3.2 Relevance

The next important development in the concept of entropy, for this thesis, came when Shannon (1948) proposed his theory of communication. This is also known as information theory, and uses entropy as a measure of information content. There is some debate about whether this meaning of entropy is consistent with Boltzmann's concept, challenging its use of the ambiguous notion of information. Shannon's theory simply refers to information as something that is communicated. However, he applies the mathematics of probability to provide an important measure of the flow of information from a source to a destination. In the process of doing so he defines entropy as a measure of uncertainty regarding what one could communicate, rather than what is communicated (Robinson, 2008). This is expressed in terms of a discrete set of probabilities $\{p_1, \dots p_n\}$:

$$H(p) = H(\{p_1, \dots p_n\}) = -\sum_{i=1}^{n} p_i \log p_i$$

which can be derived from the Boltzmann formulation. Interestingly, Shannon sidesteps some of the debates by making no claim that this particular expression is proof of his formalization of entropy as a measure of choice and uncertainty:

> *"This theorem, and the assumptions required for its proof, are in no way necessary for the present theory. It is given chiefly to lend a certain plausibility to some of the later definitions. The real justification of these definitions, however, will reside in their implications" (Shannon, 1948: Theorem 2, page 11)*

If the contexts of information and communication in Shannon's theory are set aside for a moment, his idea of special interest to this thesis is that entropy, or disorder, can be expressed in terms of a set of probabilities representing the likelihood of different microstates of a system giving rise to a particular macrostate. When the systems context is also set aside, this idea becomes an even more general definition of entropy, expressed by Renyi (1961) as a characterization of Shannon's measure of entropy for generalized probability distributions. Some combination of these latter two interpretations of entropy, the purely systems-based aspects of Shannon's communication theory, and Renyi's more general characterization, may be applicable to the research problem of this thesis. For example, it may offer a new perspective on systemic risk by providing a measure of uncertainty for potential macrostates of the global financial system.

The literature on using notions of entropy for explaining or responding to systemic risk of a financial system is sparse, as shown by a direct search and by reference to the findings of two recent surveys of systemic risk analytics (Bisias et al., 2012; Billio et al., 2010). The surveys show that, so far, contributions are limited to inferring a probability distribution for one or more variables of interest, as in extracting default probabilities from the prices of equity options, or to establishing the degree of uncertainty when defining a banking system's multivariate density function characterizing individual and joint asset-value movements. The direct search found a few more recent contributions, but they were derivations of research by Sheldon and Maurer (1998), who provide a well-cited example of the principle of entropy maximization in their analysis of interbank lending in Switzerland's banking network. The relationship between a clear definition of systemic risk of failure and a measure of systemic disorder has not been expressed for a financial system.

2.7.4 Criticality

This field of research is very trans-disciplinary, reflecting the pervasive and self-organizing nature of critical phenomena (Bak, Tang and Wiesenfeld, 1987). There are three outstanding articles of direct relevance to this thesis among recent contributions to literature on the criticality of complex systems.

2.7.4.1 Approach indications

Scheffer et al (2012) continue their previous work on early warning signals for critical transitions. They review the relevance to social sciences and medicine of research into generic indicators of system resilience in other fields, such as ecology and climate science. Examples discussed include how current work on ecological networks is revealing fundamental architectural features that may cause 'tipping points' and thresholds to appear in financial markets, and other complex systems, leading to critical transitions in their system states. Elsewhere, research is uncovering generic empirical indicators of proximity to such phenomena. The authors argue that opportunities for new approaches to anticipating critical transitions (also described as sharp regime shifts to alternative states) are appearing at the crossroads of several emerging but hitherto disconnected lines of research.

The relevant key findings identified by Scheffer et al are:

i. The heterogeneity and connectivity of a complex system's components are known determinants of its susceptibility to making critical transitions to alternative states. However, their effects are dependent on the nature of component interaction behaviour. Often, when that behaviour is conducive to stability or recovery from local damage, it is observed to have a counter-intuitive tendency to induce large-scale collapse.
ii. Strong mutualistic interactions (e.g., pollination) among networks of complex system components are predicted to be robust to critical transitions if they occur in nested structures, in which specialists are preferentially linked to generalists acting in their mutual interests as hubs of connectivity.
iii. Strong antagonistic interactions (e.g., competition) among networks of complex system components are predicted to be robust to critical transitions if they are compartmentalized into loosely connected modules.
iv. The 'critical slowing down' phenomenon is observed in topological representations of complex systems as an increasing sluggishness in the recovery rate of the system from small, local perturbations. In such

systems which normally do not have volatile fluctuations in their states, this is considered to be a general indicator for the increasing likelihood of an impending critical transition to some alternative state requiring further confirmation by other means.

v. Highly stochastic complex systems typically experience critical transitions far from local bifurcation points in such topologies, making measurement of slowing down based on local perturbations unlikely to be useful. However, as the current state of this type of system converges on an alternative basin of attraction, away from recent local critical phenomena, it can temporarily flip to an alternative state. This is described as ‘flickering’ behaviour, which is equivalent and converse to slowing down phenomena in less volatile systems, and is a known tendency of complex systems that exhibit rapid fluctuations. The different behaviour can be attributed to various causes, such as more chaotic nonlinearity, or greater sensitivity of the perturbation regime to small changes. It is, however, similar to slowing down in that it also suggests an increasing probability of a sudden critical transition.

vi. Spatial patterns in topological representations of data about complex systems are increasingly being recognized as powerful ways to expose behavioural phenomena. For example, they can be used to infer how the resilience of alternative states depends on key drivers. But it is not entirely understood how these patterns should be interpreted in different circumstances.

vii. The use of absolute values from individual indicators for particular levels of fragility is still beyond reach, but ranking situations according to scales of relative fragilities based on a complementary set of indicators is shown to be an effective way to detect increasing probabilities of critical transitions.

2.7.4.2 Regulation priorities

May and Arinaminpathy (2010) apply their perspectives from the fields of zoology and infectious diseases in exploring what they describe as simple mathematical caricatures for banking ecosystems, to understand the overall dynamical behaviour and criticality of financial systems, and to discuss potential regulations for reducing systemic risk. Their motivation for this article comes from an observation that: *"increasingly complex strategies for managing risk in individual banks have not been matched by corresponding attention to overall systemic risks"*.

A basic model of assets and liabilities in an interbank network is constructed, to show how liquidity shocks are initiated and propagated among banks in such networks through phases of systemic failure. It is described by the authors as a deliberate and extreme oversimplification, which is at best a mathematical metaphor based on earlier work that has produced useful insights. They use it for exploring the likelihood of well-intended regulatory measures having unintended adverse consequences, to gain a better understanding of the causes of current systemic failures. A series of numerical simulations generated by this model interpret bank failures as a function of their capital buffers and their mean number of inter-bank connections. By considering the results in a thought experiment based on the work of Beale et al (2011), the authors find evidence of what evolutionary biologists and ecologists respectively call the 'Prisoner's Dilemma', or the 'Tragedy of the Commons'. This is argued to show that when individual banks serve their own interests by conforming to system homogeneity, often facilitated by regulations, they create a destabilizing effect on the system as a whole which greatly increases systemic risk. The converse is also argued, whereby serving systemic interests puts individual banks at much greater risk. Therefore, May and Arinaminpathy conclude that potential regulations aimed at reducing systemic risk should first gain a clear understanding of the dynamical behaviour of the global banking network, and the impact of their decisions at both systemic and individual bank levels, and then decide their priorities.

2.7.4.3 Concentrations, exposure and diversity

Beale et al (2011) call this the regulator's dilemma: *"should regulations allow institutions to maximize their individual stability or should they safeguard stability of the system as a whole?"* Their article shows, using model systems, that exposure and diversity are the two most important global parameters for explaining the expected systemic cost of multiple failures, suggesting that regulatory intervention should promote more diversification among banks. An interesting feature of their model, of specific relevance to this thesis, is its highly stylized graphical representation of a world in which N banks invest in M assets that can inflict losses or gains proportional to the level of investment over time t. It uses a long-tailed distribution of asset price fluctuations with 1.5 degrees of freedom, and a probability of p that a bank will fail if all its investments are in a single asset class. The plausibility of this model is supported by its findings being remarkably robust to changes in the detail assumptions used. In particular, explanations of their findings are illustrated graphically with just two banks and one asset.

This importance of concentrations in exposure and diversity is confirmed by another recent article (Haldane and May, 2011), and illustrated by work in which a simulation model of complex interbank lending behaviour and criticality shows how avalanche effects lead to more instability when heterogeneity in size and exposure to risk increases among banks (Iori and Jafarey, 2001; Iori, Jafarey and Padilla, 2006).

The various characteristics of financial system criticality discussed in this sub-section will be considered later in this thesis, for theory development and in specification of the project 3 protocol.

2.7.5 Catastrophe

When taken to its extremes, the notion of criticality becomes one of catastrophe. At that point research focus turns its attention to systemic failure, but the inherent nonlinearity of related problems such as systemic risk makes the traditional use of linear mathematical models increasingly impractical.

2.7.5.1 Catastrophe Theory

Helbing (2010) cites catastrophe theory (Thom, 1975; Zeeman, 1976) among the 12 scientific techniques he lists as credible ways to address the challenges of systemic risk in complex economic systems. However, it has been criticised as an intellectual fad in many disciplines, and remains controversial in economics. In his criticism of the criticisms, Rosser Jr (2007) agrees with the conclusions of others that the baby was thrown out with the bathwater, and urges that catastrophe theory should be openly and properly used again in economics. He points out that over this last decade, hardly any papers have appeared in leading journals in economics with a reference to catastrophe theory. It was ridiculed as an intellectual bubble in the mid-1990s alongside chaos theory, complexity theory and information theory, when they were all considered to be of little consequence (Horgan, 1995). Since then, the other theories have become recognized trans-disciplinary fields of scientific research with fully established academic credentials, but catastrophe theory continues to be seen as mostly irrelevant. Rosser puts this down to the *"sins of intellectual hype and exaggeration … [and] inappropriate applications of the theory"*, and argues that *"economists should re-evaluate the former fad, and move it to a more proper valuation"*. He has certainly followed his own advice, by contributing a general theory of economic discontinuities (Rosser Jr, 2000), which is the definitive textbook on such notions drawn from both catastrophe and chaos theories.

In his later article (Rosser Jr, 2007), catastrophe theory is described by Rosser as an important aspect of bifurcation theory, within which it is the study of structurally stable singularities of dynamical systems. After describing how catastrophe theory came to be invented or discovered, and some of its essential features, Rosser lists a few reasonable applications in economics research that do not conform to critics' claims of violated assumptions or misuse of the theory that undermined its credibility. Then he reviews the controversies and debates leading to the theory's downfall, and offers an example of valid criticism, followed by a discussion of alternative approaches.

The essential features of catastrophe theory mentioned by Rosser (2007; 2000) that are relevant to this thesis are:

i. It is an important aspect of bifurcation theory.
ii. It does not have a precise, generally agreed definition.
iii. In mathematical terms it is a non-axiomatic theory.
iv. It addresses structurally stable (generic) singularities of dynamical systems.

v. It is the most appropriate method to use for modelling sufficiently low dimensional systems with gradient dynamics derived from a potential function.

vi. Singularities associated with elementary cusp catastrophe-types are of specific interest, having two control variables (the normal factor and the splitting factor) and one state variable. A pleat appears in the surface (manifold) of potential system states above a critical value for the splitting factor known as the cusp point (see example in Figure 18).

vii. The control variables of dynamical systems that exhibit these singularities are characterized as moving slowly, while state variables are characterized as moving more rapidly.

viii. There are four different behavioural patterns that a cusp catastrophe-type is recognized as being able to exhibit: bimodality, inaccessibility, sudden jumps and hysteresis.

2.7.5.2 The Standard Form

Standard (or 'elementary') catastrophe theory considers a dynamical system given by n functions on r control variables c_i, which determine its n state variables x_j, such that

$$x_j = f_j(c_1, \dots c_r).$$

Then, if V is a potential function on the set of control and state variables, where

$$V = V(c_i, x_j)$$

such that for all x_j

$$\partial V / \partial x_j = 0,$$

this set of points constitutes the equilibrium manifold M. If it is further assumed that the potential function V provides the gradient dynamic and some convention whereby system state variables are placed in this manifold, then the catastrophe function $Cat(f)$ is the projection of state variables in M onto the control variable space. Singularities in this mapping (loosely defined as points where M is not differentiable) are the focus of catastrophe theory, as in the attention paid to particular state variables associated with a bifurcation shadow area of the mapping. In the cusp catastrophe-type of interest to this thesis, M is defined by two control variables (c_1 and c_2) and one state variable (x_1). When the state function f_1 of that cusp catastrophe-type is qualitatively stable under slight perturbations, any singularity of its catastrophe function will also be structurally stable under such perturbations.

Variations of this standard catastrophe theory have been proposed by other researchers, in response to criticisms of Thom's original conceptualization, but he maintains the view that it is intended for the *"classification of analogous situations"*, to be used in *"understanding reality"* (Thom, 1975: page 382). His counter-criticism is that its detractors are attempting to apply a neo-positive epistemology to a theory intended to show how qualitative changes could arise from quantitative changes.

2.7.5.3 The Controversies

Controversies surrounded catastrophe theory almost from its inception. Although, Rosser (2007) reports that the disdain in which it is currently held by some disciplines is widely considered to be overdone by mathematicians and researchers in certain fields of physics and engineering, because it has mathematic validity when used correctly in appropriate contexts. Objections raised by its critics in economics include: excessive reliance on qualitative methods; inappropriate use of quantitative techniques; and the limitations imposed by certain mathematical assumptions. However, the overall nature of these criticisms is generally attributable to the broader qualitative-quantitative divide in theoretical modelling among economists. For example, perhaps the most fundamental challenge of the theory comes from Sussmann and Zahler (1978), who argue from a more positivist epistemological perspective that Zeeman's catastrophe model of stock market dynamics involves too many assumptions, and is essentially tautological because it fails to describe crashes in a nontrivial way, at best showing that crashes occur without explaining why. In recent models of heterogeneous agents in financial markets, the type of assumptions Zeeman makes regarding the behaviour of traders are now seen as central to determining the dynamics of bubbles and crashes. Furthermore, such qualitative explanations have subsequently been supported by more detailed bifurcation analysis and broader overviews of this type of approach.

2.7.5.4 Current Thinking

New contributions must join these debates in the literature, to defend their chosen research approach, and be prepared to articulate the arguments in favour of a return to catastrophe theory. This thesis adopts a standard interpretation of the theory, generally aligned with Thom's original intentions of providing more qualitative explanations (Thom, 1977). Therefore, Thom's statements of rebuff and those of his supporters can be taken to apply here (see Rosser Jr, 2000; sub-section 2.3.1.2).

With regard to the separate debate about how to model temporal aspects of catastrophes when using this theory, Thom makes his views clear. Although gradient dynamics do not allow for time to be a variable of the potential function, he argues that an elementary catastrophe form may be embedded in a larger dynamical system which is time variant (Thom, 1983: pp. 107-108). This gives a series of structural characteristics B of a dynamical system modelled in a larger $B \times t$ space, in which the larger system is transversal to the set of catastrophe structures in this enlarged space (Thom, 1975: pp. 38-40). In sub-sections 4.4 and 4.5 of this thesis, a model with these properties is applied to explaining the structural characteristics of systemic risk in a financial system.

A good example of how current applications of catastrophe theory in economics avoid this direct parameterization of time is provided by Ho and Saunders (1980). Their model of bank failures uses a differential equation of the form:

$$\dot{z} = f(z, a, b),$$

to represent a financial system where z is some state variable, $\dot{z}$ is its derivative, and a, b are parameters that affect the behaviour of z. In that model, all potential states of z are mapped to locus points on a static three dimensional surface, which the article illustrates using a stylized sketch of a cusp catastrophe topology. Then discussions about how z changes refer to its potential movements around the features of that supposed surface. The authors do not offer a mathematical expression for the actual topology of their model, and their considerations of change over time fail to account for the likely recursive effects in a dynamical system of changes in one time-period altering the behaviour surface topology in subsequent periods. Instead, the article simply makes broad, illustrative references to a cusp catastrophe-type, during a mostly conventional mathematical analysis of assumptions and conditions related to an overall probability of bank failures in their model, in a search for the conditions which are both necessary and sufficient to induce a catastrophic jump in that probability. They present implications derived from two versions of their model, one excluding regulators and the other including them, suggesting that a catastrophic jump in the probability of bank failure could occur, even if a continuous source of funding were available from a central bank acting as lender of last resort. Although contributions of this type offer useful qualitative insights that can inform central bank policy decisions, they do not demonstrate how catastrophe theory can be applied effectively.

In a more recent article (Pruden, Paranque and Baets, 2004), the authors investigate the possibility of predicting when a price bubble in securities trading will burst, by observing the dissipative gradient that occurs in trading behaviour patterns within the cusp zone or threshold of a cusp catastrophe model of that behaviour. Although they verify and reinforce these observations with technical market analysis, it is the catastrophe theory application that is of interest to this thesis. They essentially take a similar approach to Ho and Saunders (1980) with respect to using a cusp catastrophe topology for illustrative purposes only, and the tricky question of how to deal with time. But at least they acknowledge that *"implicit in the model is a fourth temporal dimension"*. By this it is assumed they mean 'there is an implicit fourth dimension, which is temporal'. An interesting feature of their research is its application of catastrophe theory to the Cal Tech experiment on irrational exuberance, using data collected by transcription from a video recording of the experiment. Their observations were an early insight on the focus of later work by Scheffer et al (2009) in applying the 'critical slowing down' phenomenon from dynamical systems theory to identifying early warning signals for critical transitions.

The latest directly relevant contribution identified by this thesis is a theoretical analysis of the causes of financial system brittleness based on catastrophe theory (Yang, Mu and Yao, 2009). While it does not use a standard graphical illustration of a catastrophe model, as noted in other contributions, this contribution does apply a theory of complex system brittleness to a very standard nonlinear equation often used to represent the generic form of a cusp catastrophe potential function:

$$V(x) = x^4 + ax^2 + bx.$$

The authors take this to represent a financial crisis caused by a loans sub-system, which they explain by using a *"catastrophe progression method"* on three sub-systems X, Y, Z, having a relationship described as being 'brittle'. The main problem with this use of the cusp catastrophe is that it takes a very generic mathematical expression, which is intended as a stylized example of the kind of expression that can describe a cusp, and combines this with broad assumptions such as *"assuming subsystem X has been in a collapse state"* without actually defining what a *"collapse state"* is. Fuzzy thinking of this type, covered in a smokescreen of mathematics, fails to remove this corner of economics literature from *"the unreasonable ineffectiveness of mathematics in economics"* (Velupillai, 2005) discussed in sub-section 2.5.4 of this thesis. It simply helps to fuel the bad reputation catastrophe theory has gained in economics.

2.7.6 Issues for this thesis

When the research problem of this thesis is considered in the light of current limited knowledge regarding various aspects of disorder or failure in financial systems, then evident confusion regarding how best to achieve and maintain financial stability becomes understandable.

As a complex, adaptive, dynamical system, the global financial system exhibits all the characteristics that are known to make the behaviour of such systems extremely difficult to explain, manage or predict. But recent contributions to other literatures offer economists some clues about the relationship between systemic risk and how instability of the global financial system becomes operationally catastrophic, which may suggest new explanations for that behaviour.

From the discussions in sub-section 2.7 on complexity and related topics, it seems that positivist research into emergent phenomena in behavioural economics may be reaching the limits of current formalisms. A constructivist approach to researching these phenomena, using the 'big tent' notion of complexity, encompassing a dynamic definition based on non-axiomatic foundations (Rosser Jr, 2010), is arguably the most promising alternative. It may not even be necessary to attempt reconciliation with a more positivist evolutionary perspective on emergent phenomena as Rosser suggests if some qualitative notion of the building blocks of evolutionary models (Safarzynska and van den Bergh, 2010a) can be incorporated in carefully specified simulation designs. Acceptance of such arguments does not concede to the view that emergent phenomena cannot be formalized in mathematical models; it simply adopts the most pragmatic way of identifying what is to be formalized, which is currently unclear. Then the relationship between systemic risk and the emergence of such phenomena leading to some tolerated limit of disorder or uncertainty may be explained by a suitable interpretation of entropy for financial systems.

2.8 Agent-Based Computational Economics

Agent based modelling is mentioned in previous sub-sections as a viable constructivist approach to improving current understanding about systemic risk of failure for complex adaptive socio-economic systems such as financial systems. This sub-section reviews recent key contributions to the literature relevant to that topic, and sets the scene for project 3 proposals by explaining the meaning intended when various agent-based modelling terms are used, and establishes its alignment to on-going debates in this area of research.

2.8.1 Map

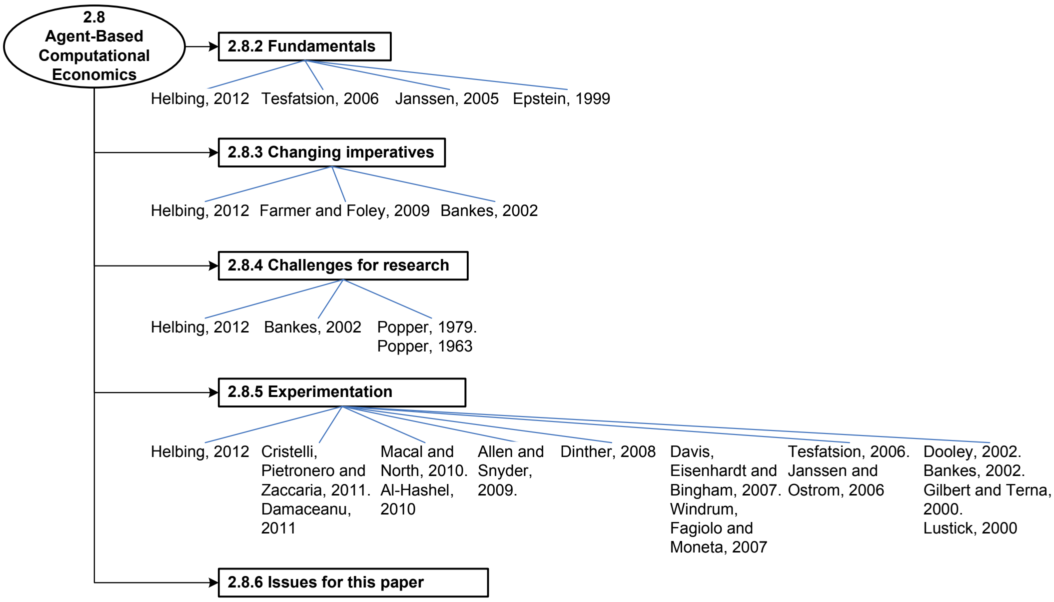


Figure 14: Literature Review Map, sub-section 2.8.

2.8.2 Fundamentals

The origins of agent-based modelling can be traced back to concepts developed by John von Neumann and Stanislaw Ulam at the end of the 1940s (Janssen, 2005). They were applied in models of cellular automata and subsequently evolved into a collection of modelling principles, to form the basis for multi-agent simulations in various scientific disciplines. In this thesis, it is the ACE interpretation of this modelling approach and its associated methodologies in economic research that is intended by references to agent-based terminology.

Agent-based computational economics (ACE) is the computational study of economic processes modelled as dynamic systems of interacting autonomous agents such as individuals, social groupings, and institutions, represented by bundles of data and behavioural rules operating in computer-generated economic environments (Tesfatsion, 2006). It takes a bottom-up constructivist approach to economic theory development by simulating the phenomena that arise from participation in economic systems, enabling theories to be tested to see if they are sufficient for understanding the empirical evidence. Among the many reasons for building such models, perhaps the most important for this thesis is the ability of this type of computer simulation to deliver research insights beyond the current range of analytical tractability (Helbing, 2012). Essentially, every agent-based model has a corresponding and equivalent partial recursive function, as suggested by the Church-Turing Thesis (Epstein, 1999). However, the set of equations describing the dynamics of many interesting computational models is often beyond current mathematical formulation.

Epstein (1999) describes this ability as a 'generative' approach to social science, with features distinguishing it from both 'inductive' and 'deductive' science. By this he means it offers powerful new forms of hybrid theoretical-computational research of particular relevance to non-equilibrium systems, in which society is viewed as a distributed computational device that is able to interpret social dynamics as a type of computation, with interesting implications for the intractability and undecidability of some problems.

A more accessible way of thinking about that ability is perhaps offered by Tesfatsion (2006), who describes ACE in terms of empirical observations on the structural conditions, institutional arrangements, and behavioural dispositions of a real world economic system translated directly into a computational model, cast at a less abstract level than equation-based economic models. It emphasizes a process of empirical understanding and creative conjecture rather than a collection of mathematical equilibrium solution techniques, and, most importantly for this thesis, ACE is better able to facilitate the development and experimental evaluation of integrated theories.

2.8.3 Changing imperatives

Farmer and Foley (2009) describe how *"leaders of the world are flying the economy by the seat of their pants"*, because the two main economic models available to them, empirical models fitted to past statistical data and DSGE (Dynamic Stochastic General Equilibrium) models, each have fatal flaws that were clearly exposed by this current crisis. In the absence of something better, economic policy responses are being guided by common sense and anecdotal analogies to previous crises. However, as discussed in earlier sub-sections of this thesis, such attempts at controlling a complex system are likely to induce unexpected and possibly catastrophic systemic reactions.

2.8.3.1 A Better Way

The article suggests there is a better way: agent-based models. After a brief review of how the history of economics brought the world to its present 'seat of the pants' situation, it describes a few examples of successful agent-based models in economics and the challenges of making improvements. The authors conclude that when the enormity of the stakes involved is considered, this is an alternative approach worth trying. A discussion then follows, in which a holistic model is proposed for the entire economy. However, most agent-based models that have contributed useful insights are small, highly simplified and focused representations of the circumstances observed to be of empirical significance for a particular economic phenomenon, whereas attempts at a more holistic examination of emergent economic phenomena are rare.

An earlier survey of the challenges to be met by agent-based modelling in social science quotes a similar conclusion among the three reasons it cites for the potential importance of the technique (Bankes, 2002):

i. the inadequacy of alternative formalisms for modelling the problems of social science;
ii. agents as a natural ontology;
iii. a greater ability to discover and demonstrate emergence.

Unrealistic assumptions imposed by alternatives to an ABM approach, including linearity, homogeneity, normality, and stationarity are now acknowledged to be too restrictive, limiting their applicability to a narrow class of problems. They were introduced to make certain problems more tractable for mathematical analysis and proof, but simulation using ABM introduces greater flexibility in exploring the implications of imperfect rationality, the effects of learning and information availability, and the influence of social and institutional structures for a more comprehensive range of problems.

2.8.3.2 Relevance

The relevance of ABM as a social science ontology for expressing knowledge about the behaviour, motivations and relationships of social agents is shown best in contrast with the abstract approaches of mathematical derivation. This advantage is illustrated by ABM's power to demonstrate emergent phenomena (Helbing, 2012: page 29), which are difficult to express and even more difficult to discover by using more traditional formalisms.

2.8.4 Challenges for research

Bankes (2002), however, points out a few issues that need to be addressed by future research involving ABMs.

2.8.4.1 Improving Credibility

A lack of clarity is identified by that article as being prevalent up to the time of its publication concerning the requirements for building credible arguments using computational models, which still seems to hold true. It recommends that the standards of rigour applied to ABM simulations should be improved to remove perceived limitations in their usefulness as a scientific technique. However, rather than aspiring to the mathematical standards of deductive proof, which would compromise advantages of flexibility, it argues that agent-based modelling and simulation should apply standards of rigour appropriate for an experimental form of mathematics, casting them as techniques of an experimental science. Then their issues of credibility and methodology could be aligned with the views of Karl Popper (Popper, 1963; Popper, 1979) and the evolutionary epistemology, allowing the findings of ABM simulations to be admissible for informing public policy decisions.

2.8.4.2 Dealing with Emergence

Simulation design, uncertainty analysis and methodology selection were other challenges noted by the article for future attention, along with establishing the best way to deal with emergent phenomena in simulations of complex systems. On the latter topic, the article observed that most demonstrations of emergence were confined to graphical examples, rarely supported by formal definitions and quantitative tests. Consequently, new disciplines were called for, to also make the analysis of emergent phenomena in ABM simulations more rigorous where it has previously been too polemical.

2.8.4.3 A New Paradigm

In his compilation and discussion of recently published papers on the latest approaches to agent-based modelling and simulation of socio-economic systems, Helbing (2012: page 61) describes many of these future requirements as demands for a paradigm shift. He shows that some of the issues raised in Bankes' paper are now being addressed, although their resolution is often far from complete. But he accepts that a new paradigm has not yet appeared.

Progress has been made, nonetheless. Data for parameter calibration and findings validation is now more readily available in the social sciences, and integration of that data in agent-based approaches to model simulation is significantly easier using improved simulation tools. There are also new opportunities to incorporate established analysis methods from disciplines such as statistical physics, and references to complex systems theory are generating a move in the literature beyond descriptive to explanatory models. However, future research in this area incorporating these advances needs to proceed carefully, by combining new and established capabilities, resources and methods with an appropriate methodology, to deliver what Bankes refers to as the *"advertised revolution in social science"* in a suitably rigorous approach to this new form of experimental research.

2.8.5 Experimentation

Unfortunately, recommendations about how to do experimentation are not well developed for agent-based simulation approaches (Allen and Snyder, 2009).

Although much has been written about: the nature and objectives of ACE (Tesfatsion, 2006; Helbing, 2012; Cristelli, Pietronero and Zaccaria, 2011); how to build ABMs and do simulation for ACE (Macal and North, 2010; Gilbert and Terna, 2000; Dinther, 2008; Dooley, 2002), how to develop theory with ACE (Davis, Eisenhardt and Bingham, 2007; Lustick, 2000); and how to test and validate ACE findings (Janssen and Ostrom, 2006; Windrum, Fagiolo and Moneta, 2007); there is very little practical advice or academic consensus on how to pull this all together in an approved experimentation approach within an ACE development and simulation methodology.

This situation contrasts with, and is distinct from, the plethora of agent-based systems development methodologies available for selection (Al-Hashel, 2010), which are not concerned with the purpose of experimentation for which those systems are intended. Most contributions of simulation results to the ACE literature have until quite recently tended to be generated by small, highly simplified ABMs involving few simulation runs. Their focus has often been the illustration of a particular economic phenomenon, in which the experimental aspect of their research context has been minor. Consequently, published results contain detailed descriptions of the agent-based model and how it was implemented by simulations, with little mention of the experimental approach taken in acquiring their results. An exception to this rule can be found in Damaceanu (2011). If, as Bankes (2002) suggests, in future research ABM modelling and simulation should be cast as the techniques of an experimental science to establish academic credibility, then attention must be given to developing a suitably rigorous approach to experimentation.

2.8.6 Issues for this thesis

There seems to be a compelling argument in favour of using ACE to model and demonstrate the validity of a solution proposal for the research problem of this thesis. However, a rigorous experimentation approach will need to be developed in the absence of any accepted standard. The implication for this programme of research is that experimental design in project 3 will be required to define both an overall approach and a specific series of experiments.

The ACE findings of the project will also require quantitative validation, to a standard of experimentation and rigour sufficient for informing public policy decisions. Preferably they should also pass the scrutiny of more demanding academic peer-review appraisals in top-ranking journals.

2.9 Literature Review Conclusions

2.9.1 Overall Assessment

It is the overall assessment of the literature reviewed that, although good progress has recently been made in understanding certain aspects of systemic risk, the paradigms currently favoured in economics for explaining it are reaching their limits of usefulness.

The main distinction between the literature review questions posed in this section and the questions being addressed in the extended core literature is one of understanding ‘how’ behavioural state transitions of the global financial system occur, not their causes or effects. That understanding begs the question: ‘what is the meaning of a behavioural state of the global financial system?’ A suitable answer would help to explain the basic principles of how a particular state occurs, and the risks associated with it, such as the risk of a transition from a state of relative stability to one of systemic failure. Then, the difficult challenge of avoiding multiple potential root causes and effects of systemic failure for that system becomes the simpler challenge of managing its current behavioural state, and potential transitions to future states, by influencing behavioural responses.

A simple metaphor of this distinction is found in the ‘broken-down’ operational state of a motor vehicle. It may have many potential root causes and effects. However, rather than attempting to understand the complex permutations of their interactions, effort is usually applied to understanding the various potential manifestations of a broken-down state, how they occur, and what should be monitored to predict, and avoid or overcome them. Based on that understanding, initiatives are introduced to influence such things as design improvements for impact resilience, the use of redundant components (e.g. extra spare wheel), resources availability (e.g. carrying or acquiring extra fuel) and safety checks (e.g. vehicle maintenance checks). None of these address potential root causes of a broken-down state, such as irrational driving behaviour, bad road surfaces, extreme weather, or the proximity of the nearest petrol station, but they do address how things could go wrong and what to do. Even in extreme cases, such as an impending crash, knowledge of a vehicle's resilience to impact may be sufficient to avoid a write-off or a multi-vehicle pile-up by a well-executed manoeuvre. In financial systems, equivalent initiatives would be considered systemic risk mitigations, but the point made by this illustration is that they are more effective if applied directly to the potential state of breakdown, not to its perceived root causes or effects. It will therefore be argued in this thesis that macroprudential intervention should mitigate the risks of actual state transitions of the system's behaviour, while regulations continue to address the potential root causes and effects of that behaviour. To some extent this is what is beginning to happen with initiatives such as quantitative easing, but the reason why they work is not understood by those who use them. Furthermore, insights into the systemic feedback implications of such initiatives may also be improved by this approach.

2.9.2 Research Problem

A plausible new theory was therefore proposed for development. It was intended to be capable of answering a question that encapsulates certain unresolved aspects of the literature hypothesis, issues identified in the extended core literature (see 2.9.1), and the 8 conjectures synthesised by project 1. After consideration of keywords and phrases from each of these, the following question was formulated so that finding its answer could serve as the research problem of this thesis.

Research Question ***"How does instability of the global financial system become operationally catastrophic, and how could that outcome generally be avoided?"***

The wording is deliberately open to multiple potential answers, to avoid confirmation bias implying that an explanation can only be found in the 8 risk-based conjectures identified by this literature review. Useful findings are therefore possible, even if the propositions and hypotheses derived from those conjectures are shown to be implausible by theory testing and validation.

3 THEORY DEVELOPMENT

3.1 Summary

This section discusses considerations that arose in methodology steps 4 and 6 during project 2 (see Figure 4), and explains how they were addressed when the outline of theory presented in section 4 was developed. As mentioned previously, findings from the exploratory search of alternative literature in step 5 are covered in the literature section.

After reviewing how a focus of research was determined within the potential offered by the research question and its 8 conjectures from project 1 (see Table 5), and defending the criteria by which an appropriate research philosophy was selected, attention turns to the perspective taken by this thesis on theory development controversies. A discussion of the most pertinent debates then leads to a walk-through the approach applied, followed by declarations of alignment with multi-disciplinary theory informing the subject matter of this thesis. Finally, the potential is considered for a unifying theory of the type proposed to make a significant contribution to multi-disciplinary literature within focus, by enhancing macro-economic theory about crises, finance theory about financial services, and complexity science theory about system behaviours.

3.2 Scope

3.2.1 Research Focus

Although the system of interest for this research is the global financial system, it is the macro-level phenomenon of systemic failure, and an understanding of the overall risk of its occurrence, that are of principal interest. Therefore, a focus on the neighbourhood of time close to when this phenomenon occurs, expressed as:

Research Focus ***"Explaining the behaviour of the global financial system when it approaches a state of operational crisis"***,

is considered broad enough to encompass that interest, but sufficiently limiting in its overall scope of attention to be manageable. This enables system behaviour to be examined within a relatively short window of time, instead of throughout all time periods, and allows a narrow operational perspective to be taken on the way micro-level activities generate macro-level phenomena. At a micro-level, participation in the system is considered exclusively for its role in generating the potential for overall systemic failure, and for its mitigation, from which conjectures are developed into propositions and hypotheses in a theoretical model presented in section 4.

3.2.2 Relevance

Aspects of the gap in understanding represented by this research focus are already understood by some academic disciplines, as shown by the exploratory search of alternative literature reviewed in sub-sections 2.5 to 2.8. However, there is still no sign of relevant theory actually being developed within the boundaries of knowledge involved. So the time is arguably right for a multi-disciplinary contribution to unify related knowledge and extend it in a theory addressing the proposed focus.

Current inadequacies may partly be due to a profound confusion concerning the meaning of risk in general, and systemic risk in particular, that appears to be distracting research attention away from such contributions. They may also be a consequence of references in some of the project 1 conjectures to an operational behaviour perspective, which is new to the combined literature reviewed and therefore unlikely to have already been considered. Whatever reasons may explain the existence of a gap, this thesis sets out to show that theory development opportunities relevant to the research problem offer the potential for a significant contribution to theory and practice, even within the proposed confines of the narrower research focus.

3.3 Research Philosophy

3.3.1 Rationale for requirements

Calls in sub-section 1.3.2 for a paradigm shift in responding to the apparent intractable nature of systemic crises in the global financial system (Beinhocker, 2011; Colander et al., 2009; Bandt and Hartmann, 2000) suggest that a more multi-disciplinary approach will be necessary. But diverse traditions of the extended core literature demand a research philosophy compromise that is sufficiently pragmatic to bridge conflicts between those traditions when assimilating their potential insights from different epistemological perspectives.

3.3.2 Selected research philosophy

Further examination of alternative contributing literatures suggested that nonlinearity is a fundamental characteristic of this type of intractable problem (see discussions in sub-sections 2.7 and 2.8), and realist constructivism (Crnkovic, 2010) is considered to offer the best potential for developing an improved understanding. It has a capacity for philosophical reconciliation between insights from different research traditions in the combined core literature by incorporating simple metaphorical references, as generally recommended (Guba and Lincoln, 2005: chapter 8; Cornelissen, 2006; Weick, 1989), into the design of operational constructs. Successfully tested theoretical propositions derived from such constructs could therefore be argued to have pragmatic validity (Worren, Moore and Elliott, 2002).

Selection of a constructivist epistemology for this research, within a realist ontology, in turn called for a suitable constructive research method for building practical, theoretical or combined artefacts to create knowledge about how a domain specific problem can be understood and explained in principle (Crnkovic, 2010). Computational modelling and simulation methods were used, as recommended in other literature (Helbing, 2012; Farmer and Foley, 2009; Heckbert, 2009). However, even with those recommendations in place, philosophical controversies remained to be addressed.

3.4 Perspectives on Theory Development

3.4.1 Philosophy of risk

From a realist constructivism perspective, this thesis accepts Holton's (Holton, 2004) argument that implies it is meaningless to ask how some absolute concept of risk may be traditionally defined and measured, but it may be useful to ask if a metric assigned to some operationally defined aspect of perceived risk captures that risk adequately for a purpose (see discussion in sub-section 2.6.8.1).

The aspect chosen was a state of operational failure, and its metric was a probability at a specific time of its potential for occurrence by some time in the future.

3.4.2 Methodology, methods and goals

Axelrod (2007) describes simulation as a scientific methodology in which the principal value lies in prediction, proof and discovery. More specifically, the primary value of developing theory through simulation methods, according to Davis, Eisenhardt and Bingham (2007), is to be found in producing novel theory through creative experimentation. Helpfully, the latter article offers a roadmap for attaining that value, which this programme of research adapts and implements as its overall research methodology (see Figure 4). However, advice on setting goals for delivering value of relevance to a specific piece of simulation research is sparse (Heath, Hill and Ciarallo, 2009). The goals of this research adapt suggestions from multiparadigm perspectives on theory building in organizational studies (Gioia and Pitre, 1990), which are used to guide research efforts. They are: 'to describe and explain in order to diagnose and understand'. A key implication of this choice is that relevance in this specific piece of research is perceived to exist in clarification through novel theory, which aligns well with its declared focus (3.2.1). Axelrod's notions of prediction and proof are not ignored, and significant progress in those directions is claimed, but they are not the principal intended contribution.

3.4.3 The meaning of theory

Weick (1995) observed that *"most of what passes for theory in organizational studies consists of approximations"*. Sutton and Staw (1995) are less forthright, but confirm that *"there is little agreement about what constitutes strong versus weak theory in the social sciences, but there is more consensus [about what is] … not theory"*. However, neither article offers a clear definition of what theory is. In his comments on the Sutton and Staw (1995) article, DiMaggio (1995) suggests there are at least three views of what theory should be: theory as covering laws, theory as enlightenment, and theory as narrative. He then argues that many of the best theories are hybrids of some combination of these three views that find an appropriate balance between the vexing choices of: clarity versus defamiliarization, focus versus multidimensionality, and comprehensiveness versus memorability. Although DiMaggio's observations are useful, there is a lack of further discussion about their practicalities.

Perhaps the most thorough examination of the meaning of 'theory' in the social sciences is contributed by Abend (2008), who confirms that *"it is quite unclear what sociologists mean by the words theory, theoretical, and theorize"*. In a detailed semantic and lexicographical analysis of the different things sociologists may mean when they use the word theory, Abend arrives at seven implied interpretations quite early in the article. Sadly, none of the alternatives listed resonate with the implied meaning of calls for new theory within the scope of potential contributions in the literature reviewed in section 0. From that point on the article fails to contribute further insights of relevance to this thesis by descending into discussions of linguistic and philosophical issues without reaching any practical conclusions.

Dubin (1978) is more helpful, but his definition is buried on page 216 in his discussion on the nature of research:

> *"A theory is a model of some segment of the observable world. Such a model describes the face appearance of the phenomenon in such terms as structures, textures, forms and operations. In order that such a model is considered dynamic, it also describes how the phenomenon works, how it functions. All scientific models, then, are the imaginative recreation of some segment of the observable world by a theorist interested in comprehending the forms and functions of selected segments of the world around him."*

This is still fairly vague. But, interestingly, in another part of that book he asserts that in his view the terms 'theory', 'model' and 'system' are identical for the purposes of theory building, and are used by him interchangeably. Considering the revised edition cited was published in the late 1970s, when systems theory was still struggling for acceptance (Bertalanffy, 1950; Oren and Zeigler, 2012), Dubin's views were extremely prescient of modern constructivist trends. His subsequent observations on developing theories of systems are of particular interest to this thesis, due to their relevance to the proposed new theory of systemic risk of failure for the global financial system.

Dubin argues in chapter 12 that the development of scientific models, and by implication social science theories, can be couched in a systems format. A 'systems-theoretic approach' to theory development is described as being capable of explaining macro-level behavioural phenomena characterized by changes in system states. Explanations are derived from propositions translated into interactions among the elements of that system according to their data and interaction rules. Furthermore, he describes how computer simulations of that system in operation are able to develop and demonstrate hypotheses as a way of building theory. In that sense the system specification is the theoretical model, and an explanation of the simulation results is the theory. Davis, Eisenhardt and Bingham (2007) describe simulation in this context as being placed in the 'sweet spot' between other more conventional theory-creating methods such as formal modelling and theory-testing methods, and they explain how it is ideally suited for building theories about complex dynamic nonlinear systems.

It is that systems-theoretic approach to theory building, incorporating a simulation-constructivist orientation towards the meaning of theory, which is applied in the research methodology prescribed (see Figure 4).

3.4.4 Methodological controversy

Although simulation is now acknowledged to be an important methodology for theory building in the social sciences, as demonstrated by influential research into topics such as social behaviour (Helbing, 2012), its perceived value generally remains *"clouded and even controversial"* according to Davis, Eisenhardt and Bingham (2007).

They identify the strength of simulation as being its ability to specify and extend theory in precise ways:

i. by providing a more coherent and transparent means of specifying theoretical assumptions and logic than through written theories alone, in satisfying the requirements of computational rigour and internal validity;
ii. by enabling superior insights into complex theoretical relationships among constructs, especially when they are longitudinal, nonlinear, or limited in the availability of real data;
iii. by offering a more effective way of understanding competing tensions, as in long versus short runs, or structure versus chaos;
iv. by clearly revealing outcomes of complex interactions among multiple intertwined processes as they unfold over time, such as inertia, change, competition and legitimation;
v. by contrasting theoretical arguments through a simplified model with tightened logical rigour and sharpened constructs;
vi. by isolating the essential determinants of complex phenomena;
vii. by creating a computational laboratory in which researchers can systematically experiment in various ways such as unpacking constructs, relaxing assumptions, varying construct values, and changing features.

Whereas, objections to it are attributed to false perceptions of:

viii. simulations simply being ‘toy models’ of actual phenomena, in which the obvious is represented while important realism is stripped away, thereby making them unable to yield valid theoretical insights;
ix. simulation constructs being ‘measured’ by empirically distant means, as when ‘0’ and ‘1’ bit strings are used to represent complex states;
x. simulation results being dynamically indeterminate and indecipherable.

Controversy involving these false perceptions is argued by Davis, Eisenhardt and Bingham to be the consequence of a limited understanding within the broad research community about simulation as a theory building method, and how it fits within the overall range of methodological choices available for that purpose. It is further claimed to be exacerbated by inappropriate selections of simulation techniques, processes, and evaluation criteria leading to bad experiences.

3.4.5 Agent-based model simulation (ABMS)

3.4.5.1 Simulation

Simulation is defined as a method for using computer software to model the operation of 'real-world' processes, systems or events (Law and Kelton, 1991); in which simulations are virtual experiments (Carley, 2001), providing simplified pictures of the world that have a carefully selected subset of the characteristics of that world (Lave and March, 1975); to evaluate computational representations of theoretical expressions for propositions (Davis, Eisenhardt and Bingham, 2007).

In a constructivist paradigm of theory development about systems, simulation models are computational representations of theoretical models that explain patterns in data about system behaviour, also known as schemes; in which system components operationalize theory by their interactions in each simulation run, and patterns materialize as emergent system behaviour.

3.4.5.2 Agent-based approach

Among various alternative approaches to simulation, ABMS appears to offer the best fit for the research problem of this thesis. In their comparison of alternative approaches, Davis, Eisenhardt and Bingham (2007) list the characteristics of each. ABMS is represented by 'cellular automata' in the Table 3 of their article, which is a particular form of that approach to simulation. The other approaches include system dynamics, NK fitness landscapes, genetic algorithms and stochastic processes. However, ABMS is the only one focused on the emergence of macro patterns from micro interactions in a population of agents representing system participants, which fits well with the research focus of this thesis (see sub-section 3.2.1). For that reason it was selected as the simulation approach in this programme of research.

3.4.5.3 Assumptions

The key assumptions of this simulation approach are:

i. it is based on a population of spatially arrayed, semi-intelligent, autonomous agents;
ii. who use local and global rules for their interactions, some of which are based on spatial processes;

iii. in which there are neighbourhoods of agents where local rules apply;
iv. with effects of interest emerging by some non-linear means from interactions among those agents;
v. giving rise to phenomena at system-level over time;
vi. which can be interpreted by some existing theory for hypothesis corroboration;
vii. that can be embedded in the agent-space topology.

3.4.5.4 Modelling

Creating a computational representation of the theory built in this programme of research involved three important tasks, performed concurrently (Davis, Eisenhardt and Bingham, 2007).

i. *Operationalize theoretical constructs*.

   This mostly involves clearly defining a conceptual model for evaluating the theory, and constructing a computational representation of that model in which the units of theory are identified and measurable in a way that can be linked to hypothesis predictions. It helps to ensure that construct validity can be claimed, by eliminating measurement errors associated with imprecise specifications.

ii. *Build algorithms that enact the theoretical logic*.

   The logic implemented by software code in ABMS should be compatible with the goals and concerns of a constructivist paradigm of theory building (Davis, Eisenhardt and Bingham, 2007: Table 3), concerned with the generation of macro-level patterns from spatial processes that operate at micro-level (e.g. diffusion, competition, propagation, and segregation), often involving tensions between two opposing processes. Levels of algorithmic complexity in the code should find a balance between parsimony and accuracy in the representation of theoretical logic (Pfeffer, 1982).

iii. *Specify assumptions inherent in the theory, and reflected in simulation results*.

   Internal validity is an important strength of theory development by simulation methods. It is achieved by a precisely specified computational representation that accurately reflects a simplified theoretical model having known assumptions with expected implications for simulation results. Any deficiencies in that model, or its assumptions and expected implications, will have a negative effect on its perceived internal validity, and the credibility of the theory it is used to produce. The precision of computational representation requires assumptions to be made about such things as boundary conditions, the degree of complexity stripped out of the theoretical logic, and scope limitations. Therefore specifications of that representation must make those assumptions, their justifications, and their implications for simulation results explicit.

These tasks were incorporated in the activities of computational model development in project 3 during theory testing and evaluation, as described in sub-section 5.4.

3.4.6 Size and Complexity Considerations

Most academic articles that publish the simulation results of an agent-based model in the public domain use a small and highly simplified model to produce results validated by a single technique over multiple simulation runs (Heath, Hill and Ciarallo, 2009). Unsurprisingly, most advice about how to apply agent-based simulation methods is also focused on this type of contribution. However, large-scale simulations of highly complex multi-disciplinary problems are becoming more common, and have reached a threshold at which improved or different techniques of verification and validation are demanded (Post and Votta, 2005).

Figure 15 places the computational representation developed by this thesis among other examples, illustrating its relationship to this trend in the literature. The financial market simulation by Raberto et al (2001) is representative of small-scale multiple run simulations prominent in the literature, whereas Tumer and Agogino (2007) illustrates an increasing use of complex large-scale simulations that are allowed to continue running for extended periods of time, or even in real-time. The 'frequency of simulation' axis refers to results validation runs, not model calibration and verification runs, and the scale axis refers to the number and variety of agents and data points being simulated. Dynamic complexity refers to the degree of non-linearity of interactions among autonomous agents and number of rules applied.

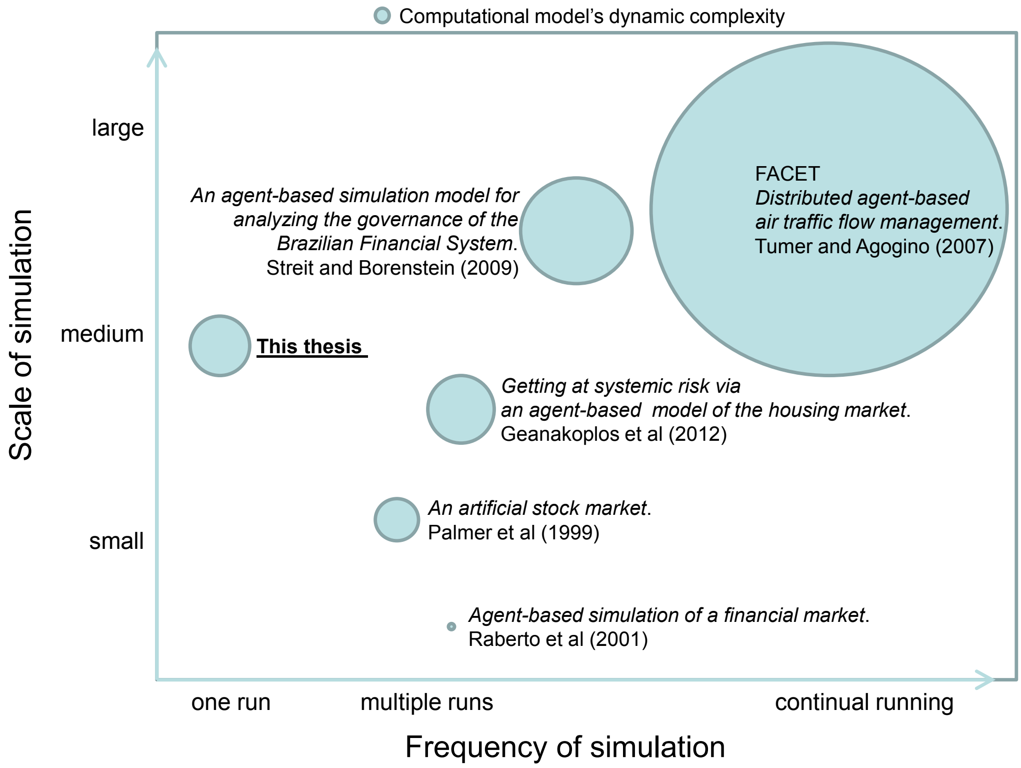


Figure 15: Examples of simulation size and model complexity

The simulation approach of this thesis is placed in the medium range on the scale axis, with a one run frequency, using a dynamically complex computational model relative to most contributions in the literature (represented by Raberto et al, 2001), in line with the recent growing trend of larger scale simulations.

A 'one run' validation frequency was selected due to the scarcity of empirical data, the purpose of simulation, and the consequent decision to use theoretical triangulation (Denzin, 1970) as a complementary approach to checking both the quantitative and qualitative validity of the computational representation and its empirical output (see explanation in sub-section 3.5.10).

3.4.7 Experimentation

According to the methodology applied by this thesis, there are two steps in the process of theory building when simulation occurs: during calibration of the computational representation, and during experimentation when it is being tested, validated and refined. However, as discussed in sub-section 2.8.5, there is very little practical advice or academic consensus on approved experimentation approaches for agent-based simulation, particularly for more complex simulations (Post and Votta, 2005). Nonetheless, it has become a common practice to deploy multiple simulation runs during both steps in theory building (Davis, Eisenhardt and Bingham, 2007), in which initial values, parameters and assumptions are varied to establish robustness and sensitivity.

A popular strategy combined with such practices calls for beginning with a relatively simple computational representation, and subsequently increasing realism to build confidence in the generalizability of its theory. Another strategy calls for building theory by a 'disciplined imagination' approach to simulation using an evolutionary process of speculative experimentation (Weick, 1989). Both strategies were used in project 3, but they were restricted to simulating for calibration and verification purposes. Only one simulation run was deployed for validating the computational representation in its final form (see Figure 15).

The overall intention of this decision about how to deploy simulation experiments for theory development can be compared to the intentions addressed by final stages in design research, for example, when a model aircraft is stressed in a wind tunnel under the known conditions prior to a real air crash to establish how failure occurred. If the research purpose is to refute a null hypothesis that metal fatigue could <u>not</u> explain how that failure occurred, this is achieved by one simulated failure in which relevant measurements show that a critical component failed at a point of fatigue prior to the crash, and those measurements match the real crash findings. However, demonstrating the likelihood of that occurrence, and the range of necessary conditions, would require many more experiments. Different originating causes could be argued and simulated, such as exceeding operational tolerances, but if the fundamental nature of a failure is the primary interest then one experimental simulation may be sufficient to support a theory about similar cases. General applicability of that theory could then be the purpose of further research, based on an explanation developed out of the first simulation, along with any insights about pre-emptive diagnosis of that failure and an improved understanding about its avoidance.

In this thesis, systemic failure of the global financial system is equivalent to the air crash, known conditions prior to a real air crash are equivalent to archived data and academic analysis about the initial conditions of a real financial system failure, and the intention of establishing by simulation whether metal fatigue could not explain how that air crash occurred equate to the intention to demonstrate by simulation whether a proposed outline theory could not explain how a real financial system failure occurred. However, in both cases further evidence is required to support any arguments founded on assumptions that the simulation is a valid representation of reality, and refuting the null hypothesis can only indicate plausibility of the proposed theory. Further research is always necessary to establish general applicability. Nevertheless, a single-run approach to simulation for validating results is consistent with a 'granular' form of pragmatic validity (see subsection 3.5.10.1) and the goal assertion of this thesis (see sub-section 3.5.1).

3.4.8 Results assimilation

Validation steps 11 and 12 in the methodology process (see Figure 4) are considered together for results assimilation in this thesis. Although some theorists argue that creating an interesting theory is a useful contribution to knowledge, without the necessity for immediate validation (Weick, 1989; Whetten, 1989), many still disagree. There is a substantial literature on testing simulation results and validating them with empirical data (Janssen and Ostrom, 2006; Windrum, Fagiolo and Moneta, 2007), but advice on how to interpret those results and place their meaning in the context of existing theory is scarce. The overall constructivist epistemology of this programme of research will, therefore, require careful justification for any argued assimilation of its result into current theory.

3.4.9 Principles adopted

Issues raised in preceding sub-sections 3.4.1 to 3.4.8 are addressed in a set of methodology principles declared as follows:

i. A systems-theoretic approach, incorporating a simulation-constructivist orientation towards the meaning of theory, is applied to theory building (Dubin, 1978; Crnkovic, 2010).
ii. Theory is expressed using four key elements: constructs, propositions that link those constructs together, logical arguments that explain the underlying theoretical rationale for the propositions, and assumptions that define the scope or boundary conditions of the theory (Dubin, 1978; Davis, Eisenhardt and Bingham, 2007).
iii. Among the potential starting points for theory building, a pre-existing simple theory is assumed (Davis, Eisenhardt and Bingham, 2007), represented in this research programme by the 8 conjectures synthesised from the boundaries in the literature gap exposed in project 1.
iv. The process followed in this methodology is according to a roadmap for constructing theory using simulation methods (Davis, Eisenhardt and Bingham, 2007: Table 1).
v. Theory building proceeds by that roadmap from the initial set of conjectures, through proposition construction, hypothesis development, computational representation, verification, experimentation (with theory refinement), and empirical validation.
vi. The simulation approach selected is ABMS (agent-based model simulation).

3.5 Approach

3.5.1 Goals

As discussed in sub-section 3.4.2, the goals selected for this research are: 'to describe and explain in order to diagnose and understand'. When they are considered in the context of the research problem (2.9.2) and focus (3.2.1) of this thesis, they can be expanded into the following combined assertion:

Goal Assertion ***"To describe how instability of the global financial system becomes operationally catastrophic, and explain that operational behaviour, in order to diagnose when it approaches a state of operational crisis and understand how that outcome could generally be avoided"***.

This is henceforth used as a more precise expression of research intent for evaluating the theory development outcome of this thesis than seeking to answer the research question alone.

3.5.2 Methodology implementation

3.5.2.1 Project context

A formal methodology was selected (see Figure 4) in response to a call in the literature for improvements in the rigour of computational approaches to research in the social sciences (Bankes, 2002). The term 'rigour' is interpreted here in its widest sense, to imply thoroughness in the pursuit of relevance. Appendix E describes the process followed. It required research effort to be applied in four phases of development (see Figure 16): exploration, explanation (outline), confirmation and explanation (completed). The following sub-sections describe the contribution each phase made towards a final outcome of new theory.

3.5.2.2 Exploration

The first phase of research identified an explanatory gap in knowledge from a comprehensive evidence-base of relevant literature. A qualitative process of thematic synthesis generated a set of conjectures about potential answers from an interpretive analysis of that gap, to pose a research question.

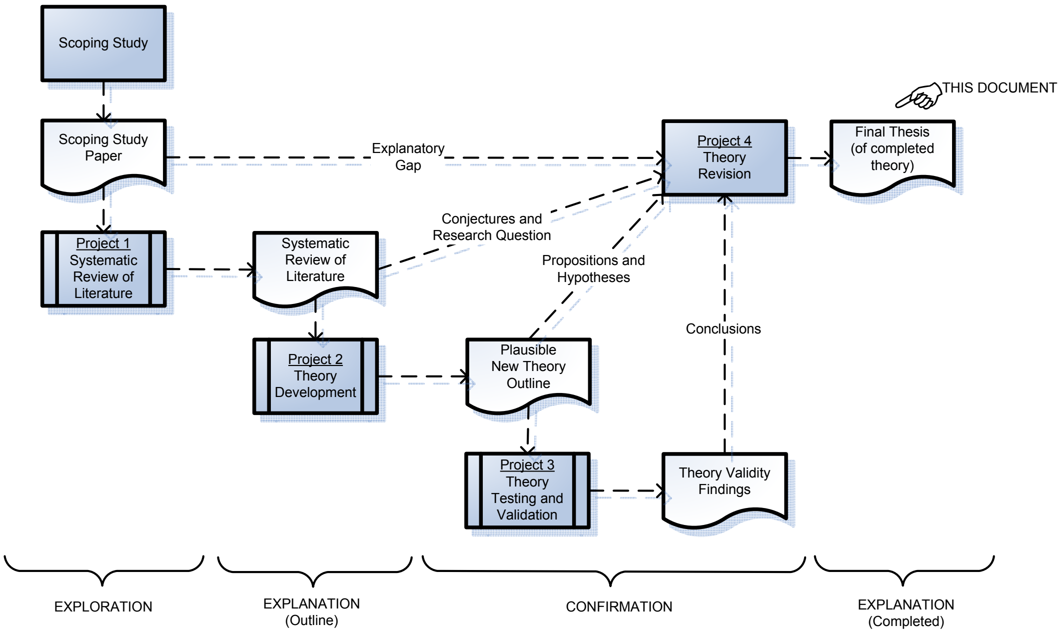


Figure 16: Phases of a Constructivist Theory Building Methodology

3.5.2.3 Explanation (outline)

After considering the implied scope of research, a re-assessment of intentions recommended a narrower focus and a few revisions of conjectures. Then, a more exploratory search of relevant alternative literature found new applicable insights in current lines of thinking and debates from a wider range academic disciplines, and used them to expound an outline of new theory, in the form of a theoretical model and an initial set of propositions and hypotheses.

3.5.2.4 Confirmation

Confirming the theory's plausibility began with collecting empirical data about a real systemic failure from annual financial reporting archives, and reviewing academic commentary about it, to produce a financial analysis of the circumstances in which it occurred. Then, by developing a conceptual model of the system described in that analysis suitable for testing the proposed theory by computational means, and using the collected data for empirical validation, it became possible to determine by simulation experiments if the real systemic failure could be shown to refute the outline theory's hypotheses.

This was achieved by constructing and verifying an agent-based computational representation of the conceptual model for simulating the proposed theory. Then a preliminary series of simulation experiments demonstrated how phenomena related to theoretical propositions were able to emerge, making adjustments to the representation and re-verifying as necessary to eliminate error effects generated by coding defects rather than emergence. These were followed by experiments to evaluate the robustness and sensitivity of the representation to a limited range of initial values and conditions, to demonstrate it behaved consistently as a plausible financial system. Finally, the initial values, conditions and strategies of the representation were set according to data from the financial analysis in an experiment, for the purpose of replicating the macro-level financial effects of strategies observed in the real failure from simulated micro-level participant interactions, to a pre-determined degree of empirical approximation. At which point, phenomena emergent at overall system-level in the simulation interface were examined to qualitatively determine if they supported the null hypothesis about the outline theory.

3.5.2.5 Explanation (completed)

After failing to refute the outline theory's hypotheses, it was fully expounded to integrate refinements suggested by experimentation and any new insights. A discussion about the overall implications of this final version of the theory, and the testing and validation results of its outline version, then concluded with a plausibility argument expressed as an outcome for the goal assertion.

3.5.3 Methods

The approach combined a quantitative method for providing a longitudinal financial analysis of the Icelandic financial system collapse, with a generative simulation method (Epstein, 1999) for replicating that collapse and observing emergent phenomena. This mixed methods approach placed an assessment of its combined results on the relevance side of the rigour-relevance debate, in which theoretical assertions cannot be proven but their plausibility can be argued (see 'evaluating mixed methods', Creswell and Plano Clark, 2007: page 162).

3.5.4 Foundations

Appendix F presents the theoretical foundations on which the theory is based, such as the boundaries, unit of theory, accepted principles, constraints, assumptions and practicalities (Dubin, 1978; Pawar, 2009).

3.5.5 Results generation

Testing and validation of the theory proposed by this thesis was conducted in project 3 using agent-based computational tools and techniques in a series of simulation experiments, validated using archival data mining techniques. Both qualitative and quantitative results were generated by this constructivist approach to demonstrating how systemic risk arises as bifurcations among the potential operational states of a financial system, interpreted by the patterns of dynamic discontinuities from bifurcation theory and its derivative catastrophe theory. The experiments simulated the interplay between diversity and exposure (Beale et al., 2011; Haldane and May, 2011) in a highly simplified dynamical financial system of supply and demand tensions among system participants (SIPs) over financial services (SIFS).

3.5.6 Experimentation Objectives

Simulation experiments in project 3 were designed to provide an appraisal of the proposed outline of theory, focused on hypotheses 1, 2 and 5 of project 2, by empirical validation of simulation results against real systemic failure data from the Icelandic financial system collapse, and subsequent theoretical triangulation. This enabled project 4 to make refinements to the theory, and explain how observed emergent phenomena were determined by the conditions, variables and rules of the computational representation.

Heath, Hill and Ciarallo (2009) describe these types of objectives as defining a 'mediator' role for simulation, in which it is used to gain insight into the system of interest. Their survey of a sample of 279 articles found that 60.2% used simulation in that role.

3.5.7 Results interpretation

3.5.7.1 Generative social science

The systems-theoretic approach taken by this research is a form of 'generative' science of particular relevance to non-equilibrium systems. Epstein (1999) describes it as a third option, offering an alternative to both 'inductive' and 'deductive' science (see sub-section 2.8.2). Social dynamics are viewed by this form of science as a type of computation in a distributed computational representation of society.

Therefore, experimental results appear as different kinds of computational phenomena in an agent-space or simulation dashboard, requiring some degree of translation into real phenomena. Quantitative results manifest in the simulation dashboard as plotted lines, bar charts, or financial values in the 'output' window (see Appendix G.2.1), whereas qualitative results manifest as the behaviour of agents in the 3D-View. In both cases they vary by tick, in a standard progression of discrete time-periods. Then computational phenomena are observed as unusual formations in a succession of results over time, translated into their equivalent real phenomena by hypothesis specifications.

3.5.7.2 Corroborating theory

By shaping the agent-space as a manifold within a three-dimensional state-space of the type described by catastrophe theory, with the principal agent in that space defined as an operational state, and by using the discrete time periods of simulation experiments to represent a larger dynamical system that is time variant in which that state-space is embedded (see temporal discussion in 3.6.4), triangulation of empirically validated results with a corroborating theory became possible. This enabled observed phenomena attributed to the predictions of operational hypotheses from the outline theory developed in project 2 to be operationally validated as examples of standard system response behaviour corroborated by an existing (catastrophe) theory.

3.5.8 Verification

Verifying the computational representation against the theory before its use in simulation experiments ensured theoretical logic had been accurately embodied in computational form (i.e. in software code; see in-line comments in the code listing provided in Appendix G3), and confirmed that logic was internally valid (see Table 8 in sub-section 5.5). Then artefacts nominated in criteria for validating hypotheses were tested to ensure necessary and sufficient conditions were satisfied, and empirical indicators could be properly observed. Finally, robustness checks were performed by changing the values of simulation parameters, constants and conditions to confirm consistent effects were being manifested.

3.5.9 Sensitivity Analysis

During those robustness checks, standard forms of sensitivity analysis examined such concerns as the sensitivity of simulation results to changing the values of micro/macro parameters; ergodicity; and across-run variability. However, instead of the usual emphasis on exploring a wide range of values, this analysis progressively narrowed down its focus on the values necessary to improve the approximation of simulated results to the financial effects identified in archival data about the real financial system collapse by financial analysis (see the rationale for this in the following sub-section).

3.5.10 Validation

3.5.10.1 Pragmatic validity

On the relevance side of the rigour-relevance debate, it is important to establish how the validity being demonstrated is distinct from the well understood positivist meaning of that term. In this thesis, a propositional mode of pragmatic validity is applied (Worren, Moore and Elliott, 2002). Pragmatically valid theory according to that mode contains three major components: explicit hypotheses that are testable; operational definitions of constructs; and descriptions with embedded rules for how to operationalize the theory. With those components in place, if the theory is shown to be plausible in at least one case on the basis of empirical evidence, it is described by Davis, Eisenhardt and Bingham (2007) as exhibiting ‘granular validity.’ The theory’s general applicability can then be demonstrated by further research.

3.5.10.2 Project context

During project 3, after completing verification and sensitivity analysis in step 10 of the methodology process, the main series of experiments began by loading empirical data from step 7, for the time when a real financial system failure was considered to have begun, as initial values and conditions in the simulation. Results generated by subsequent experiments were then statistically analysed in step 12 for external validity by using further empirical data from step 7 about real events leading up to that failure, over the period of time being simulated. When a quantitative comparison of effects observed in simulation results with that empirical evidence found a reasonable match, it was considered to indicate external granular validity of the simulation. Overall plausibility of the theory was then argued based on that claim, with corroboration by theoretical triangulation.

3.5.10.3 Literature context

In their survey of ABMS practices, Heath, Hill and Ciarallo (2009) found that 95% of research was not validated by statistical techniques, relying instead on expert opinion and qualitative comparisons of behaviours.

3.5.11 Falsification

Although the 'generative' nature of the systems-theoretic approach taken by this research is distinct from more traditional inductive or deductive approaches (see sub-section 2.8.2), it shares the problem of induction whereby no amount of theory confirmation can establish the truth of its universal generalisation. Advice in theory development literature about simulation methods stops after validating a theory, with few recommendations for addressing this weakness in the overall plausibility of theory developed by such approaches. Popper (1963) describes it as a problem of demarcation between scientific methods and pseudoscience. His recommendation is for scientific theory to be required to make predictions that are potentially refutable by observation. However, not all theories can be practically refuted. That property of a theory is termed its falsifiability.

In this thesis, all five hypotheses offer predictions with criteria for testing and external validation of the proposed theory, but only hypotheses 1, 2 and 5 are tested and validated by simulation because they directly address the goal assertion. The other two hypotheses are left for future research to confirm. However, any validation achieved can only be claimed for the empirical results of the specific simulation experiment actually performed, not all experiments using the same computational representation with slightly different settings and values. This is due to the representation's complex and stochastic nature. Furthermore, validation is subject to correctly translating observed simulation phenomena into real-world phenomena.

Therefore, the general plausibility of a theory for real circumstances cannot simply be demonstrated by a few specific simulations, even if they are endorsed by other means, such as the corroboration of empirically validated simulation results by theoretical triangulation. However, if a theory's falsification statement is refuted by at least one validated simulation, the theory can claim to describe those special circumstances, and explanations it offers may help to diagnose and understand similar circumstances, which is sufficient for satisfying the goal assertion of this research. For that reason a falsification statement is added in sub-section 0 after the hypotheses, with a description of how the proposed theory can be refuted, satisfying Popper's 'scientific method' condition.

3.5.12 Assimilation

Placing the proposed new theory in the context of existing theory then becomes a matter of descriptive alignment and logical argument (see sub-section 3.6 below, and sub-section 4.2).

3.6 Multi-disciplinary Research Issues

Two debates permeate the multi-disciplinary literature reviewed in section 0. They are the subjectivist versus objectivist debate, which is also common throughout many single-discipline literatures, and the constructivism versus formalism debate, which is particularly intense in the literatures of complexity. Alignments to the theories informing this thesis are explained in the following sub-sections from positions taken in general debates of this type, and from theory-specific debates.

3.6.1 Economic theory

The need for a paradigm shift is hotly debated between the proponents of contemporary economics of the neoclassical era and new economics of the complexity era, as discussed in sub-section 2.5. This thesis aligns with the latter. It takes the position that notions such as DSGE were shown to be unable to anticipate or explain the current financial crisis, and previous attempts at a theory of systemic risk based on DSGE have demonstrated it is inappropriate for addressing the research problem of project 2. This thesis does, however, accept that a combination of neoclassical and other less orthodox work is probably a better way forward than the total revision of economics proposed in revolutionary alternatives promoted by some academics. A shift to a new paradigm is needed, but sudden, traumatic change is probably unnecessary.

3.6.2 Evolutionary theory

An evolutionary perspective on the complex, intrinsically dynamic phenomena of economic reality is considered to offer a better alternative to the deficiencies of neoclassical thinking in the literature. This thesis agrees, and views systemic risk of failure through the lens of evolutionary economic theory. It applies the fundamental principles of that theory in a constructivist approach to new theory development through multi-agent computational modelling. That places contributions made by this thesis on the subjectivist side of the debate about the use of terms such as risk in evolutionary economic literature, and on the constructivism side of the debate with formalism.

3.6.3 Complexity theory

Within the broad field of complexity science, it is theory about complex adaptive systems that is of most interest to this thesis. In particular, notions of a ‘phase space’ of system states are used to translate an operational perspective on conjectures into the idea of a ‘state space’ of all potential operational states of the global financial system. Then, evolutionary economic theory provides insights about the adaptive nature of that system, and features such as ‘sensitivity to initial conditions’ and ‘emergence’ are used to define specific macro-level changes as that system’s operational behaviour.

More specifically, a 'big tent' meaning is adopted by this thesis in what Rosser (2009) calls a dynamic definition of complexity (see discussion in sub-section 2.7.2). This places the contributions of this thesis on the constructivism side of the debate versus formalism, due to the non-axiomatic foundations of dynamic complexity, and aligns with the view that positivist research into emergent phenomena in behavioural economics is reaching the limits of current formalisms.

3.6.4 Catastrophe theory

Operational behaviour approaching a state of criticality is then explained through the lens of catastrophe theory, which is now recognized in the literature as an important aspect of bifurcation theory (Rosser Jr, 2007). It is used in this thesis to explain manifestations of nonlinearities representing systemic failure in the operational state space of the global financial system. Among the controversies surrounding catastrophe theory, this thesis adopts a standard interpretation aligned with Thom's (1977) confirmed original intentions of providing more qualitative explanations of catastrophic phenomena. However, the thesis departs from existing uses of the theory by applying it to developing a new evolutionary theory of systemic risk that explains how bifurcations can change over time. This is also aligned with Thom's (1983: pp. 38-40) original view regarding the separate debate about how to model temporal aspects of catastrophes when using this theory, in which he argues that an elementary catastrophe form may be embedded in a larger dynamical system which is time variant.

3.6.5 Computational theory

Evolutionary effects of emergence are demonstrated in project 3 by a non-conventional approach to agent-based modelling of complex phenomena that transcends the usual stylized illustrations and generic mathematical analyses in current literature. This is further enhanced by efforts to improve the rigour of computational theory development, in which a research protocol is specified (see Appendix H) for agent-based simulation experiments to test, validate and verify the theory's plausibility, using a well-defined methodology. This enables the experimental findings presented here to be replicated and developed further by other researchers.

3.7 Implications

Section 3 describes how this programme of research approached making a contribution to a gap in explanatory value in the literature, from a systems-theoretic approach to theory building, incorporating a simulation-constructivist orientation towards the meaning of theory, which is argued to have the potential to overcome the logical inconsistencies and intractabilities of more positivist approaches currently favoured in the literature. However, careful attention to experimental rigour will be necessary in project 4 to ensure that maximum validity is demonstrated for the theory proposed. When false perceptions about the approach taken are eliminated, remaining methodological controversies can be overcome by a set of principles that apply the best of current understanding about how to test and empirically validate new theory of this type.

It is therefore argued that a plausible basis for this thesis to make a significant contribution to macro-economic theory of crises, finance theory of financial services, and complexity science theory of system behaviours is: a computational interpretation of the ‘big tent’ meaning of complexity; applied to explaining systemic risk of failure and its mitigation; from a new operational behaviour perspective on supply and demand in financial services; viewed through the lens of catastrophe theory.

4 THEORY

4.1 Summary

This section presents an outline of new theory developed in step 4 of the research methodology during project 2 (see Figure 4), using the approach described in sub-section 3.5.

4.2 Main Informing Concepts

4.2.1 System dynamics and complexity

The global financial system is modelled in this thesis as a type of system known as 'dynamical', from the applied mathematics of critical phenomena in complex systems (Strogatz, 1994: page 9; Rosser Jr, 2000; Chan Man Fong and De Kee, 1999). Such systems have a state given by a vector that can be represented by a point in a geometric manifold or state space, in which there is a critical point where phase transitions can occur. As such it has a deterministic evolutionary rule that describes what future states follow from the current state. From statistical physics it is known that self-organized criticality (Bak, Tang and Wiesenfeld, 1987) is a property of this type of system, whereby their macroscopic behaviour displays scale-invariance at the critical transition in the form of spontaneous complexity emerging from simple local interactions. Furthermore, the related notion of universality observes that this behaviour is robust to being modelled by widely differing sets of variable parameters without the need for sensitivity to operational details of the system. Which suggests it is possible to build a reliable model of the system to analyse simple local interactions around a critical phenomenon of interest using a few well-chosen features and parameters. In the model proposed, the state space is a three-dimensional surface of potential operational states, each state being comprised of a set of coordinates defining its operational effectiveness, together with a state categorization. This surface, and its boundary, represents the full range of potential operational behaviour of the global financial system, projected out of a two-dimensional control surface of operational focus. It takes the form of a cusp catastrophe-type model from catastrophe theory (Thom, 1975; Zeeman, 1976), with a critical point located at the singularity of the cusp fold in the operational behaviour surface. Particular attention is given to macroscopic behaviour that emerges around this cusp fold, and the insights it can offer regarding how an operational state of systemic failure occurs, to explain the general nature of systemic risk and its mitigation. This macroscopic behaviour is conjectured to emerge as spontaneous complexity in the form of shifts in the overall operational effectiveness of supply satisfaction of demand, derived from simple individual interactions over SIFS that cumulatively comprise the collective operational behaviour of system participants.

4.2.2 Evolutionary economics of supply and demand

The evolutionary nature of this theory is explored using a multi-agent model of the global financial system as complex dynamical system, with inherent deterministic evolutionary rules, conceptualized in terms of the components of evolutionary-economic models (Safarzynska and van den Bergh, 2010a) as follows:

G.1.2.1 Diversity

This is related to behaviour in the proposed theory. Under certain circumstances normally diverse behaviour of SIPs, differing by rules of commercial intent, professional conditioning, response to peer or regulatory pressure, and risk appetite gives way to a narrower range of contagious, convergent or catastrophic behaviour that is reflected in the overall operational behaviour of the system. This potentially becomes systemic failure by way of a feedback loop to future participation behaviour. Insights such as emergent norm theory (Turner and Killian, 1987), and the notion of cognitive dissonance (Akerlof and Dickens, 1982), help to explain how opportunities for individual SIPs to select from diverse behavioural options are diminished by emergent systemic behaviour inducing extreme concentrations and persistence in collective SIPs behaviour.

G.1.2.2 Innovation

Various forms of innovation are represented, such as opportunism in the search for unregulated commercial advantages, or evasiveness in behavioural rules for responding to regulatory pressure. Then practical models of motivation in behaviour such as the resourceful, evaluative, maximizing model REMM (Jensen and Meckling, 1994) help to explain how those innovations gain popularity and create concentrations in financial services participation.

G.1.2.3 Selection

This occurs at the level of simple local interactions through the adaptive learning of SIPs, when learning routines and application rules (Dosi et al., 1999) are applied to selecting appropriate behavioural strategies. At overall system level it is also inherent in the deterministic evolutionary rules of state transitions in this type of dynamical system.

G.1.2.4 Bounded rationality

When individual SIPs imitate majority strategy (Shiller, 2000; Smelser, 1962; Lux, 1995), and when their intentional actions are supplanted by consequential actions (Cyert and March, 1992) among complex patterns of routinized behaviour (Nelson and Winter, 1982), they exhibit bounded rationality.

G.1.2.5 Diffusion

The mechanism of distress propagation through contagious behaviour among SIPs induces a form of diffusion, observed system-wide as emergent operational behaviour following similar principles to those described in threshold models of collective behaviour (Granovetter, 1978) and reciprocation theory (Axelrod and Hamilton, 1981).

G.1.2.6 Path-dependence and lock-in

This can take various forms, such as peer or stakeholder pressure to imitate, and regulatory feedback or intervention (Smelser, 1962; Mackay, 2004; Slattery and Nellis, 2011).

G.1.2.7 Co-evolution

The operational behaviour paradigm of the proposed theory, based on supply and demand activities, is co-evolutionary (Safarzynska and van den Bergh, 2010b).

G.1.2.8 Multilevel evolution and group selection

Differences between operational behaviour emergent at system level and distress arising at the level of collective operational behaviour among SIPS are an example of this (Potts, 2000). Although Figure 18 only shows the topology of the former, the proposed outline theory encompasses both.

G.1.2.9 Mechanisms of growth

These are found in distress propagation (Mishkin, 1992); growth through variety by the introduction of new SIFS, variations in SIFS, and new SIPs entries; and growth by new participation opportunities in SIFS, sometimes leading to extreme growth effects by irrational exuberance (Shiller, 2000).

4.2.3 An operational behaviour perspective

At the core of this theory there is an operational behaviour paradigm based on the concept of an operational state of the global financial system, representing the overall operational effectiveness of supply satisfaction of demand in SIFS at a point in time. The full range in potential operational behaviour of that system then becomes a geometrical manifold or state-space of all potential operational states for a point in time, the topology of which can vary over time. It follows that an actual operational state of the system at a particular time can be plotted as coordinates in the current potential state-space, derived from execution-level participation data. The system's actual operational behaviour is therefore the direction and distance of shifts between current operational states plotted in this changing potential state-space over a specified period in time. However, derivation of operational states from execution-level participation data is not a simple mathematical expression. It is the consequence of complex non-linear behaviour emergent at system-level from simple local interactions among SIPs in a dynamical system. As such, the operational states and behaviour of this system are best explained by a computational model using a simple set of entities, parameters and rules capable of describing their local interactions in a way that can isolate the key determinants of particular emergent complexities. With that model it becomes possible to ask questions about how a potential operational state such as systemic failure actually occurs, the overall risk of it occurring, and how that risk could be mitigated. The purpose of doing this is to understand how distress propagates as changing operational states in this system, and how it can be managed. A key assumption being that, whatever the causes or effects of distress, understanding the way it propagates operationally through the system is crucially important for recognizing, avoiding and responding to potential systemic failures.

4.3 Conjectures

The following sub-sections integrate theorising introduced in project 2 with the 8 conjectures synthesised by project 1 from an identified gap in explanatory value found in the literature (see Table 4 in sub-section 2.3.17). They present a set of revised conjectures that are more closely aligned with the intentions of this thesis and latest academic thinking.

4.3.1 Conjecture 1: The nature of the global financial system

Many alternative views exist regarding what is meant by this system, such as: the functional view (Merton and Bodie, 1995); the bank versus market view (Levine, 2000); and the evolving view (Vedder, 2009). However, formally declared definitions are rare in the literature. Implied or informal descriptions usually involve an organized body of participants comprised of financial services institutions and their customers, intermediaries, governing bodies and regulators; together with their policies, financial resources, technology, sub-systems and infrastructures; that interact on international, regional, national or local levels.

From a research point of view, this is far too broad in scope to get a useful grasp on particular features or behaviours of the system. Systemic risk literature usually gets around that problem by reducing scope down to a single market, industry or financial paradigm; or by modelling limited aspects of the system using linear mathematical expressions (Velupillai, 2005). But thorny issues such as the global financial system's interconnectedness, and the unknown implications of extreme assumptions, remain a significant barrier to simplification.

For a more practical interpretation of that system, this thesis turns to an operational behaviour paradigm (see figure 1), and focuses more on researching the fundamental principles of how the global financial system works as a system of supply and demand in financial services, and less on a detailed representation of the system. It is argued that this approach captures the essential nature of the system, while emphasizing features relevant to understanding systemic risk. The corresponding synthesised conjecture from project 1 can be revised to reflect this supply and demand focus as follows:

Conjecture 1 summary - The essential nature of the global financial system can be represented by: a dynamical, complex, adaptive systems model of all potential operational states that system is able to assume; based on an operational behaviour paradigm of participation in the supply and demand of financial services; for the purpose of investigating the risk of systemic failure (i.e. systemic risk).

4.3.2 Conjecture 2: The nature of systemic failure

However, any such investigation must first determine what is meant by a materialization of that risk, namely systemic failure. The operational behaviour paradigm used in conjecture 1 suggests that outcome manifests as a fundamental failure to continue operating as a global financial system, resulting from distress emerging somewhere in the system and spreading throughout when unchecked.

Two examples are:

i. when irrational exuberance induces globally expanded supply in derivative instruments, that spreads the contamination of risk-exposures in residential real-estate transactions from one country to others, while drastically diminishing global participation in alternative assets having more diversified risk/reward profiles, until escalating risks make participation untenable; or,

ii. when a concentration of demand for short-term funding in the banking industry creates a spike in funding requirements internationally, reducing funding availability for exceptional requirements such as sovereign debt refinancing, creating a bank-sovereign risk-feedback loop until the general availability of funding dries up.

As the corresponding synthesised conjecture from project 1 already takes this view of the nature of systemic failure, it does not require substantial revision, and can be confirmed as follows:

Conjecture 2 summary - Systemic failure of the global financial system can be defined as an operational state which represents a sustained inability of the entire system to operate as required.

4.3.3 Conjecture 3: How distress occurs

When distress occurs, it seems to affect participants anywhere in the global financial system due to their interconnectedness. If the concept of a 'part' of the system is accepted to be sufficiently broad that it encompasses any physical, functional or organizational subdivision, then distress can be argued to arise as undesirable effects for participants in any part of the system from exogenous sources, or from endogenous participation behaviour that is unsupportive of overall system operations due to perceived incentives and disincentives. Actual barriers to supportive behaviour may also be introduced, such as misguided regulations or institutional policies.

Understanding this behaviour and the operational nature of the distress it can generate is arguably more useful for dealing with systemic crises, and the avoidance or mitigation of systemic risk, than establishing root causes. Economic history suggests that different stimuli can cause the same behavioural response with similar effects, and this multiple causality may vary over time (Kindleberger and Aliber, 2005: chapter 2). Therefore, attributing causes to effects among complex system interactions exposes a theory to confirmation bias when many possibilities exist, and leads to retrospective theoretical justifications for distress in the system when a particular stimulus was deemed to be the root cause. So the value of causal theories in this field is arguably limited to occurrences of similar circumstances. Whereas, an explanation based on operational behaviour may be more relevant for a general theory applicable to all circumstances.

The corresponding synthesised conjecture from project 1 requires substantial revision to reflect the above discussion, and to properly distinguish what distress is, and how it occurs, from a simple notion about how it propagates. A new version follows that combines these objectives while maintaining relevance to the identified gap in theory from which the original conjecture was synthesised:

Conjecture 3 summary – The occurrence of distress in the global financial system can be explained by describing it as an operational process whereby undesirable effects arise for system participants from exogenous sources, or from endogenous participation behaviour that is unsupportive of overall system operations by reinforcing perceived disincentives or actual barriers to supportive participation, or perceived incentives for unsupportive participation.

4.3.4 Conjecture 4: How distress is propagated

However, a general theory would also need to explain, for a wide range of supply and demand circumstances, how participation behaviour propagates distress throughout the system. If this is understood, and can be managed, then potential root causes become less relevant. A distinction should be made here between a local risk of a severe sub-system failure (such as a sovereign state's potential default on its bonds), which may initially just involve relatively few participants, and the emergence of system-wide instability when distress is propagated through the collective operational behaviour of many participants (as in a situation of wide-scale simultaneous panic). In the former situation, the risk of systemic failure would not immediately escalate unless the potential for distress propagation already exists, as when there is no option to re-schedule payment of the sovereign state's debts. In the latter situation, it would escalate rapidly in the absence of swift intervention from governing authorities.

The corresponding synthesised conjecture from project 1 generally supports this view, but makes no mention of system-wide instability being a potential consequence of distress propagation. It can be revised to reflect this as follows:

Conjecture 4 summary – The propagation of distress can be explained as some collective behaviour transmission mechanism that spreads concentrations in unsupportive participation behaviour from where they arise to other parts of the global financial system by: increasing the intensity of collective focus on that behaviour, and reducing diversity in participation, thereby generating further distress in more parts through operational interdependencies; to potentially emerge as a shift in the system's overall operational state in the direction of greater system-wide instability.

4.3.5 Conjecture 5: When systemic failure occurs

Some level of systemic risk will always exist, varying according to the system's ability to absorb shocks and continue operating without disruptive failure (its failure tolerance), and its ability to recover quickly from shocks if they do occur (its failure resilience). Therefore effective management of systemic risk requires a critical threshold to be established among potential operational states of the system, based on tolerance and resilience assessments, where operational distress is deemed to have breached performance criteria as system operations become increasingly unstable. Then systemic failure is considered to occur when a current actual operational state has crossed that threshold by a succession of shifts between potential operational states. In a similar way, an outer boundary can be established where operational distress is deemed to become contagious. Then general guidelines on acknowledging the occurrence of systemic failure could be published in terms of such criteria, similar in principal to the criteria used by economists to confirm when an economy has moved into a state of recession.

The corresponding synthesised conjecture from project 1 generally supports this view, but makes no mention of the criteria by which systemic failure is deemed to have occurred. It is revised to reflect this as follows:

Conjecture 5 summary - If operational behaviour of the global financial system is represented by a succession of shifts in actual operational states over a period of elapsed time, then systemic failure can be thought to occur when contagious, convergent or catastrophic operational behaviour emerges and crosses into the region of those operational states defined as failing to satisfy aggregate distress tolerance and resilience criteria.

4.3.6 Conjecture 6: The nature of systemic risk

From conjectures 1 to 5 it then becomes possible to derive a definition of systemic risk based on an operational behaviour paradigm. If the nature of systemic failure is taken to be an emergent operational behaviour, a plausible definition of systemic risk could be based on the probability of distress spreading from local epicentres of adverse behaviour in participation, towards ultimate materialization as deemed failure in the system's overall operations. Implying the root causes of systemic failure are less relevant than 'how' it occurs and 'when' it is likely to happen, if no attempt is made at risk mitigation.

The corresponding synthesised conjecture from project 1 generally supports this view, but simplifications are made in this revision to improve clarity and remove overlaps with other conjectures, as follows:

Conjecture 6 summary - Systemic risk of failure can be defined as: the probability at a current time of the global financial system entering an operational state of systemic failure by a specified time in the future; in the absence of new efforts to mitigate that probability.

4.3.7 Conjecture 7: Mitigation of systemic risk

The implications of conjecture 4 are that increases in the diversity of participation combined with dispersal of participation focus, would counteract the risk of systemic failure. Interventions by regulatory authorities for the purpose of systemic risk mitigation could use these implications to influence the operational behaviour of the global financial system by selective intervention, such as: redirecting participation away from extreme concentrations of supply or demand by introducing short term incentives, alternatives or penalties; or, limiting extreme participation focus by reducing supply or demand side availability.

The corresponding synthesised conjecture from project 1 generally supports this view, but simplifications are made in this revision to improve clarity and remove overlaps with other conjectures, as follows:

Conjecture 7 summary - Mitigation of systemic risk of failure can be achieved by influencing operational behaviour, through increasing diversity in participation where there are extreme concentrations, and dispersing focus in participation where there is extreme intensity.

4.3.8 Conjecture 8: How the system interacts with its environment

Although conjectures 1 to 7 offer explanations for key aspects of crises in the global financial system, the interactions between emergent phenomena in that system and macroeconomic phenomena in its environment are not obvious. Some translation is necessary, enabling economic decision makers to understand how complex circumstances arise, and the potential impacts of responses.

The corresponding synthesised conjecture from project 1 generally supports this view, but it is revised to reflect the operational behaviour paradigm of Figure 1 more closely, as follows:

Conjecture 8 summary - Operational behaviour of the global financial system can be thought to interact with macroeconomic events in a two-way process that translates those events into: their effects operationalised in the system on the collective behaviour of participation (assertion **A** in Figure 1); and conversely, from the emergent operational behaviour of the system derived from that collective behaviour, into its effects manifested in macroeconomic events (assertion **F** in Figure 1).

4.4 Theoretical Model

A cusp catastrophe-type model of the global financial system is now presented (see Figure 17, Figure 18 and Figure 19), based on catastrophe theory (Thom, 1975; Zeeman, 1976) and 8 revised conjectures from an operational behaviour paradigm of systemic failure (see Figure 1), which were developed out of preliminary conjectures about systemic risk of failure and its mitigation synthesised in project 1. The model refers to a three-dimensional cusp surface B_t comprised of the coordinates for all previous and predicted operational states of the system at time t (see Figure 18) in a three-dimensional state-space, representing its operational behaviour topology projected out of a two-dimensional control surface F_t of overall operational focus (see Figure 17). Then the system's actual operational state is defined by a specific point with coordinates $(x, y, z) = b_t$ plotted on surface $b_t \in B_t$ representing the system's overall operational effectiveness for supply satisfaction of demand in SIFS at time t, together with a state-category attributed to the region in F_t in which those coordinates fall (e.g. the state category of 'systemic failure' attributed to a subset of states in the region F_t^{fail}). By projecting shifts in this placement of actual operational states over several periods of time from that three-dimensional surface B_t back onto the control surface F (independent of t), operational behaviour of the system can be identified as the direction and distance of those shifts (see Figure 19). The effects of that behaviour are described by the topology of surface B_t, as actual operational state shifts over boundaries and into regions that have consequences attributed to them. For example, the system is considered to have failed gradually when the projected placement in F of its actual operational state b has shifted over a period of time into the systemic failure region F_t^{fail}, and it is considered to have failed immediately when b has dropped vertically onto the control surface F at some coordinate $(x, y, 0)$, if in either case it remains there outside required operating parameters for longer than a time limit set by the financial system's regulator.

In this model, operational behaviour of the global financial system approaching region F_t^{fail} is conjectured to exhibit an increasing focus of participation in fewer

SIFS, while overall supply satisfaction of demand is also diminishing, until the system is deemed to have ceased to operate. By which time its operational state has entered that region of systemic failure by directional shifts in operational behaviour that are contagious, convergent or catastrophic. These system-level shifts are further conjectured to emerge due to the propagation of operational distress at lower levels of the system, among execution-level activities of individual participations. This is thought to occur by some participation behaviour transmission mechanism, suggested by such notions as herding (Lux, 1995; Acharya and Yorulmazer, 2008), generating changes in the collective operational behaviour of system participants. The operational nature of this mechanism is argued to be of crucial importance to understanding how distress becomes pervasive among execution-level activities system-wide. With that knowledge it becomes possible to explain how an operational state of systemic failure emerges using complex systems theory, and show how such operational behaviour of the global financial system generally interacts with familiar macroeconomic events.

In sub-section 4.5, the key features of this model are illustrated by a theoretical topology which combines graphics and narrative in an informal academic style, to integrate theorising introduced in this sub-section with the revised conjectures of sub-section 4.3. This leads to a more formal outline of theory in sub-sections 4.6 to 4.9, using predicate logic to express propositions of new theoretical insights about the nature of systemic risk and its mitigation. Then in sub-section 4.11, five hypotheses are developed with the criteria for testing and validating the proposed theory to be used in project 3.

4.5 Model Topology

4.5.1 Control surface

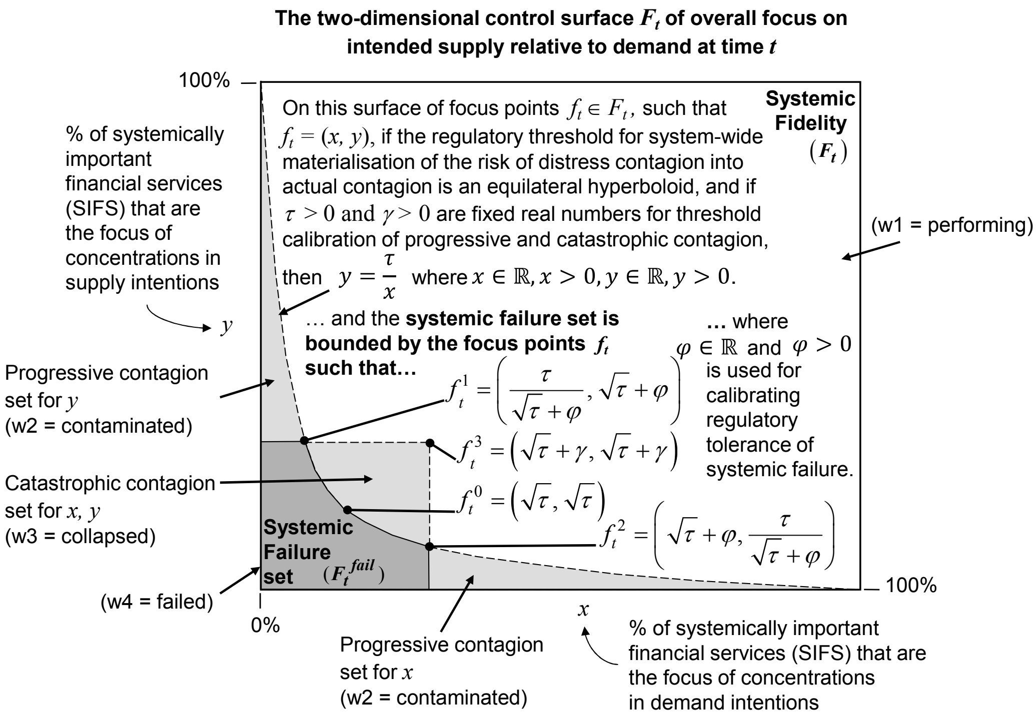


Figure 17: Instability thresholds on the control surface F_t

4.5.1.1 Focus of participation

Figure 17 shows the two control parameters x and y of the control surface F_t in the cusp catastrophe-type model discussed in the previous sub-section. The percentage of SIFS that are the subject of intended demand concentrations is given by x, and the equivalent for supply is given by y, forming a surface in which each coordinate point (x, y) represents a focus f_t of intended demand versus supply in SIFS at time t. More specifically, x is the percentage of all SIFS which, when clustered according to suitably determined types of affinity in intended demand-related execution-level activities at time t, belong to clusters where those activities are above an operationally significant demand/bid level. Conversely, y is the percentage of all SIFS which, when clustered according to the same types of affinity in intended supply-related execution-level activities at time t, belong to clusters where those activities are above an operationally significant supply/offer level.

Therefore, each parameter pair (x, y) can be interpreted as an aggregate participation ratio for the percentage of all SIFS clustered together according to similarly high concentrations of intended supply versus demand focused on them at time t, above a predetermined level of intensity. This shows the relative overall emphasis between intended supply and demand in the system, expressed as the proportions of all SIFS involved on either side of participation. Significant reductions in those proportions, or an imbalance between them, are then taken as key indicators that instability is increasing in the system.

As clustering varies according to participation activities, this ratio does not simply reflect aggregate participation levels. For example, when high levels of intended supply participation are evenly dispersed among activity types for SIFS, while similar levels of intended demand participation place an emphasis on certain activity types for SIFS (e.g. extreme 'Bid' activity for 'Short term funding' SIFS), there is a resultant weakness in the supply side of focus relative to the demand side even though their levels of participation are comparable.

In this F_t plane, no attempt is made to indicate the degree of actual supply satisfaction of demand, just their relative concentrations of intention or focus (f_t). This is sufficient, for example, to identify thresholds of materialization for progressive contagion when there is an increasing overall supply or demand focus on a decreasing percentage of SIFS. It also enables the boundary of systemic failure to be identified.

4.5.1.2 Rationale

The rationale for selecting values for the parameter pair (x, y) derived from concentrations of intended demand and supply in SIFS is based on a combination of: recent research exploring inter-bank correlations in herding behaviour and risk-shifting phenomena involving particular asset types (Beale et al., 2011; May and Arinaminpathy, 2010; Acharya, 2009); and new approaches to complexity-based modelling of financial systems (Zeidan and Richardson, 2010; Allen and Gale, 2007). Theorising in this thesis moves the former thinking away from a balance-sheet perspective on a narrow scope of emergent behaviour to an operational model of system-level supply and demand in a wide range of SIFS. Then complexity notions are applied to model interactions between SIPs over those SIFS across the entire global financial system. The scope of potential complexity is managed by reducing it down to a focus on conjectures about what may be the fundamental features of this operational behaviour as it approaches instability, in a deliberately over-simplified model consistent with the usual approach to modelling applications of chaos theory.

4.5.2 Behaviour surface

When a third parameter z, representing the percentage of all available SIFS that achieve an overall minimum level of actual supply satisfaction of demand is projected out of this control surface, the three dimensional surface B_t appears (see Figure 18). Where each point is a potential operational state of the system, and the entire surface B_t represents the system's full range in potential operational behaviour at time t. With surface B_t it becomes possible to visualise the contours of this operational behaviour topology, in which catastrophe theory suggests there will be a cusp fold representing catastrophic collapse in the system's operational state, potentially leading to systemic failure. The standard nonlinear form of that type of cuspoid surface, called the potential function, is given by:

$$V(b_t) = z^4 + xz^2 + yz$$

where $b_t \in B_t$ such that $b_t = (x, y, z)$ uses coefficients x and y to represent control parameters, and the variable z to determine the system's behaviour.

This standard form of cuspoid surface has one fold direction, and is often oriented around the singularity point $x = y = z = 0$, with two control variables (the normal factor and the splitting factor) and one state variable. Whereas in the proposed model, the fold is symmetrically aligned on the diagonal vector converging on the systemic failure set at the origin of surface F_t. Then as surface B_t varies with t, it can fold either left-to-right (when viewed from the origin as shown in Figure 18) or right-to-left, as the roles of normal and splitting factor are swapped between the control variables (x, y).

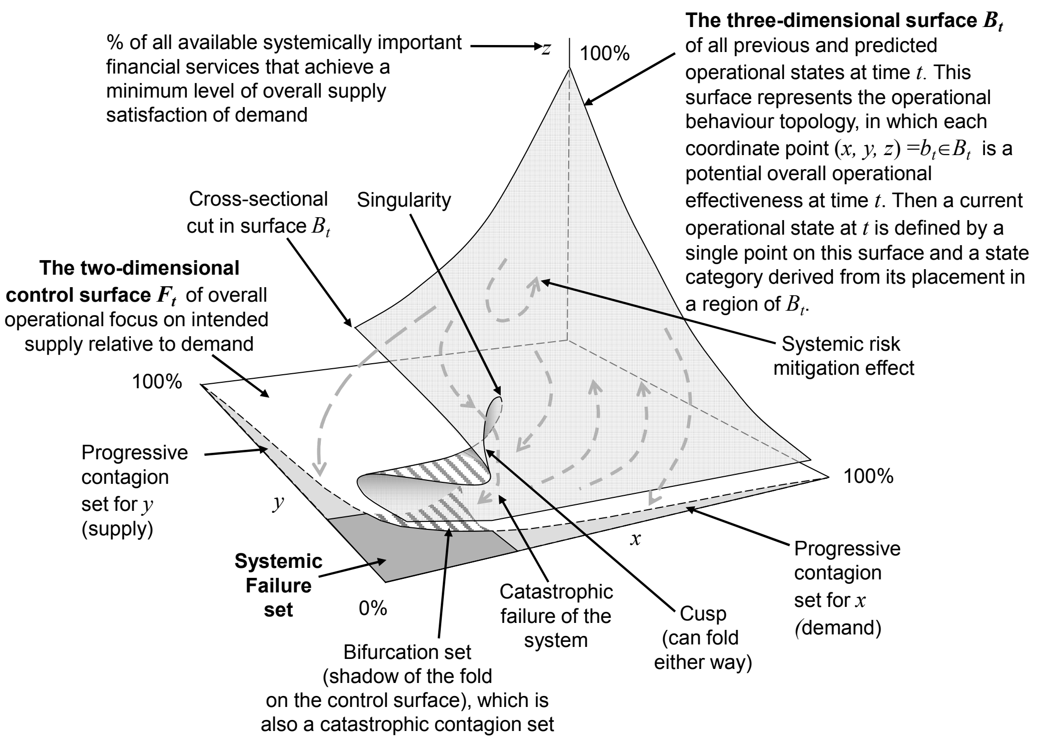


Figure 18: A cusp catastrophe-type model of systemic failure.

Temporal aspects of catastrophic failures are not part of standard catastrophe theory, and there are debates in the literature about how they should be treated. However, Thom makes his views clear. Although gradient dynamics do not allow for time to be a variable of the potential function, he argues that an elementary catastrophe form may be embedded in a larger dynamical system which is time variant (Thom, 1983: pp. 107-108). This gives a series of surface structures B for a dynamical system modelled in a larger $B \times t$ space, in which the larger system is transversal in time to the set of structures in that space (Thom, 1975: pp. 38-40).

That approach is taken in the proposed theory, and fits well with the simulation intentions of this programme of research. It furthermore implies that the cusp fold may also vary dynamically over time as its singularity point moves, and the roles taken by the two axes of the control surface are no longer fixed but may swap.

4.5.3 Behavioural shifts

Projections of operational behaviour from shifts in the actual operational state coordinates b_t over a progression of behaviour surfaces, B_t, B_{t+1}, B_{t+2}, … , back onto the control surface F (when independent of t) can be described as shown in Figure 19, by extending notions from catastrophe theory. These descriptions of behaviour are useful for explaining how a system is responding to the stimuli of collective participation activity. When that response is a contagious, convergent or catastrophic shift of operational state in the direction of the systemic failure set, increasing distress will be observed in the system.

However, the effects of this emergent behaviour at system level are not the same as distress propagation, which happens at lower levels of the system by some behaviour transmission mechanism among individual participations in execution-level activities of supply and demand for financial services. How this mechanism works is the subject of conjectures and propositions in the following sub-sections, and demonstrating its validity will be one of the objectives of the hypothesis testing phase of this research programme in project 3.

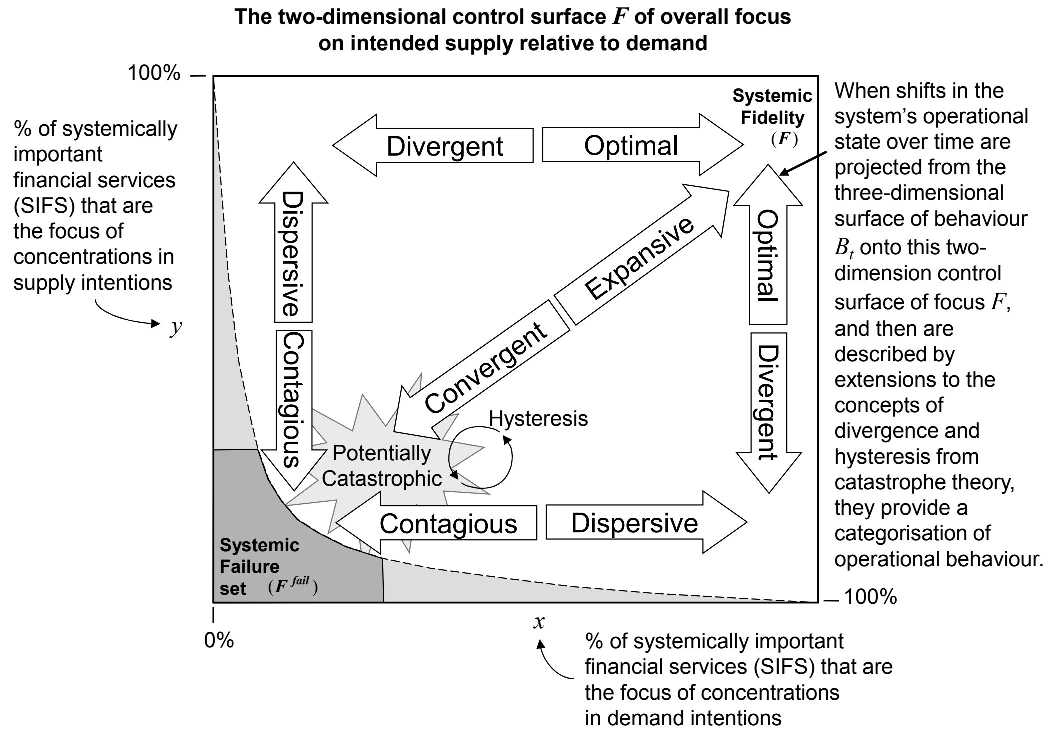


Figure 19: Operational behaviour reflected in the control surface *F*.

4.6 Proposition Development

With the global financial system defined in terms of the preceding theoretical model, topology and conjectures, it became possible to construct new propositions about systemic risk of failure based on well-established theoretical foundations, to inform an experimentation strategy for agent-based simulation of the programme research problem.

Due to a lack of consensus in social sciences regarding distinctions between a conjecture and a proposition, and how theory development progresses from the former to the latter, this thesis takes a stance on what appears to be the most coherent approach (Pawar, 2009: page 56-57; Dubin, 1978: page 160). It applies Dubin's definition of a proposition as: *"a truth statement about (or logical consequence of) a theoretical model"*, to make 12 propositions (+1 from theory revision) derived from the theory's model topology, developed out of the set of 8 improved conjectural statements from sub-section 4.3 informed by the literature review. In terms of the research methodology (see Figure 4) this happened in step 6, and produced the formal propositions outlined in sub-sections 4.7, 4.8 and 4.9 as a series of logical expressions, which became the foundations on which a computational model was developed for simulation experimentation.

4.7 Recognizing Systemic Failure

The operational behaviour paradigm of systemic failure is extended here by two propositions for recognizing when that failure occurs. They apply notions of participation, focus and contagion that were introduced in the theoretical model and topology of sub-sections 4.4 and 4.5, and integrated with the improved conjectures of sub-section 4.3, to contribute alternatives to standard explanations offered in the literature for the causes and effects of such events, typically centred on the financial issues of markets and industries (Acharya and Richardson, 2009; Huang, Zhou and Zhu, 2009; Bhattacharyay, 2003; Allen and Gale, 2007); or sub-system failures (Ho and Saunders, 1980); and system characteristics such as brittleness (Yang, Mu and Yao, 2009). Whatever endogenous or exogenous root causes may be attributed to systemic failure, the view is taken in this thesis that it is concentrations in what participants do or fail to do that precipitate and propagate distress, potentially culminating in a system-wide failure to operate. Otherwise, failure remains relatively localised, except in the extreme event of instant annihilation of the entire system. Theoretical discussion begins with the context in which systemic failure emerges.

4.7.1 Proposition 1: The transition threshold of contagion

If the current focus of participation in the global financial system is defined by a placement in the two-dimensional control surface of a cusp catastrophe-type model (see Figure 17), in which all potential such placements are plotted as a pair of control coordinates (x, y), then the following region can be used to represent the percentage of SIFS that are the focus of concentrated demand intentions X (e.g. bids) relative to that of supply intentions Y (e.g. offers) at time t:

$$F_t := \{(x, y) \in \mathbb{R}^2 | (0 < x \leq 100) \wedge (0 < y \leq 100), x \in X, y \in Y\}. \quad (1)$$

In that region, the threshold of transition from potential distress contagion into actual distress contagion, arising from an intensifying focus of participation, can be represented for regulatory purposes by a rational function such as:

$$y = \frac{\tau}{x}, \quad \tau \in \mathbb{R},\ \tau < 0. \quad (2)$$

This produces an equilateral hyperboloid describing where the transition is considered to occur. A fixed real number τ is used for calibrating this threshold as a regulatory determinant of where actual system-level contagion is acknowledged to begin in F_t, with contagion occurring on the side of this threshold where:

$$y < \frac{\tau}{x}\,. \quad (3)$$

4.7.2 Proposition 2: Systemic failure as participation unsustainability

As the current focus of participation (x, y) converges on $(0, 0)$ within that actual contagion side of the threshold of contagion in region F_t, due to escalating distress, it enters the control surface sub-region of participation unsustainability F_t^{fail} representing a failure of focus in F_t, which is outlined as the functional image set:

$$\text{Failure}(F_t) := \left\{\left(x, \text{Failure}(x)\right) \in F_t^{fail} \,\middle|\, \left(\left(0 < x \leq \left(\sqrt{\tau} + \varphi\right)\right) \wedge \left(\left(0 < \text{Failure}\ (x) \leq (\sqrt{\tau} + \varphi)\right) \wedge \left(\text{Failure}\ (x) \leq \frac{\tau}{x}\right)\right)\right)\right\} \qquad (4)$$

where $\varphi \in \mathbb{R}$ and $\varphi > 0$.

The fixed real number φ is used for calibrating the boundary of this region for regulatory tolerance of focus contagion[2]. If focus persists in this region for longer than a predetermined period of time, systemic failure must be acknowledged. This is similar in principle to the rules about successive periods of negative GDP used by economists to determine when an economy has moved into a state of recession. Clarity in recognizing when systemic failure is deemed to be occurring is a prerequisite for its mitigation.

4.8 Operational States of Participation

From propositions 1 and 2, an explanation was developed for how the global financial system's operational state moves into F_t^{fail}. This begins by defining a set E of financial service activity-type executions in that system, generated by inter-agent participation and collected for a sufficient number of observations within discrete periods of time during simulation. They are the lowest granularity of data about system activity in this theoretical model, from which the system's operational state changes emerge over time. Basic specifications of this data are given in expression (5), from which the expressions in following sub-sections are derived. Related definitions of sets are given as follows: let S be the set of all SIPs (participants) identified in the data; and similarly let P be the set of all products ; and let A be the set of all financial service activity-types (also referred to as SIFS); then let E be the set of relevant executions of A by S for P; let Q be the pair of treatments "offer" and "bid"; and let T be the set of all points in time for which this data is collected; with v being the value of related open offers or bids. Then

[2] Separate φ values may be necessary for the demand and supply axes, as in φ^x and φ^y.

the members of each set are: $s \in S$, $p \in P$, $a \in A$, $e \in E, q \in Q$, $t \in T$, with $v \in \mathbb{R}$, as referenced in:

$$P := \{p_1, p_2, \dots, p_M\} \quad \text{where } M \in \mathbb{Z}. \tag{5}$$
$$E := \{e_1, e_2, \dots, e_N\} \quad \text{where } N \in \mathbb{Z}.$$
$$e := \{(s, p, a, q, t, v) \in E\}.$$
$$\therefore e_n = (s_n, p_n, a_n, q_n, t_n, v_n) \quad \text{where } 1 \leq n \leq (C^o + C^\beta).$$
$$E^{\text{Offer}} := \{E^{\text{Offer}} \subset E \mid q = \text{'Offer'}\}.$$
$$\therefore e_o^{\text{Offer}} = (s_o^{\text{Offer}}, p_o^{\text{Offer}}, a_o^{\text{Offer}}, q_o^{\text{Offer}}\ t_o^{\text{Offer}}, v_o^{\text{Offer}}) \quad \text{where } 1 \leq o \leq C^o.$$
$$E^{\text{Bid}} := \{E^{\text{Bid}} \subset E \mid q = \text{'Bid'}\}.$$
$$\therefore e_\beta^{\text{Bid}} = (s_\beta^{\text{Bid}}, p_\beta^{\text{Bid}}, a_\beta^{\text{Bid}}, q_\beta^{\text{Bid}}, t_\beta^{\text{Bid}}, v_\beta^{\text{Bid}}) \quad \text{where } 1 \leq \beta \leq C^\beta.$$

Where $C^o \in \mathbb{R}$ is the count of offer executions e_o^{Offer}, and $C^\beta \in \mathbb{R}$ is the count of bid executions e_β^{Bid}.

4.8.1 Proposition 3: Affinity in participation

From this type of execution-level data it becomes possible to identify participation affinities over supply and demand intentions for SIFS. Various alternative methods can be applied, such as using a clustering function, or equivalent algorithms, with appropriate similarity coefficients κ and partitioning levels λ, to cluster on relevant activity types and associated activity volumes and values for each SIFS. To simplify the translation of this proposition into a computational model, similarities in the adoption by SIPS of the same bid and offer strategies for their collective participation in SIFS at any point in time were used to identify bid and offer affinities. For each product, that becomes the two sided proposition:

4.8.1.1 Bid affinities

Affinities between all participants $s \in S$ in their demand for a product $p \in P$ can be expressed as the total open bids value $\theta_t^p \in \mathbb{R}$, at time $t \in T$, of bid activity-type executions for p in the image set of a summation function for the sub-set E^{Bid}, such that:

$$\text{Bid}(E^{\text{Bid}}, p, t) := \left\{\theta_t^p \in \mathbb{R} \,\middle|\, \left(\theta_t^p = \sum_{\beta=1}^{C^\beta} v_\beta^{\text{Bid}}\right),\ p_\beta^{\text{Bid}} = p,\ t_\beta^{\text{Bid}} = t\right\}. \tag{6}$$

4.8.1.2 Offer affinities

Whereas, affinities between all participants $s \in S$ in their supply of a product $p \in P$ can be expressed as the total open offers value $\phi_t^p \in \mathbb{R}$, at time $t \in T$, of offer activity-type executions for p in the image set of a summation function for the sub-set E^{Offer}, such that:

$$\text{Offer}\left(E^{\text{Offer}}, p, t\right) := \left\{\phi_t^p \in \mathbb{R} \,\middle|\, \left(\phi_t^p = \sum_{o=1}^{C^o} v_o^{\text{Offer}}\right),\ p_o^{\text{Offer}} = p,\ t_o^{\text{Offer}} = t\right\}. (7)$$

4.8.2 Proposition 4: Intensity of participation

These notions can be extended further, by calculating the intensity of participation focus on certain products, to understand imbalances created by extremes in collective behaviour.

4.8.2.1 Intensity of Demand Focus

For this theoretical model, demand focus is represented by the variable x, which is calculated as the percentage measuring the sum of open bid values $\theta_t^{p_{1\,to\,M}}$ at time $t \in T$ for all products $p_m \in P$ except the p_m with the maximum open bid value, in proportion to the sum including that value. As this variable decreases it suggests there is less diversity in demand intentions, and focus may be increasing on one product, unless open bid values are decreasing a similar amount for all products.

$$x = \left(\frac{\left(\sum_{m=1}^{M} \theta_t^{p_m}\right) - \max\left\{\theta_t^{p_{1\,to\,M}}\right\}}{\left(\sum_{m=1}^{M} \theta_t^{p_m}\right)}\right) \times 100, \quad \text{where } x \in \mathbb{Z}. \qquad (8)$$

4.8.2.2 Intensity of Supply Focus

In a similar way, supply focus is represented by the variable y,

$$y = \left(\frac{\left(\sum_{m=1}^{M} \phi_t^{p_m}\right) - \max\left\{\phi_t^{p_{1\,to\,M}}\right\}}{\left(\sum_{m=1}^{M} \phi_t^{p_m}\right)}\right) \times 100, \quad \text{where } y \in \mathbb{Z}. \qquad (9)$$

4.8.3 Proposition 5: Focus (or diversity) of participation

The tension between intended demand versus supply at time t then becomes the overall focus $f_t^{(x,y)}$, defined by:

$$\text{Focus} := \{(x, y) \in F_t\} \qquad (10)$$

in which coordinates x and y define the axes of control surface F_t (see Figure 18).

4.8.4 Proposition 6: Actual operational effectiveness

For any point of focus the system exhibits, at specific (x, y) coordinates in F_t, there can be an actual satisfaction percentage $\sigma_t^{p_m}$, at time t, for every product $p_m \in P$ (not just those with current supply or demand intentions). That value is a proportion calculated as the maximum between filled offers and bids over the maximum between available offers and bids, where $m \in \mathbb{Z}$ such that:

$$p_m = \left(\psi_m^{\text{available}}, \omega_m^{\text{available}}, \psi_m^{\text{filled}}, \omega_m^{\text{filled}}, t\right) \quad \text{where } 1 \leq m \leq M, \tag{11}$$

with $\psi_m^{\text{available}}$ and $\omega_m^{\text{available}}$ defined as available offers and bids respectively, and ψ_m^{filled} and ω_m^{filled} defined as filled offers and bids respectively, such that:

$$\sigma_t^{p_m} = \left(\frac{\max_t\left\{\psi_m^{\text{filled}},\ \omega_m^{\text{filled}}\right\}}{\max_t\left\{\psi_m^{\text{available}}, \omega_m^{\text{available}}\right\}}\right) \times 100, \quad \text{where } \sigma_t^{p_m} \in \mathbb{Z}. \tag{12}$$

Then an overall satisfaction percentage z is given by:

$$z = \left(\frac{\left(\sum_{m=1}^{M} \sigma_t^{p_m}\right) - \max\left\{\sigma_t^{p_{1\ to\ M}}\right\}}{\left(\sum_{m=1}^{M} \sigma_t^{p_m}\right)}\right) \times 100, \quad \text{where } z \in \mathbb{Z}. \tag{13}$$

This defines the third axis z of the cusp catastrophe-type model of systemic failure (see Figure 18), which relates a satisfaction parameter to each instance of focus $f_t^{(x,y)}$ to create an instance of actual operational effectiveness $b_t^{(x,y,z)}$, among all potential b_t on the surface B_t at time t.

4.8.5 Proposition 7: The global financial system's operational state

Then one of four regions in B_t can be assigned to each potential placement of actual operational effectiveness b_t by the string constants $\rho_1, \dots, \rho_4$, depending upon where in F_t its focus f_t falls (see Figure 17), to describe it as: $\rho_1 =$ performing (outside distress regions); $\rho_2 =$ contaminated (inside the progressive distress contagion region calibrated by the threshold $\tau \in \mathbb{R}$); $\rho_3 =$ collapsed (inside the catastrophic distress contagion region calibrated by the threshold $\gamma \in \mathbb{R}$); or $\rho_4 =$ failed (inside the systemic failure region calibrated by the failure tolerance number $\varphi \in \mathbb{R}$); expressed as:

$$\text{Region}(b_t, \tau, \gamma, \varphi) = \rho, \ \text{ where } \rho \in \{\rho_1, \rho_2, \rho_3, \rho_4\}. \tag{14}$$

Therefore, in summary, a current operational state of the global financial system is more usefully represented in a cusp catastrophe-type surface B_t by an instance of actual operational effectiveness $b_t^{(x,y,z)}$ at the current time t, for specific (x, y, z) coordinates, determined by the relative supply and demand focus of participation intentions $f_t^{(x,y)}$ in active products, contrasted against actual supply satisfaction of demand z for all products at that time, and further qualified by its placement in a region ρ of B_t according to calibrations of distress contagion (τ and γ) and systemic failure tolerance (φ). This qualified definition becomes:

$$\text{Current}(B_t, \tau, \gamma, \varphi) := \left\{b_t^{(x,y,z)}, \text{Region}\left(b_t^{(x,y,z)}, \tau, \gamma, \varphi\right)\right\}, \tag{15}$$

in which the complete set B_t of operational states representing previous and potential operational behaviour at time t can be expressed as the qualified set $\mathcal{B}_t$:

$$\text{Manifold}(B_t, \tau, \gamma, \varphi) := \left\{\left(b_t, \text{Region}(b_t, \tau, \gamma, \varphi)\right) \in \mathcal{B}_t \ \middle|\, b_t \in B_t\right\}. \tag{16}$$

4.9 Systemic Risk of Failure to Operate

It follows from propositions 1 to 7 that the potential of the current operational state of the global financial system at time t to move towards and cross over the threshold of distress contagion into the systemic failure zone within a certain period of time, based on the probable future direction of shifts in that state and the changing contours of B, may have some relevance to the research problem.

4.9.1 Proposition 8: Operational behaviour of the system

The shifts broadly categorized as shown in Figure 19 and expression 15 can be modelled as the operational behaviour of the system, in the transformation:

$$\text{Behaviour: } \text{Current}(B_t, \tau, \gamma, \varphi) \mapsto \text{Current}(B_v, \tau, \gamma, \varphi) \tag{17}$$

where $t \in T$, $v \in T$ and $t < v$. This behaviour is a phenomenon that emerges by nonlinear means from participation activities, interpreted at system level as movements in actual operational effectiveness b over successive surfaces representing B between the data collection points in time t and v, from point b_t in surface B_t to point b_v in surface B_v. Effectively, time t could be considered another dimension, giving a four-dimensional catastrophe-type model, but visualization of this proposition is kept relatively simple in Figure 18 and Figure 19 by showing the behaviour surface B in three dimensions at a single point in time. Nonetheless, this thesis aligns with Thom's view on temporal aspects of his theory by assuming an elementary catastrophe form is embedded in a larger dynamical system which is time variant (see temporal modelling comments in sub-section 3.6.4). It should simply be remembered, as suggested in sub-section 4.5.2, that B_t and B_v are two different surfaces within a temporal progression of B surfaces in which the topology and conjectured cusp fold of B may change (also see Hypothesis 3). The transformation of state topology over time in this way seems to be a principal driver of catastrophic operational behaviour.

4.9.2 Proposition 9: A definition of systemic failure

Then systemic failure at a time t, denoted as $\Finv_t$, can be defined by regulations as a succession of failed operational states resulting from operational behaviour sustained over a period of time $\mu \in \mathbb{N}_+$, in which each failed current state

$$\xi_v := \{\text{Current}(B_v, \tau, \gamma, \varphi) \in \mathcal{B}_v \mid \text{Region}(b_v, \tau, \gamma, \varphi) = \rho_4,\ v \in T\}, \quad (18)$$

is a member of the succession of states $\Finv_t$ such that:

$$\Finv_t := \left\{\{\xi_v, \xi_{v+1}, \dots, \xi_{v+(\mu-1)}\} \,\middle|\, \xi_t \in \Finv_t,\ t = v + (\mu - 1)\right\}, \quad (19)$$

where ξ_t is the most recent of μ such states.

4.9.3 Proposition 10: Probability of systemic failure

As this particular operational behaviour emerges, probability can be used within a short time horizon as a metric at a current time t for a potential increase in operational distress among participation activities resulting in systemic failure by time v, denoted p_t^v, where $v \in T$, $t < v$. However, irregular behaviour arising from the system's nonlinearity, and its sensitivity to initial conditions, will make predictability of systemic failure decay quickly, suggesting that a simple probability is not a good candidate for a longer range metric of extreme distress potential, namely systemic risk of failure.

4.9.4 Proposition 11: A practical definition of systemic risk

Nonetheless, the philosophical view implicit in this proposition holds it is more meaningful to assign a metric to some operationally defined aspect of risk than attempting a more direct and objective definition, for the reasons discussed in sub-section 3.4.1. Therefore a practical definition of systemic risk of failure may be achieved by closely linking the short-term probability metric of systemic failure from proposition 10 to some longer range notion of disorder or uncertainty of the system within a proximity of interest, to account for its nonlinearity.

By taking Shannon's (1948) expression of entropy:

$$H(p) = H(\{p_1, \dots, p_n\}) = -\sum_{i=1}^{n} p_i \log p_i \tag{20}$$

representing a measure of uncertainty regarding what could be communicated (for discussion see sub-section 2.7.3.2), and replacing its set of information probabilities with a series of probabilities of systemic failure p_t^v for all intervening time periods v between t and u, denoted $p_{t:u}$, where $t < v \leq u$, over the elapsed time ending in u, to give:

$$H(p_{t:u}) = H\left(\left\{ p_t^{(t+1)},\ p_t^{(t+2)}, \dots,\ p_t^{u} \right\}\right), \tag{21}$$

a more general interpretation of entropy can be proposed along similar principles to Renyi (1961), in the form:

$$\text{Entropy}(p_{t:u})\ = -\sum_{i=t+1}^{u} p_t^i \log p_t^i. \tag{22}$$

This defines a metric for uncertainty regarding the probability of operational behaviour shifting the system into the systemic failure state by some time v, where $t < v \leq u$. From which a new metric for systemic risk of failure can be outlined, by the expression:

$$\text{Risk}(\Finv_u, t) := \{\, p_t^u, \text{Entropy}(p_{t:u})\}, \tag{23}$$

where $\Finv_u$ denotes the systemic failure state at time u, and $t < u$.

It is therefore the conclusion of this thesis that a plausible metric of systemic risk of failure can be expressed informally by: *"a measure of the overall probability at a current time of the system entering an operational state of systemic failure by a specified time in the future; qualified by a measure of uncertainty determined by the system's entropy for a series of probabilities about the shortest succession of future operational states considered to be capable of that outcome by the specified time; in the absence of new mitigation efforts"*. For practical purposes when philosophical concerns are set aside, the formal definition in expression 23 can be expressed in this less formal terminology as a definition of systemic risk of failure.

4.9.5 Proposition 12: Emergence of operational behaviour

If the operational behaviour of the system, from expression 17, is now restated in terms of participation P_t at execution-level E_t from which it arises, it becomes the transformation:

$$\text{Participation } (E_t)\text{: Conditions}(P_t) \mapsto \text{Conditions}(P_{t+1}) \qquad (24)$$

Then, assertion **E** from the operational behaviour paradigm (see Figure 1) can be expressed as the transformation:

$$\text{Emergence: Conditions}(P_{t+1}) \ \mapsto \text{Current}(B_{t+2}, \tau, \gamma, \varphi) \qquad (25)$$

in which the conditions created by collective participation in execution-level activities from expression 24 are transformed into emergent operational behaviour of the system in expression 25 through some nonlinear relationship with actual operational states in succeeding time periods. Catastrophic instability is proposed as a special case of this transformation, whereby distress Δ conditions arising at time $t+1$ somewhere are propagated by some operational mechanism at execution-level, to generate emergent operational behaviour by time $t+2$ reflecting that distress system-wide, as in the expression:

$$\text{Distress: Conditions}(\Delta_{t+1}) \ \mapsto \text{Current}(B_{t+2}, \tau, \gamma, \varphi), \qquad (26)$$

where $\Delta_{t+1} \subset P_{t+1}$. A feedback loop may further exacerbate this distress, as in:

Feedback: $\text{Current}(B_{t+2}, \tau, \gamma, \varphi) \ \mapsto \text{Conditions}(\Delta_{t+3})$, where $\Delta_{t+3} \subset P_{t+3}$. (27)

This describes a propagation mechanism of distress transformations which occur spontaneously out of micro-level participation in SIFS supply and demand.

4.10 Propositional Implications

4.10.1 For Current Theory

If propositions 1 to 12 are shown to be plausible, they provide current theory about financial system instability described in section 0 and sub-section 3.6.1 with a unifying theory capable of bridging related gaps and debates in multi-disciplinary understanding. In particular, later sections of this thesis show that a computational representation of the systemic risk notion from proposition 11 offers a very practical new interpretation suitable for guiding risk mitigation. Future research, focused on extending this theory to predict where and when systemic risk exposure is likely to materialize, may then offer additional significant insights for financial stability management in general.

4.10.2 For Current Policy

Emphasis placed by the goal assertion of this thesis (see sub-section 3.5.1) on understanding ‘how’ instability of the global financial system becomes operationally catastrophic, and ‘how’ it can be avoided, is reflected in the explanation offered by proposition 12. As the culmination of all 11 preceding propositions, it explains how operational behaviour emerges from execution-level participation by a propagation mechanism of distress transformation. Then risk mitigation techniques discussed in sub-section 7.2 can be based on policy guidance for intervention in these transformations.

4.11 Hypotheses

The notion of hypothesis is taken from Dubin (1978: page 206), in which he states: *"*[It] *may be defined as the predictions about values of units of theory in which empirical indicators are employed for the named units in each* [of its] *propositions"*. On the relationship between hypotheses and propositions, he explains: *"Every hypothesis is homologous with the proposition for which it stands. The homology is determined by the dimensionality of the theoretical definition of the units contained in the proposition.* [Therefore] *each empirical indicator has to meet the necessary and sufficient conditions of* [its] *theoretically defined unit"*.

The strategy adopted for hypothesis construction in this thesis involves a generative approach to theory building (see sub-section 2.8.2). As with inductive approaches, it begins with the 'ad hoc' hypotheses presented in the following sub-sections, which are tested and empirically validated by agent-based simulation experiments in project 3 (see Figure 4). If they are not disproven, project 4 generalizes and refines the original theoretical model into a completed theory.

4.11.1 Hypothesis 1: Focus (or diversity) and satisfaction correlation

4.11.1.1 Rationale

If the cusp catastrophe-type surface presented in the theoretical model and topology of sub-sections 4.4 and 4.5, and outlined in propositions 1 and 2, is an accurate interpretation of operational behaviour in the global financial system; then as parameters (x, y) approach $(0, 0)$ in surface F, the value of parameter z also diminishes until it moves catastrophically over the cusp threshold in surface B, or continues to diminish contagiously or convergently towards the systemic failure sub-region projected out of F^{fail} onto surface B.

4.11.1.2 Prediction

This predicts a correlation between an increasing intensity of operational focus on fewer SIFS and decreasing overall supply satisfaction of demand, as overall operational effectiveness approaches collapse. Conversely, it predicts an increasing diversity of operational focus on more SIFS has the opposite effect.

4.11.1.3 Criteria for testing and validation

The relevant units of theory are: the coordinates (x, y, z) of surface B. The necessary condition for plausibly measuring their predicted correlation requires that assigned values must not be directly dependent on each other, by calculation formula or equivalent algorithmic derivations. The sufficient condition for that measurement requires them to be able to move with enough freedom around the coordinate space of B, to the extent they can potentially be observed to move without correlation, thereby refuting this hypothesis.

4.11.1.4 Empirical indications

An appropriate empirical indicator of correlation would be a clear down-sloping gradient in a chart plotting the values of demand focus x, supply focus y, and satisfaction z, for a simulated financial system approaching systemic failure. That indicator could similarly be confirmed by observation of an operational state moving down a gradient in a behaviour surface manifold in a behaviour state-space representing phenomena in that simulation explained by catastrophe theory.

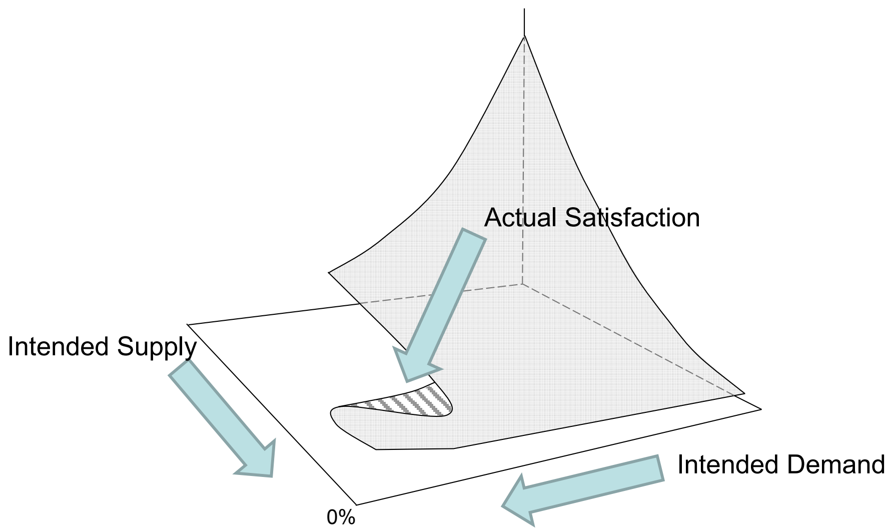


Figure 20: Hypothesis 1 – Focus and satisfaction correlation

4.11.2 Hypothesis 2: Catastrophic tendencies at critical points

4.11.2.1 Rationale

The rationale from hypothesis 1 is extended by an additional assertion about systemic failure from proposition 9.

4.11.2.2 Prediction

In combination, they predict that operational behaviour can exhibit catastrophic tendencies resulting in systemic collapse or failure at critical points on surface B.

4.11.2.3 Criteria for testing and validation

The relevant units of theory are: the coordinates (x, y, z) of surface B; regulatory boundaries of systemic failure regions on surface B; and the time period t. The necessary condition for plausibly measuring the predicted collapse or failure is that the (x, y, z) coordinates of the current operational state can move within regulatory boundaries of systemic failure regions on surface B. The sufficient condition for that measurement is that enough time periods can be observed to create a reasonable opportunity for collapse or failure to occur.

4.11.2.4 Empirical indication

Then, an appropriate empirical indicator of collapse or failure would be when the level of overall satisfaction level z plotted on a chart plunges below a vertical boundary representing a regulatory determination of systemic failure. That indicator could similarly be confirmed by observation of an operational state dropping from a previously maintained level on a behaviour surface manifold in a behaviour state-space explained by catastrophe theory.

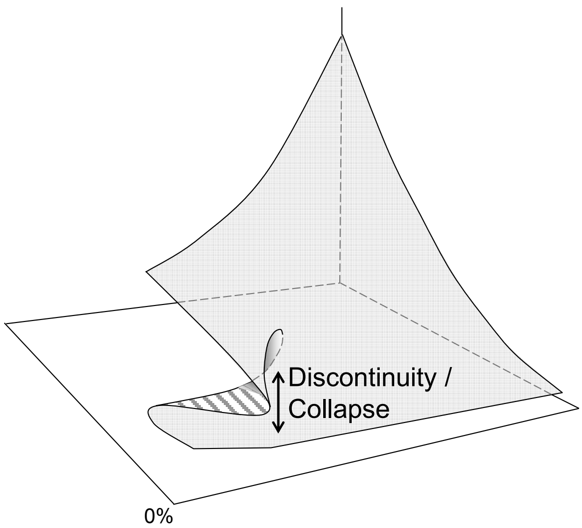


Figure 21: Hypothesis 2 - Catastrophic tendencies

4.11.3 Hypothesis 3: Quantum behaviour analogy

4.11.3.1 Rationale

As a consequence of temporal considerations in proposition 8, the direction of the cusp fold, left-to-right or right-to-left, cannot be known until shortly before a catastrophic collapse or failure. At that time, as emergent operational behaviour slides towards the cusp, massive mitigation initiatives such as quantitative easing can 'flip' this direction of fold in successive surfaces of B_t. These will have opposite gradients, offering temporary respite through intervention by reversing the decline of operational states. However, if a 'see-saw' effect is observed in emergent operational behaviour because it has insufficient momentum to escape the cusp, current mitigation strategies will ultimately fail unless further complementary mitigations take effect. This uncertainty in behaviour is analogous to recent experimental results from quantum physics concerning quantum behaviour on a macroscopic scale (Vedral, 2011). Thereafter, when mitigation effects begin to fail, closeness to the cusp and possibly its orientation may be predicted by such indicators as the slowing down effect known to occur when a critical threshold is approaching (Scheffer et al., 2009).

4.11.3.2 Prediction

This predicts that the cusp fold in the operational state surface will not appear until shortly before a catastrophic collapse or failure, and can disappear abruptly following intervention efforts.

4.11.3.3 Criteria for testing and validation

The relevant units of theory are: the coordinates (x, y, z) of surface B; and the time period t. The necessary condition for measuring the predicted cusp fold appearance is that the coordinates are independent of time periods. The sufficient condition for that measurement is that enough time periods can be observed to create a reasonable opportunity for the cusp fold to appear.

4.11.3.4 Empirical indication

An appropriate empirical indicator of fold appearance would be a series of values for the coordinates (x, y, z) of $b^{(x,y,z)}$ suggesting a significant change in the gradient of B_t ahead of $b^{(x,y,z)}$ in the direction of operational behaviour.

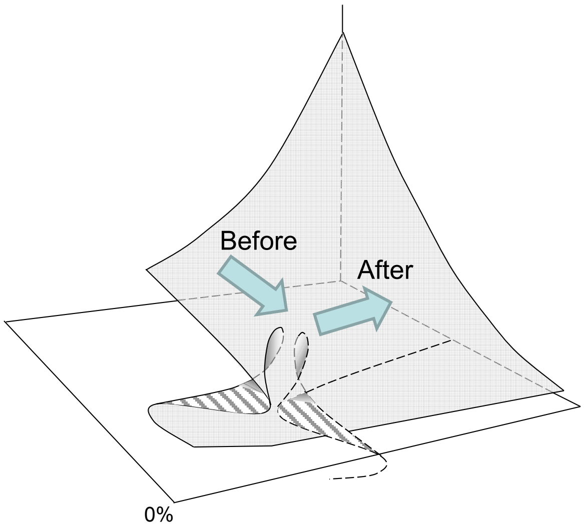


Figure 22: Hypothesis 3 - Quantum behaviour analogy

4.11.4 Hypothesis 4: Synchronicity effects

4.11.4.1 Rationale

When affinities in execution-level activities begin to cluster and focus as described in propositions 3, 4 and 5, future synchronicities are likely to develop if unchecked. They can take many forms, but all essentially create ripples in the future focus of collective participation behaviour on the same or related SIFS. An example of this occurs when many individual banks are refinanced simultaneously, as part of a massive systemic risk mitigation exercise by central bank authorities. If the periods of refinancing are not staggered, and subsequent alternative sources for on-going funding are not secured by a majority of those individual banks, then there is an increased risk of an intense concentration of focus on such SIFS emerging again as a new round of simultaneous funding requirements at the end of that common funding period. Even if systemic risk mitigation efforts are successful and take synchronicities into account, vigilance is still necessary for avoiding unintended secondary effects such as the creation of a bubble in a particular asset class. Synchronicities will have both positive and negative effects on emergent operational behaviour. Systemic risk mitigation techniques can be developed to use these effects for dispersing concentrations of focus well in advance with small interventions, so that feedback loops in emergent operational behaviour are avoided.

4.11.4.2 Prediction

This predicts there is a tendency for an instance of focus intensity to recur if participation behaviour induces a synchronized response.

4.11.4.3 Criteria for testing and validation

The relevant units of theory are: the coordinates (x, y, z) of surface B; regulatory boundaries of systemic failure regions on surface B; and the time period t. The necessary condition for measuring the predicted synchronicity effects is that the (x, y, z) coordinates of the current operational state are independent of time periods. The sufficient condition for that measurement is that enough time periods can be observed to create a reasonable opportunity for synchronicity effects to occur.

4.11.4.4 Empirical indication

An appropriate empirical indicator of synchronicity effects would be repetition in the movements of $b^{(x,y,z)}$ between two non-consecutive periods t and v.

4.11.5 Hypothesis 5: Bi-Polar (tight hysteresis) operational behaviour

4.11.5.1 Rationale

As a special case of the hysteresis loop of standard catastrophe theory, expression 27 allows for the potential of tight loop-back behaviour around the singularity, which explains why a series of mitigation attempts close to the catastrophe cusp can cause emergent operational behaviour to cycle repeatedly through its slide towards and over the cusp. This is similar in effect to the bipolar condition in human psychology, with its reversals of optimism and despair at the edge of personal catastrophe. It will be more noticeable in the global financial system after initial brushes with catastrophe, when financial authorities are actively monitoring distress propagation and mitigating systemic risk accordingly. It is the principal reason why the risk of systemic failure tends to reverberate for some time.

4.11.5.2 Prediction

This predicts there will be a loop pattern in operational behaviour around a critical point induced by operational feedback close to the cusp.

4.11.5.3 Criteria for testing and validation

The relevant units of theory are: the coordinates (x, y, z) of surface B; and the time period t. The necessary condition for plausibly measuring the predicted bi-polar operational behaviour is that the (x, y, z) coordinates of the current operational state are independent of time periods. The sufficient condition for that measurement is that enough time periods can be observed to create a reasonable opportunity for bipolar effects to repeat a sufficient number of times for loop-back in operational behaviour to be observed.

4.11.5.4 Empirical indication

An appropriate empirical indicator of bi-polar behaviour would be a series of repeated values for the coordinates (x, y, z) representing circular motion in the movements of the current operational state over consecutive time periods. Those indicators could similarly be confirmed by observation of an operational state moving in circles on a behaviour surface manifold in a behaviour state-space representing phenomena in that simulation explained by catastrophe theory.

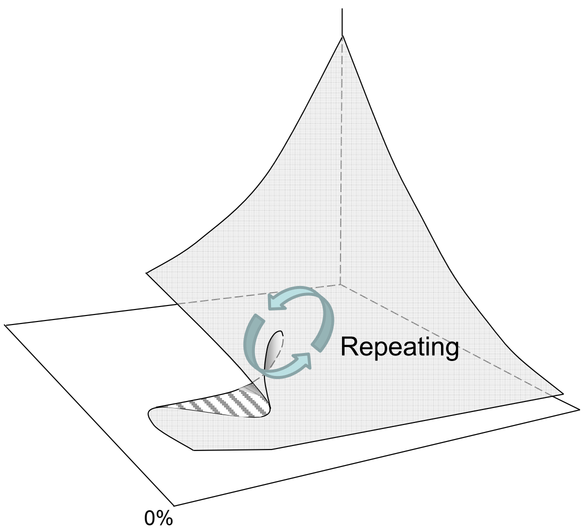


Figure 23: Hypothesis 5 - Bi-polar operational behaviour

4.11.6 Falsification statement

Hypotheses 1, 2 and 5 are specifically relevant to the circumstances of the only recent case of a real financial system collapse that occurred in Iceland over the years 2003 to 2008. Therefore, in a generative science context, this theory can be falsified by demonstrating a null-hypothesis that states:

Null-Hypothesis ***"A plausible (verified and empirically validated) simulation of a real financial system collapse, corroborated by theoretical triangulation with catastrophe theory, will not confirm the predictions of hypotheses 1, 2 and 5."***

Rejecting this null-hypothesis would neither prove nor demonstrate the general plausibility of the theory in all real world cases (Popper, 1959), but it could support an assertion about a non-empty class of computational models capable of simulating reality according to its propositions. That would satisfy the goal assertion of this thesis (see sub-section 3.5.1), for the single real world case of Iceland, while providing significant insights about the notion of systemic risk of failure for future research into its general applicability.

5 THEORY TESTING AND VALIDATION

5.1 Summary

This section reviews testing and validation of the proposed outline of theory, using the approach described in sub-section 3.5.

It begins by presenting the financial analysis of step 7 based on data collected from archived annual reports of firms directly involved in the Icelandic financial system collapse between the years 2003 and 2008, along with a brief review of associated academic commentary. Then the conceptual model of that system from step 8 based on the financial analysis, and its agent-based computational representation from step 9 incorporating the proposed outline of theory, are used to establish how verification of real world abstraction has been achieved in step 10. After which key aspects of simulation experiments and their results from step 11 are reported for potential replication, and validated findings are presented with an overall outcome summary.

Finally, a critical assessment of project 3 findings is expressed in terms of the original goal assertion.

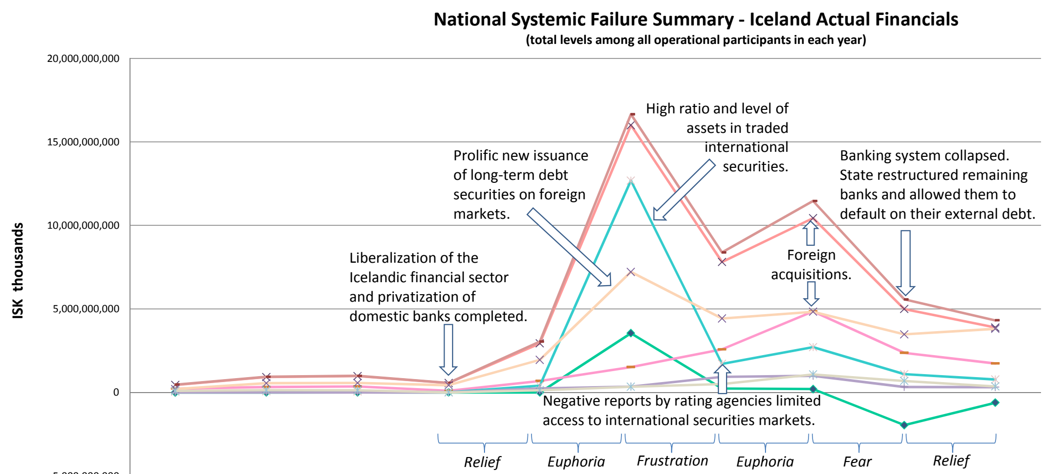
5.2 Financial Analysis

5.2.1 Objectives

Step 7 of the theory development methodology (see Figure 4) requires collection of empirical data for financial analysis, to identify simulation datapoints and translate them into a conceptual model design and results validation criteria.

5.2.2 Data Collection

The primary source of empirical data was Bankscope, a comprehensive global database of bank financial statements, ratings and other intelligence offered by Bureau Van Dijk (see http://www.bvdinfo.com/en-gb/products/company-information/international/bankscope). It was collected by downloading an excel workbook file containing extracts from the reported accounts of all 51 financial institutions active in Iceland over the years 2000 to 2009. That file, with additional tabs containing extract tables and charts presented in this thesis, is among the supporting materials supplied on CD with this thesis (see Appendix I).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
tot_profit_act	1,656,700	4,312,100	8,403,100	2,276,100	6,020,600	3,549,845,139	239,599,662	206,412,248	-1,953,841,290	-607,881,900
tot_assets_act	451,393,500	924,935,100	981,676,800	565,522,000	2,939,201,500	15,999,713,336	7,811,197,543	10,435,219,325	4,996,139,748	3,887,703,500
tot_liabilities_act	468,318,500	939,790,100	995,786,700	570,690,500	3,044,863,900	16,654,898,860	8,383,680,300	11,465,867,885	5,574,049,530	4,318,728,400
tot_liquid_act	231,931,800	330,242,100	363,716,300	103,713,500	691,861,200	1,525,669,113	2,581,366,364	4,860,068,189	2,374,534,591	1,734,561,200
tot_securities_act	53,084,900	74,062,800	67,007,000	17,630,800	407,113,000	12,681,175,749	1,712,223,256	2,715,050,572	1,093,228,923	774,386,700
tot_debt_act	202,975,600	557,257,400	572,129,000	437,710,500	1,951,623,900	7,215,230,684	4,429,202,641	4,835,106,317	3,480,337,873	3,811,485,100
tot_loans_act	0	0	0	0	250,700,200	354,177,740	934,168,278	999,915,622	332,978,327	323,283,500
tot_deposits_act	92,725,900	138,312,400	136,906,900	5,807,700	136,177,400	342,577,782	511,286,489	1,081,272,784	688,948,932	362,818,900

Source: Extracted from the reported accounts of all 51 financial institutions in the Iceland database of Bankscope.

Chart 1: Icelandic financial system data, for the years 2000 to 2009.

A summary of the financial analysis is provided in Chart 1. It shows total actual values for a set of financial reporting variables, with interpretive comments pointing to features observed by this thesis. In later sub-sections Chart 1 will be compared with simulation results for the period of particular interest from the end of 2003 to the end of 2008.

5.2.3 Interpretation

5.2.3.1 Thesis observations

Over the ten years from 2000 to 2009 analysed by Chart 1, six features were identified as representative of participant sentiment corresponding to anecdotal evidence and academic commentary. They occurred during the years 2003 to 2009, and are characterized by this thesis respectively as: relief, euphoria, frustration, euphoria, fear and relief. Completed liberalization and privatisation of the Icelandic financial sector marked the beginning of this period at the end of

2003, and central bank intervention to head off total losses marked the end in 2008. In between, a dash for asset growth is evidenced by prolific new issuance of debt securities on foreign markets that was grossly disproportionate to more traditional banking activities, ending in a fall in counterparty confidence, followed by a change in tactics, with a subsequent collapse.

A light regulatory regime in place at the time allowed domestic institutions to engage in this type of 'hybrid' banking activities. The chart suggests that when bad reports by rating agencies limited access to international securities markets, Icelandic banks sought new cash flows and asset growth by making foreign acquisitions. Interestingly, when it became clear to the central authorities that a total failure of the system was imminent, it froze assets and allowed local banks to default on their obligations. For this thesis, it confirmed that systemic failure does not simply occur when the last participant turns out the lights on their way out of business, rather it is when the system is deemed to have failed and gets shut down. In Iceland's case that left 13 financial institutions surviving under the protection of central authorities in the year after shut-down.

5.2.3.2 Academic commentary

An overall prognosis is contributed by Nielsson and Torfason (2012), who describe Iceland's economic collapse as being *"... primarily home-brewed, and a consequence of an unbound, risk-seeking banking sector and ineffective (or non-existent) actions of the Icelandic authorities"*.

Relief after de-regulation of the domestic banking sector is attributed by them to a dramatic ascent of the country's banking system after a *"managed privatisation among friends"*, excluding foreign buyers, in which sales were conducted in a way that ensured the 'right' price.

The euphoria that followed, according to Benediktsdottir, Danielsson and Zoega (2011), was due to a business model combining investment and commercial banking financed initially by borrowing extensively in European bond markets. As a consequence, the total assets of the banking sector rose from 174% of GDP at the end of 2003 to 744% of GDP at the end of 2007.

Frustration set in as domestic banks' access to the European securities market became severely restricted when ratings agencies published negative reports at the beginning of 2006, after which retail deposit accounts became the main source of funding (Benediktsdottir, Danielsson and Zoega, 2011).

But euphoria came back when domestic banks discovered the asset growth and cash-flow potentials created by large acquisitions of foreign banks in Norway, Denmark and Britain (Nielsson and Torfason, 2012).

Then fear set in as shrinking liquidity began to set in globally, and a parallel currency crisis in the Krona became severe at the same time that panic surrounded the fall of Bear Stearns in March 2008 and the fall of Lehman Brothers in the autumn of that year (Nielsson and Torfason, 2012).

Finally, central authority intervention created relief after Iceland's financial system failed over a two week period in October 2008 and its stock market was almost completely wiped out, the foreign currency markets closed down and the external payments system froze (Benediktsdottir, Danielsson and Zoega, 2011).

5.2.4 Relevance to Hypotheses

Hypotheses 3 and 4 are not exhibited in this financial analysis. Hypothesis 3 requires data from multiple cases of systemic failure, to determine that operational behaviour is consistent with its quantum analogy, whereas hypothesis 4 requires a longer time period over which synchronicities due to mitigation efforts can emerge.

Nonetheless, hypotheses 1 and 2 should be exhibited in every systemic failure, and hypothesis 5 is highly probable in the Icelandic failure at the major reversal of sentiment in 2005.

5.2.5 Simulation Datapoints

The six sets of variable values in the table of actual data in Chart 1 for each year from 2003 to 2008 comprised the simulation datapoints for empirical results validation, of which there were 48 in total (8 variables by six years). Appendix G4 shows the equivalent values from the final simulation experiment.

5.3 Conceptual Model of the System

5.3.1 Introduction

This model instructs an apparatus of experimentation (see Figure 28 and Appendix G) to address the research goals by specifying a set of operations corresponding to the theory's propositions about systemic risk of failure, to explain how that risk occurs in a financial system, diagnose circumstances in which it materializes, and offer insights into how it may be mitigated.

It conforms to the normal practice of expressing relevant characteristics of a complex system through an extremely simplified conceptual interpretation, in which the essential features of interest can be specified.

5.3.2 Principles

Although the proposed theory addresses systemic risk of failure of the global financial system, there has never been a total failure of that system. Even the Great Depression of 1929 did not result in a complete failure (Kindleberger and Aliber, 2011). Consequently, there is no real world data for empirically validating a simulation of that scale of failure, even if it were considered a reasonable thing to attempt in a doctoral thesis. However, there have been many failures of national financial systems. After careful consideration when designing this conceptual model and its agent-based representation, a four-level structure was proposed based on a micro-level in which all individual participation occurs. The other levels reflect activity in that micro-level at different stages of aggregation. There is a meso-level showing collective participation, a macro-level showing operational state interplay in a behaviour manifold from catastrophe theory, and a phenomenal level showing operational behaviour as the interplay between operational focus and satisfaction. The remainder of this sub-section describes a national-centric conceptual design chosen for the micro-level, embedded in the global financial system by simple interactions with 'foreign' participants and a single international market. Other levels will be described in later sub-sections.

Figure 24 is an overview diagram of that design showing the key participants along with products and activity-types. It is a model of interactions between systemically important participants (SIPs), involving financial service products, traded as executions of systemically important financial service activity-types (SIFS). The most important simplification of the model is a bid/offer market design for all interactions between participants. This removes the need to model direct interactions between participants. Bids/offers are placed in the market according to selected strategies, in a configurable number of trading cycles each tick, and randomly matched as fills according to various trading rules. As market sentiment changes, rules about changing rules are applied, while trading reactions are driven by the evolving circumstances of participants.

Proximity among participants is determined by similarities in their current strategy and trading tactics. They do not have a physical location, but assets and liabilities flow between them through market exchanges, and participants can individually fail. However, there is no provision for new startups.

A few features of the original model are suppressed by parameter choice to reflect known circumstances of the Icelandic collapse, and corresponding code has been removed from the computational representation to reduce its complexity to a more readable version only containing code that is actually run by simulations. Examples of such removals are the implementation of a fine policy, and regulatory budget collection. These were removed due to a 'lack of authoritative response' (Nielsson and Torfason, 2012) from regulatory authorities and the central bank in Iceland over the period in time simulated, jointly modelled as the central authority. The parameters involved are 'strategies and policies', which were set to 'MIN-REGULATION', 'NO-FINES' and 'DO-NOTHING'.

The key design principles applied in the conceptual model design are: simplification of reality to expose essential features of interest, using a participation mechanism that allows catastrophe theory principles to be embedded in the computational representation to interpret results for corroborating hypotheses.

5.3.3 Agents and Interactions

Six generic systemically important financial service products are traded in this model as executions of systemically important financial service activity-types

(SIFS) for those products. Finance and economics literature provided little help in identifying what those high level generically representative products should be. Furthermore, there is little evidence for explicit definitions of a 'financial service'. Whenever that term is mentioned, it is usually linked to accounting notions from annual reports, such as 'loans', 'deposits', or 'credit derivatives'. There is no distinction drawn between products, services related to those products, and execution of those services. For example, academic references to financial services in the balance sheets of annual reports by banks show aggregate values for executions of products in an accounting period, not financial services totals.

In order to model the interaction between supply and demand in financial services, it was necessary to make a distinction between a product, such as a 'loan', and its related financial service activity-types (SIFS) 'lending' and 'borrowing', and execution of those activity-types in an actual provision of a financial service. This is a standard approach applied in systems development of banking computer applications, but it is often confused in academic literature.

With that distinction modelled, the generic selection of products became: loan, deposit, debt, settlement, security, and fund. Their respective SIFS became: lending/borrowing, taking/placing, issuing/holding, retiring/discharging, tendering/acquiring, and providing/receiving. Then separate rules were developed for each SIFS, qualified by market sentiment and the individual circumstances of participants. This particular combination of generic notions about supply and demand in financial services has no exact precedent in either academic or practitioner literature, but was considered to be the most accurate simplification of reality after a series of 862 simulation experiments to refine the model's efficacy.

Agent-sets were created in the computational representation for these conceptual model components, along with the range of participant types shown in Figure 24, and the operational process and rules by which their members interact defined in Figure 25, and Table 7 respectively. They can all be found in the computational representation code extract listed in Appendix G.3, and the full code listing provided on the companion CD mentioned in Appendix I.

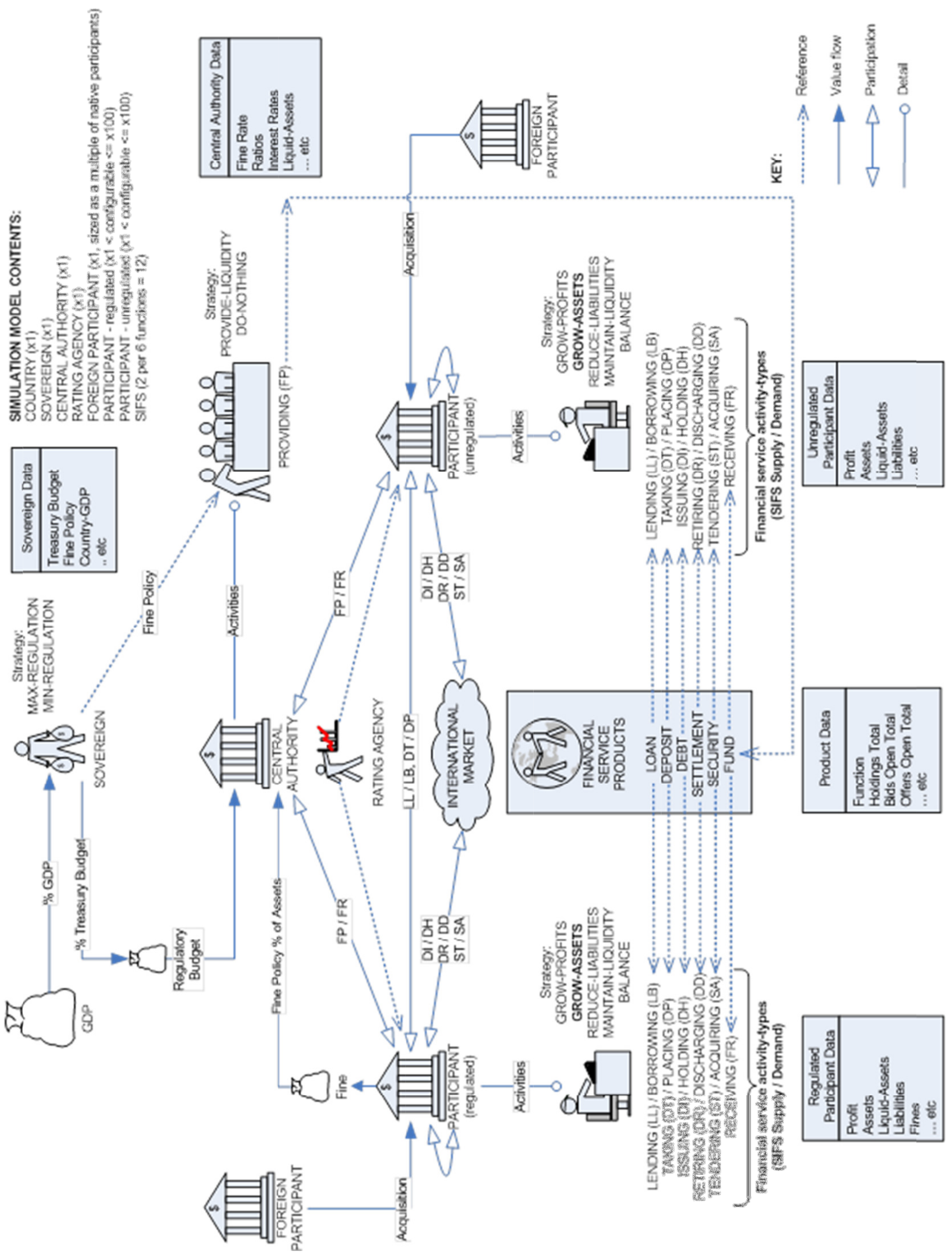


Figure 24: A Highly Simplified National Financial System

5.3.4 Operations

A flowchart is presented in Figure 25 below, specifying the process by which financial system participation in the conceptual model is operationalised in the computational representation. It has 23 separate steps, with 10 dedicated to simulation run setup and the other 13 performing tick-related actions. Procedure names given in this flowchart exactly match names used in the computational representation, and the number and textual description of each step can be found as a comment line before the code block for that step's logic. Finally, the organization of code broadly follows the flowchart sequence.

This close coupling of the conceptual model with its representation is intended to make verification easier, by enabling navigation to specific code of interest in a moderately complex design. Further extensive in-line commentary explains the logic and purpose of the code it surrounds, enabling it to be read by reviewers who are not familiar with the NetLogo programming language.

5.3.5 Rules

Conceptual model rules are documented in the verification table (see Table 8), and repeated as in-line commentary of the computational representation using matching rule numbers, for the same reason as discussed in the previous section. Depending on the process step in which they are found, rules will either implement setup logic, tick loop logic, or error/diagnostics logic. For example, setup rules include logic for randomly assigning initial values for variables across all simulation participants using national maximum, upper and lower year-end reporting totals from the previous year. They appear among relevant agent-set initialization code.

Other un-numbered logic exists, such as process flow logic, 'rules about rules' reasoning and simulation interface logic, but these are not documented in the conceptual model. They are usually performed in the computational representation across multiple code-blocks that are not easily cross-referenced, and best understood by reading general in-line commentary. Simulation interface logic refers to agent-specific code for visualization agent-sets used to present results in the meso-, macro-, and phenomenal levels of the simulation interface, such as the agents comprising the behaviour-state manifold from catastrophe theory. These agents and their agent-sets are not part of the conceptual model, because they do not exist in the micro-level. They are explained in sub-section 5.4.

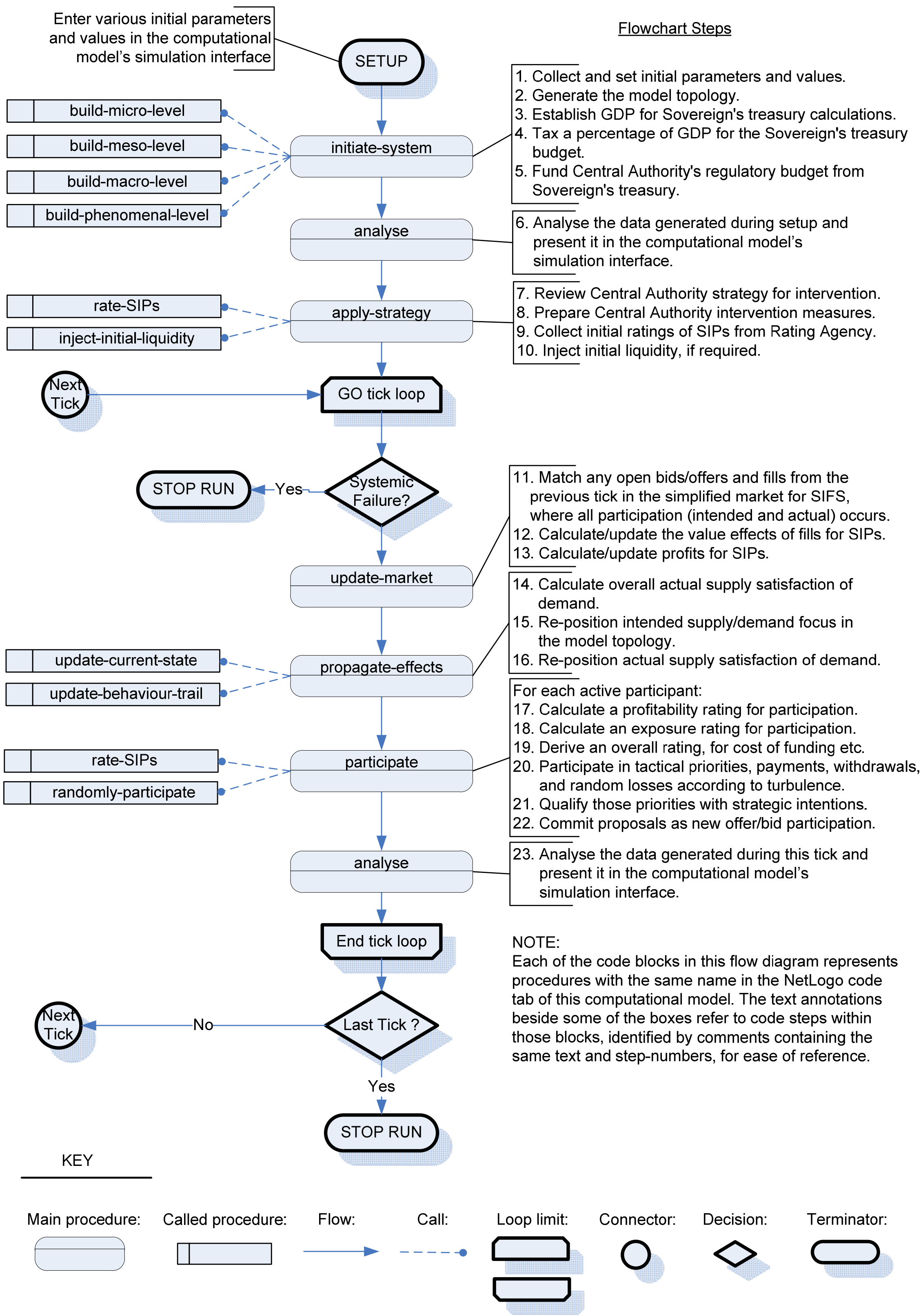


Figure 25: Operational Flowchart

5.3.6 Simplifications and Assumptions

The six generic systemically important financial service products introduced in sub-section 5.3.3 are shown in the left-most column of Table 7 next to their activity-types (SIFS) and associated financial effects. They are all highly simplified, and not intended to represent any particular accounting standard. Nonetheless, calibration runs of this computational representation and final simulation experiments demonstrated they generate a reasonable approximation of the real effects of financial services provided between systemically important participants.

Product	**Activity-types (SIFS)** *s- supply/offer* *d- demand/bid*	**Asset Effect** *} = share liquid-asset flow*	**Liability Effect** *} = share liquid-asset flow*	**Liquid-Asset Flow Effect** *i = incoming* *o = outgoing*
Loan	Lending *(s)*	loans-to-SIPs (− o) liquid-assets (− o)		o (deal)
		loans-to-SIPs (− i) liquid-assets (+ i)		i (repayment)
	Borrowing *(d)*	liquid-assets (+ i)	borrowings-from-SIPs(+ i)	i (deal)
		liquid-assets (− o)	borrowings-from-SIPs(− o)	o (repayment)
Deposit	Taking *(s)*	liquid-assets (+ i)	deposits-from-SIPs (+ i)	i (deal)
		liquid-assets (− o)	deposits-from-SIPs (− o)	o (withdrawal)
	Placing *(d)*	liquid-assets (− o) deposits-with-SIPs (+ o)		o (deal)
		liquid-assets (+ i) deposits-with-SIPs (− i)		i (withdrawal)
Debt *(origination)*	Issuing *(s)*	trading (+ i) liquid-assets (+ i) }	debt-issued (+ i)	i (deal)
	Holding *(d)**	debt-held (+ o) liquid-assets (− o)		o (deal)
(Debt) Settlement	Retiring *(s)*	trading (− o) liquid-assets (− o) }	debt-issued (− o)	o (deal)
	Discharging *(d)**	debt-held (− i) liquid-assets (+ i)		i (deal)
Security	Tendering *(s)*	securities (− i) trading (+ cash) }	on-margin (− credit) }	i (deal)
	Acquiring *(d)*	securities (+ o) trading (− cash) }	on-margin (+ credit) }	o (deal)
Fund	Providing *(s)***	liquid-assets (− o)		o (deal)
	Receiving *(d)*	liquid-assets (+ i)	funds-received (+ i)	i (deal)
		liquid-assets (− o)	funds-received (− o)	o - refund

* Activity exclusively performed by the Foreign Participant counterparty.
** Activity exclusively performed by the Central Authority counterparty (refunds not shown).

Table 7: Financial effects of simplified product activities

A ‘loan’ is assumed to be repaid periodically, and never repaid at once in full, whereas ‘debt’ is always settled at once in full (by the ‘settlement’ product). Other variations of loan-type products in the real world, such as repos, are then approximated by these three generic products. A ‘deposit’ is similarly straightforward, representing any interest-bearing placement of assets by one participant with another, other than central bank funding (see ‘fund’ product comments). On the investment side, the ‘security’ product represents all types of traded assets, such as stocks, bonds and derivatives, whereas the ‘fund’ product is a hybrid between loan products and investments such as bailout finance, offered by the central authority to individual participants.

By their nature, these simple generic products have no direct equivalent among the plethora of complex real world financial service products, but they are designed to collectively simulate the overall financial effects of such products.

The following example of how to read Table 7 applies to the row containing an ‘issuing’ activity-type of the ‘debt (origination)’ product. In the right-most cell of that row, ‘i(deal)’ indicates that incoming liquid-assets flow from a debt issuance deal, which is shown in cells to the left to be recorded as a ‘debt-issued’ liability effect, and shared as an asset effect in some proportion (decided by allocation rules for liquid-assets flow) between trading and liquid-assets. All other rows in this table follow a similar logic as relevant to their activity-types.

5.4 Computational Representation

5.4.1 Construction

This model conforms to the normal practice of expressing relevant characteristics of a complex system through the construction of an extremely simplified computational representation, in which the essential features of interest can be explored. Within that approach, it extends previous notions about representing such systems by physically incorporating catastrophe theory into the model topology to provide a recognized basis for interpreting emergent phenomena in experimental observations, and corroborating the theory by theoretical triangulation. The intention being to represent a plausible conceptual model for simulating essential features of the global financial system, from a national sub-system perspective, capable of describing how catastrophic failure of the Icelandic financial system occurred between the years 2003 to 2008. The representation is comprised of a particular set of configuration parameters and rules of system participation, together with a 3-dimensional agent-based simulation interface and a separate run-time dashboard. It is designed to simulate a reasonable approximation to the financial effects of that failure based on official accounts of events over that time, and archived annual reports data (see sub-section 5.2), to show how their hypothesized consequences as emergent phenomena can be interpreted through the lens of catastrophe theory and corroborated.

Appendix G describes more aspects of this representation, while sub-sections 5.4.1 to 5.4.4 explain its purpose.

5.4.2 Simulation Interface

5.4.2.1 Purpose

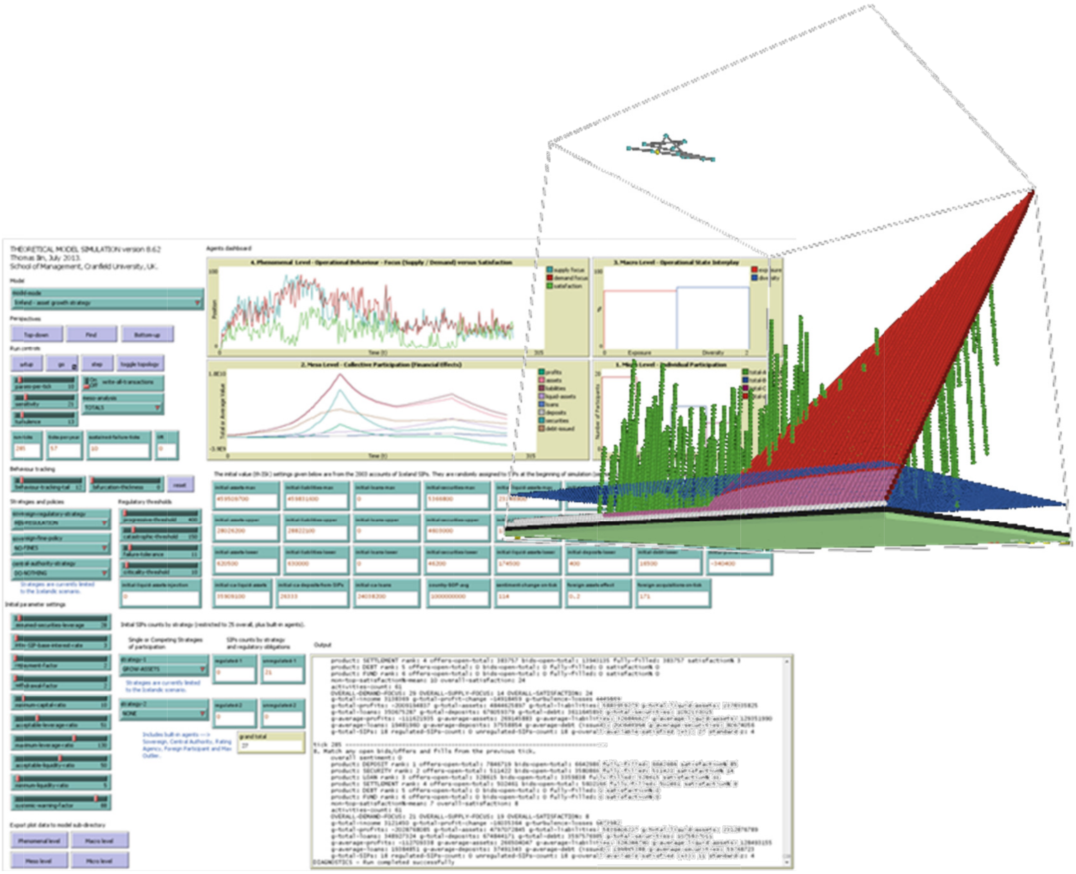


Figure 26: Simulation Dashboard and 3D View

This section explains how the computational representation is structured and used when testing and validating the proposed theory. Due to the ‘one-run’ nature of validated simulation in this thesis, as explained in sub-section 3.4.7, the simulation files provided with supporting evidence and materials in Appendix I can be loaded into NetLogo 3D 5.0.4 and run by simply pressing the ‘run’ button. When replicating the claimed results, all initial conditions are pre-set in the interface parameters, and initial values are pre-loaded into data entry fields. As a run proceeds, six interface controls present testing and validation results for analysis. In their relative order of information detail, from most detailed to most summary, they are: the ‘output’ text box situated at the bottom middle of the simulation interface, containing detailed micro-level participation data; the four charting boxes for micro-, meso-, macro- and phenomenal level results presentation; and the separate 3D window for corroborating results as phenomena interpreted by catastrophe theory.

The meso-level chart has two modes, controlled by a ‘meso analysis’ drop-down selector. It is normally in the ‘TOTALS’ selection, which produces a chart that can be visually compared with the output chart from financial analysis (see sub-section 5.2). The other setting of ‘AVERAGES’ produces a chart that plots totals from the previous tick averaged by the number of participants remaining after failures have been dropped.

The output text box has two settings, controlled by a ‘write-all-transactions’ toggle switch in the interface, which is normally in the ‘off’ position. In addition to setup and end-run diagnostics, this default setting loads summary information into the text box after each tick ends, whereas the ‘on’ position also dumps all micro-level execution information into that box as it happens.

Hypotheses are tested by examining patterns in the four chart boxes in conjunction with phenomena observed in the 3D window, using catastrophe theory to independently interpret those phenomena for credible corroboration of the null-hypothesis (see sub-section 0).

5.4.2.2 Reading the 3D Window

Phenomena are presented in this window on three surfaces: the control plane, behaviour surface, and phenomenal plane (see Figure 27).

The control plane performs two functions:

i. Its bottom-surface is coloured green, and presents a dynamic summary of micro-level participation executions in the form of supply or demand arrows for each of the 12 activity-types, organized on the diagonal emerging from the origin coordinates (0, 0) in descending sequence of their changing values for open bids or offers.
ii. Its top-surface is coloured black, and forms the state-space floor on which the behaviour surface comes to rest as states approach the origin coordinates (0, 0, 0). This is the way the representation interprets the standard meaning of a control surface in catastrophe theory.

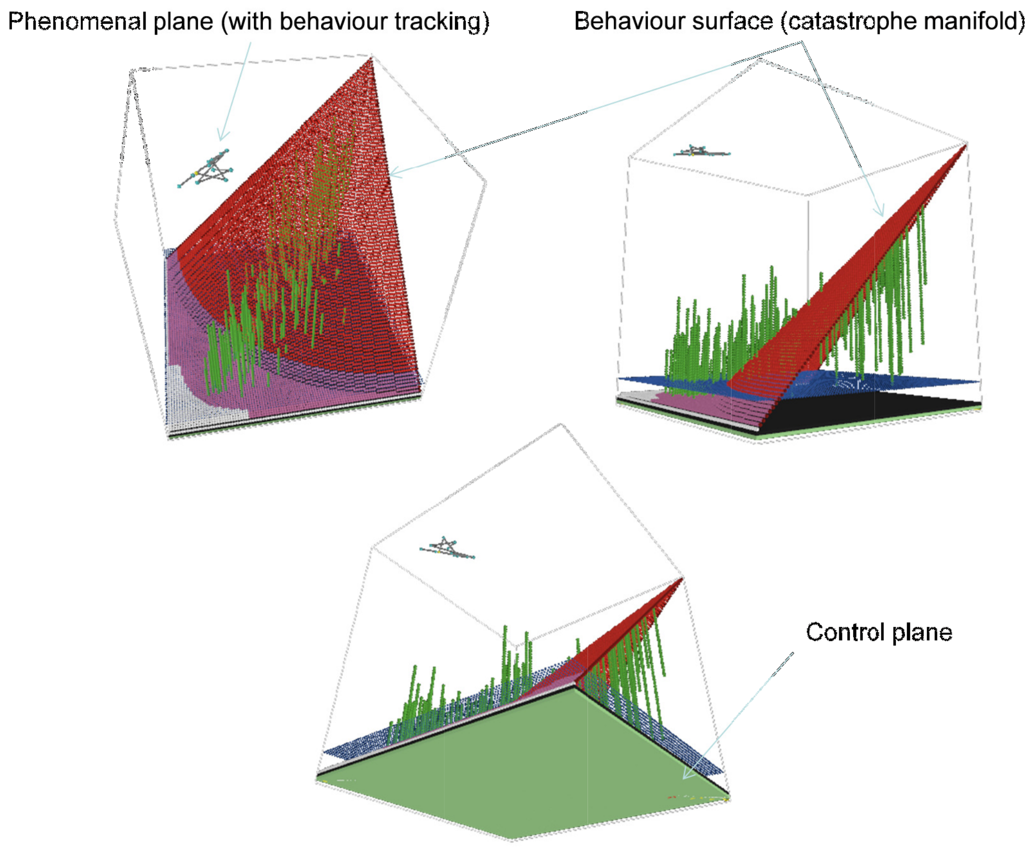


Figure 27: 3D View of the three surface operational behaviour topology

The third dimension of this state-space extends upwards to accommodate any potential future operational state. Within that extended state-space there is a standard surface comprised of agents representing (red) nodes in a hypothetical state manifold or behaviour surface from catastrophe theory (before a bifurcation is formed), providing a reference surface for potential future operational states. As the actual current operational state is simulated, and moves over this reference surface over time, deviations in its z coordinate from the standard state-surface can be plotted as additional (green) nodes, and overlaid on each other if they pass over the same (x, y) coordinates on that surface, to gradually suggest a surface of extremes in actual operational states over time. This allows experimental observations to be made, looking for gradients and perturbations in that surface of extremes in relationship to the hypothetical standard state-surface, that may have relevance for theory hypotheses.

Finally, the upper surface of the state-space ceiling presents a dynamic summary of phenomenal level operational behaviour as a 2D projection of 3D movements in the current operational state in the form of a growing connected trail of changes in the position of its (x, y) coordinates.

5.4.3 Run-Time Features

In the final validated version of this computational representation, operational strategies used for simulation are limited by parameter to 'GROW-ASSETS', which is acknowledged in the literature to have been the shared objective of most participants in Iceland during the period of interest (Nielsson and Torfason, 2012). This setting is operationalised by participation rules that emphasize tactics for assets acquisition.

During run-time, the consequence of following that strategy can be observed in the micro-level bar-chart as reductions in participant ratings by a rating agency according to its rules, and subsequent failures. Meanwhile operational state interplay between exposure and diversity can be observed in the macro-level bar-chart. Neither of these charts is directly referred to when comparing simulation results with the output of financial analysis for corroboration assessment, but they do provide additional insights for risk mitigation.

5.4.4 Capabilities and Limitations

Simulation experiments for calibrating the computational representation were able to reasonably approximate the financial effects of the Icelandic failure over the years 2003 to 2008, based on official accounts of events over that time, and archived annual reports data, to show how their hypothesized consequences as emergent phenomena could be interpreted through the lens of catastrophe theory.

However, originally constructed capabilities were subsequently limited to the requirements of the Icelandic failure, reducing potentials for: strategies in effect (only asset growth), regulatory intervention (or lack of it), creation of new participants (no new participants created after initial setup, but failures allowed), and central bank bailout injection (none occurred). Although the criticality surface (coloured blue), added as a new feature during interface design that is not shown in the figures of section 4, introduced a better capability of simulating bifurcations involving immediate catastrophic failures, rather than just progressive ones.

5.5 Verification

5.5.1 Objectives

Verification is considered by Davis, Eisenhardt and Bingham (2007) to be roughly analogous to manipulation checks in laboratory experiments. They describe its purpose as ensuring that the computational representation accurately embodies the theoretical logic. Sargent (1996) and Kleijnen (1995) go further, by using various object-oriented techniques and related approaches in the structural design of simulation code to facilitate additional verification. However, the NetLogo simulation tool lacks object-oriented or structural features, and so is limited in its verification capabilities (NetLogo has simulation objects called 'turtles', but it is not an object-oriented language with features such as inheritance, encapsulation and polymorphism). When other considerations are also taken into account, such as the relative complexity of the simulation being verified, and its unusual approach to theoretical triangulation, less conventional techniques seem appropriate. The general approach taken by this thesis to verification is specified in sub-section 3.5.8; whereas this sub-section examines the contents of Table 8 and Table 9, created for verification purposes in project 3 to establish if real world abstraction has been successfully achieved in step 10 of the methodology.

5.5.2 Operational

Table 8 maps data entry fields in the computational representation to their sources of initial values in the spreadsheet downloaded from Bankscope; and further maps both to their equivalent code variable (given the same name as its conceptual model equivalent); which is in turn linked to rules for value disbursement and use among other variables, and their impacts; and associated with one or more steps in the operational flowchart to facilitate their discovery in the code. This describes where initial values are sourced, where they are allocated, and the rules by which those allocations are setup and subsequently used at run-time, their value impacts, and where that impact occurs in code. In that way a mapping is provided between source data, the computational representation interface, internal variables and rules in simulation code, artefacts in the conceptual model with the same names, and steps in the operational flowchart.

(a) Simulation: initial value field *see simulation console (max values are from any extreme outlier SIPs, other than the built-in agents. Upper and lower values represent the normal range of most SIPs)*	**(b) SIFS-related**	**Source: Simulation Analysis Spreadsheet** *(Containing an extract of financial reporting data from Bankscope about the Iceland financial system failure. Refers to the 2003 data in Table 1 of the 'Source Data' tab).* **(c) Data value**	**(d) Data Source Reference**	**(e) SIP agent-field**	**(f) Rule for value allocation to individual SIPs**	**(g) Impact on assets 'A', liabilities 'L', liquid-assets 'LA'.**	**(h) Generates income (+) or expense (-)**	**(i) Explanatory note** *(identifying the steps in the operational flowchart where rules are implemented, and where explanatory comments can be found in the simulation code)*
initial-assets-max	No	459,509,700	'Source Data'!M186	assets	**R01** - Setup distributes random** values derived from the data values in (c) to all SIPs through their SIP agent-field named in (e).	Initial A		R01 in step 1 (in 'build-micro-level' called procedure).
initial-assets-upper		28,026,200	'Source Data'!M189					
initial-assets-lower		620,500	'Source Data'!M183					
initial-liabilities-max	No	459,831,600	'Source Data'!S186	liabilities	**R02** - Setup distributes random** values derived from the data values in (c) to all SIPs through their SIP agent-field named in (e).	Initial L		R02 in step 1 (in 'build-micro-level' called procedure).
initial-liabilities-upper		28,822,100	'Source Data'!S189					
initial-liabilities-lower		630,000	'Source Data'!S195					
initial-loans-max	Yes	0		1. loans-to-SIPs,	**R03** - Setup distributes random** values derived from the data values in (c) among half of the SIPs through their SIP agent-field 1 named in (e).	Already in A		R03 in step 1 (in 'build-micro-level' called procedure).
initial-loans-upper		0						
initial-loans-lower		0			**R04** - Then run-time fills of LENDING activities adjust asset levels,	A (+), LA (-)	(+)	R04 in step 12.
					R05 - with random** periodic repayments having a reverse* effect.	A (-), LA (+)		R05 in step 20.
				2. borrowings-from-SIPs	**R06** - Setup distributes random** values derived from the data values in (c) among the other half of SIPs through their SIP agent-field 2 named in (e).	Already in L		R06 in step 1 (in 'build-micro-level' called procedure).
					R07 -Then run-time fills of BORROWING activities adjust liability and liquid-asset levels,	L (+), LA (+)	(-)	R07 in step 12.
					R08 - with random** periodic repayments having a reverse* effect.	L (-), LA (-)		R08 in step 20.
initial-securities-max	Yes	5,366,800	'Source Data'!DC186	securities	**R09** - Setup distributes random** values derived from the data values in (c) among all SIPs through their SIP agent-field named in (e).	Already in A and L		R09 in step 1 (in 'build-micro-level' called procedure).
initial-securities-upper		4,603,000	'Source Data'!DC189					
initial-securities-lower		46,200	'Source Data'!DC199		**R10** - Then run-time fills of securities TENDERING activities adjust asset levels.	A (-), L (+)	(+/-)	R10 in step 12.
					R11 - Or run-time fills of securities ACQUIRING activities adjust asset levels.	A (+), L (-)	(+/-)	R11 in step 12.

Table 8: Iceland - initial conditions, values and rules verification.

(a) Simulation: initial value field *see simulation console (max values are from any extreme outlier SIPs, other than the built-in agents. Upper and lower values represent the normal range of most SIPs)*	(b) SIFS-related	Source: Simulation Analysis Spreadsheet *(Containing an extract of financial reporting data from Bankscope about the Iceland financial system failure. Refers to the 2003 data in Table 1 of the 'Source Data' tab).* (c) Data value	(d) Data Source Reference	(e) SIP agent-field	(f) Rule for value allocation to individual SIPs	(g) Impact on assets 'A', liabilities 'L', liquid-assets 'LA'.	(h) Generates income (+) or expense (-)	(i) Explanatory note *(identifying the steps in the operational flowchart where rules are implemented, and where explanatory comments can be found in the simulation code)*
initial-liquid-assets-max	No	23,146,900	'Source Data'!AF186	liquid-assets	**R12** - Setup distributes random** values derived from the data values in (c) to all SIPs through their SIP agent-field named in (e).	Already in A, Initial LA	(+)	R12 in step 1 (in 'build-micro-level' called procedure).
initial-liquid-assets-upper		17,600,700	'Source Data'!AF189					
initial-liquid-assets-lower		174,500	'Source Data'!AF187					
initial-deposits-max	Yes	3,520,000	'Source Data'!BW189	1. deposits-from-SIPs	**R13** - Setup distributes random** values derived from the data values in (c) among half of the SIPs through their SIP agent-field 1 named in (e).	Already in L		R13 in step 1 (in 'build-micro-level' called procedure).
initial-deposits-upper		542,500	'Source Data'!BW188					
initial-deposits-lower		400	'Source Data'!BW200					
					R14 - Then run-time fills of deposit TAKING activities adjust liabilities and liquid-assets,	L (+), LA (+)	(-)	R14 in step 12.
					R15 - with random** periodic withdrawals having a reverse* effect.	L (-), LA (-)		R15 in step 20.
				2. deposits-with-SIPs	**R16** - Setup distributes random** values derived from the data values in (c) among the other half of SIPs through their SIP agent-field 2 named in (e).	Already in A		R16 in step 1 (in 'build-micro-level' called procedure).
					R17 - Then run-time fills of deposit PLACING activities adjust asset levels,	A (+), LA (-)	(+)	R17 in step 12.
					R19 - with random** periodic withdrawals having a reverse* effect.	A (-), LA (+)		R18 in step 20.
initial-debt-max	Yes	424,978,700	'Source Data'!CU186	1. debt-issued	**R19** - Setup distributes random** values derived from the data values in (c) among among half of the SIPs through their SIP agent-field 1 named in (e).	Already in L		R19 in step 1 (in 'build-micro-level' called procedure).
initial-debt-upper		7,164,000	'Source Data'!CU189					
initial-debt-lower		16,500	'Source Data'!CU201					
					R20 - Then run-time fills of debt ISSUING activities adjust liability and liquid-asset levels,	A (+), L (+)	(-)	R20 in step 12.
					R21 - with random** periodic retiring of debt issued having a reverse* effect.	A (-), L (-)	(-)	R21 in step 12.
				2. debt-held	**R22** - Setup distributes random** values derived from the data values in (c) among the other half of SIPs through their SIP agent-field 2 named in (e).	Already in A		R22 in step 1 (in 'build-micro-level' called procedure).
					R23 - Then run-time fills of debt HOLDING activities adjust asset and securities levels,	A (+), LA (-)	(+)	R23 in step 12.
					R24 - with random** periodic discharge of debt held having a reverse* effect.	A (-), LA (+)	(+)	R24 in step 12.

Table 8 (cont): Iceland - initial conditions, values and rules verification.

(a) Simulation: initial value field *see simulation console (max values are from any extreme outlier SIPs, other than the built-in agents. Upper and lower values represent the normal range of most SIPs)*	**(b) SIFS-related**	**Source: Simulation Analysis Spreadsheet** *(Containing an extract of financial reporting data from Bankscope about the Iceland financial system failure. Refers to the 2003 data in Table 1 of the 'Source Data' tab).* **(c) Data value**	**(d) Data Source Reference**	**(e) SIP agent-field**	**(f) Rule for value allocation to individual SIPs**	**(g) Impact on assets 'A', liabilities 'L', liquid-assets 'LA' .**	**(h) Generates income (+) or expense (-)**	**(i) Explanatory note** *(identifying the steps in the operational flowchart where rules are implemented, and where explanatory comments can be found in the simulation code)*
initial-profits-max	No	1,678,200	'Source Data'!G186	profit	**R25** - Setup distributes random** values derived from the data values in (c) to <u>all SIPs</u> through their SIP agent-field named in (e).	Already in A		R25 in step 1 (in 'build-micro-level' called procedure).
initial-profits-upper		233,900	'Source Data'!G187		**R26** - Then profits / losses from SIPs participation in activities are calculated each tick using a cost of money based on the 'inter-SIP-base-interest-rate' simulation parameter. Losses due to turbulence and failed SIPs are also deducted according to the turbulence parameter setting.	A (+/-), L (+/-)		R26 in steps 12 and 20. Value effects on securities of market price movements are simulated by range-bound random profits or losses when TENDERING is filled .
initial-profits-lower		-340,400	'Source Data'!G207					
initial-ca-loans	Yes	24,038,200	'Source Data'!BO205	loans-to-SIPs	**R27** - Setup directly loads the full data value from (c) to the Central-Authority's SIP agent-field 1 named in (e).	Already in A		See rules implementation in the loans section above for run-time rules and impacts. These loans allow the Central-Authority to act as counterparty of last resort, when necessary.
initial-ca-deposits-from-SIPs	Yes	26,333	'Source Data'!CE182	deposits-from-SIPs	**R28** - Setup directly loads the full data value from (c) to the Central-Authority's SIP agent-field 1 named in (e).	Already in L		See rules implementation in the deposits section above for run-time rules and impacts. These deposits allow the Central-Authority to act as counterparty of last resort, when necessary.
initial-ca-liquid-assets	Yes	35,909,100	'Source Data'!AF205	1. liquid-assets	**R29** - Setup directly loads the full data value from (c) to the Central-Authority's SIP agent-field 1 named in (e). **R30** - Then run-time fills of funds PROVIDING activities alter asset levels.	Already in A A (+), LA (-)		Offered to SIPs when liquidity availability is low, and the Central-Authority strategy is <u>not</u> 'DO-NOTHING'. The Icelandic simulation assumption is that none of the funds provided are repaid.
				2. liquid-assets	**R31** - Then run-time fills of funds RECEIVING activities by the other SIPs adjust liability and liquid-asset levels.	L (+), LA (+)		

* *Note: Use of identical repayment / withdrawal / recall calculations for all open SIFS-related amounts in the SIP agent-fields shown in (g) results in those calculations netting-out to zero between SIPs.*

** *Based on a random-normal distribution.*

Table 8 (cont): Iceland - initial conditions, values and rules verification.

5.5.3 Theoretical

Table 9, on the other hand, presents a mapping from propositions in the theoretical model to internal variables and code procedures. Interestingly, the main purpose of this thesis expressed simply as proposition P11 appears to be unverifiable. However, it should be remembered that this is the aim of validation (see sub-section 5.7).

Proposition (P)	**Verified by …**
P1: The transition threshold of contagion	Code implementing the *catastrophic-threshold* interface parameter.
P2: Systemic failure as participation unsustainability	Code implementing the sustained-failure-ticks interface parameter.
P3: Affinity in participation	Code calculating the global variables *g-matching-list-bids* and *g-matching-list-offers*.
P4: Intensity of participation	Code calculating the variables *overall-demand-focus* and *overall-supply-focus*.
P5: Focus (or diversity) of participation	Code calculating the global variable *g-overall-demand-focus*.
P6: Actual operational effectiveness	Code calculating the global variable *g-overall-available-satisfied*.
P7: The global financial system's operational state	Code calculating the global variable *g-current-state*.
P8: Operational behaviour of the system	Code implementing the *draw-behaviour-surface* procedure.
P9: A definition of systemic failure	Code implementing the *failure-tolerance* interface parameter.
P10: Probability of systemic failure	Not simulated (systemic failure is simulated, but not the calculation of its probability).
P11: A practical definition of systemic risk	Not simulated (see P10).
P12: Emergence of operational behaviour	Code implementing the *propagate-effects* procedure.

Table 9: Proposition Verification

When considered in combination with commentary in the NetLogo code, these two tables facilitate more thorough verification than could be achieved by such techniques as the application of structured methods, given the limitations of NetLogo.

5.6 Simulation

5.6.1 Apparatus

Figure 28 shows the experimental apparatus used in project 3 during simulation, testing and validation. Agent-based modelling and simulation requirements were satisfied by the NetLogo 3D 5.0.4 tool, while MS Office Excel 2010 and the SPSS statistical software package covered analytical functionality, and data about the Icelandic financial system collapse was extracted from the Bankscope annual reporting archive, then saved to local disk storage for subsequent analysis. The main artefacts used by this apparatus during experimentation are also shown.

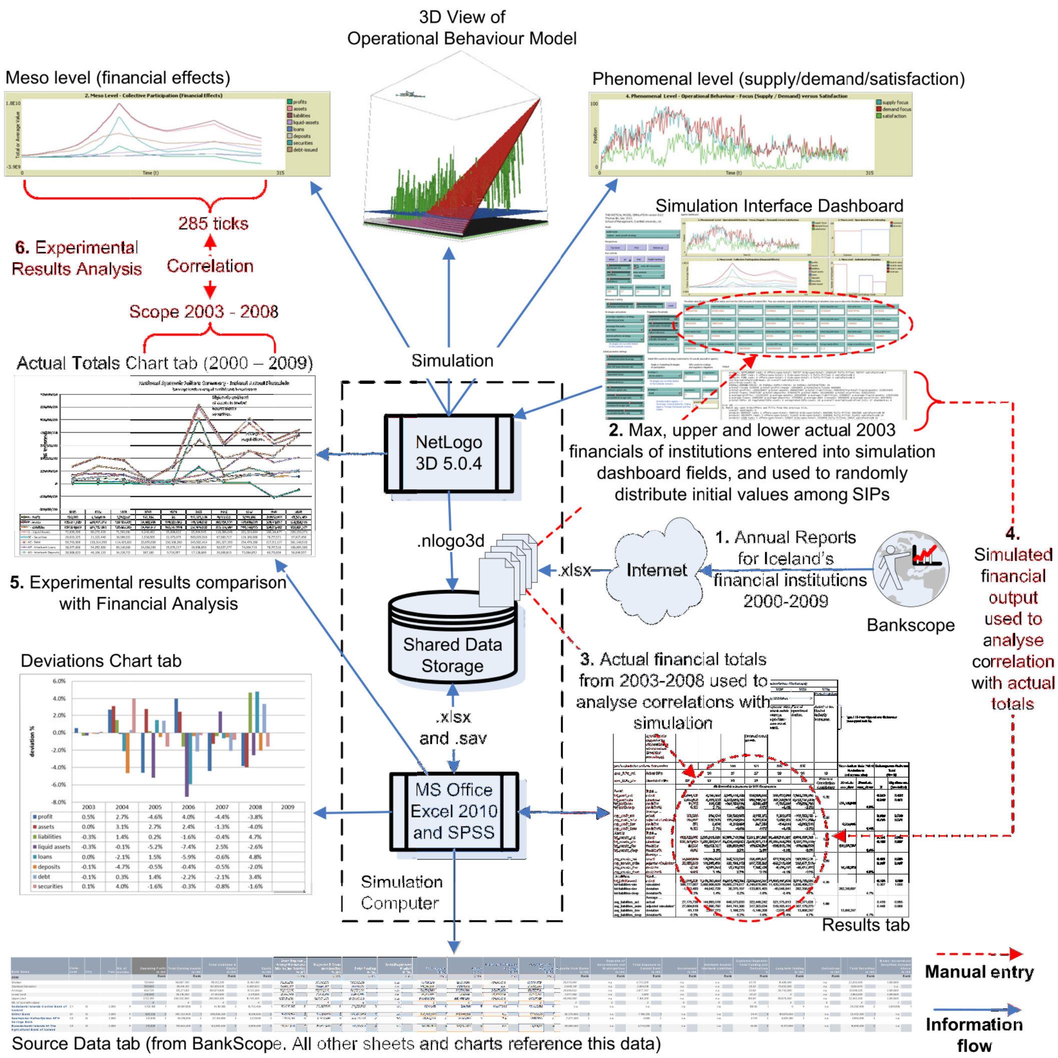


Figure 28: Experimental apparatus and simulation steps

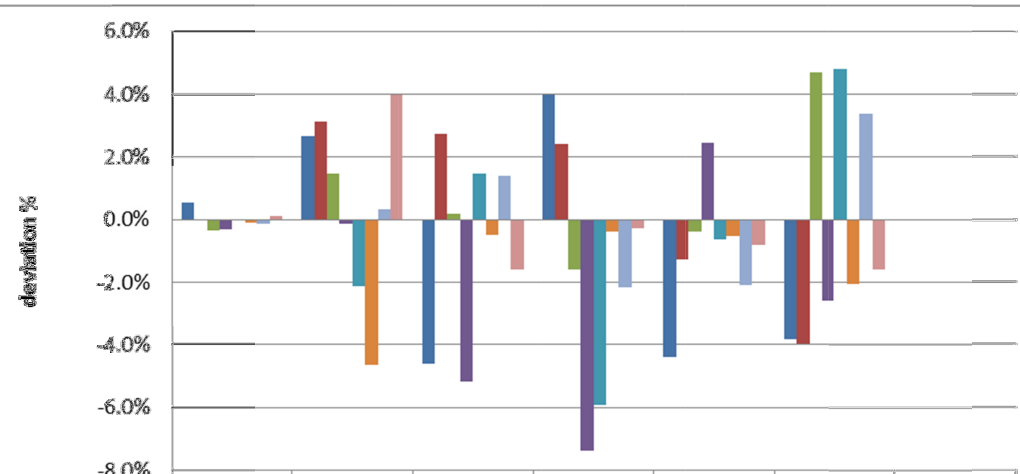
5.6.2 Process

Figure 28 summarizes the six-step process followed by the final simulation, as specified in the simulation protocol (see Appendix H). After downloading extracts during step 1 from the annual reports of the 51 financial institutions active in Iceland over the years 2000 to 2009, step 2 involved entering maximum, upper and lower values into the simulation interface of the financial variables requiring initial values for experimentation setup. Then step 3 required a complete set of actual financials to be entered into Table 10, to be compared with equivalent values generated by simulation in step 4.

Then, after various table extracts and charts were produced by step 5, step 6 conducted experimental results analysis involving the calculation of statistical correlations between actual and simulated results.

5.6.3 Results

5.6.3.1 Micro-level



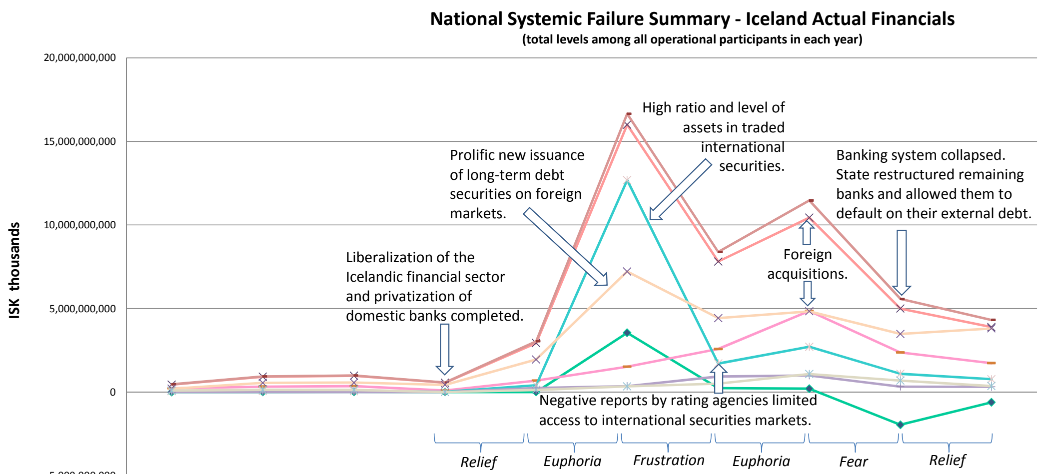
	2003	2004	2005	2006	2007	2008	2009
profit	0.5%	2.7%	-4.6%	4.0%	-4.4%	-3.8%	
assets	0.0%	3.1%	2.7%	2.4%	-1.3%	-4.0%	
liabilities	-0.3%	1.4%	0.2%	-1.6%	-0.4%	4.7%	
liquid assets	-0.3%	-0.1%	-5.2%	-7.4%	2.5%	-2.6%	
loans	0.0%	-2.1%	1.5%	-5.9%	-0.6%	4.8%	
deposits	-0.1%	-4.7%	-0.5%	-0.4%	-0.5%	-2.0%	
debt	-0.1%	0.3%	1.4%	-2.2%	-2.1%	3.4%	
securities	0.1%	4.0%	-1.6%	-0.3%	-0.8%	-1.6%	

Chart 2: Micro-level result deviations from actual

Although individual acts of participation at the micro-level are invisible, the bottom surface of the control plane (see the 3D View in Figure 27) presents a summary of intended supply and demand activity (i.e. bids and offers) for each financial service activity type (SIFS). On a tick-by-tick basis, this shows how participation focus volumes shift among SIFS, giving a breakdown by SIFS for the overall operational focus of the current state in the 3D View's behaviour space. This is useful for identifying risk mitigation opportunities when examined for each tick in combination with the micro- and macro-level bar charts in the simulation interface. However, deviations of simulated financial results from actual values at this level of participation granularity offer a better understanding of simulation accuracy. Chart 2 presents this information, derived from datapoint summaries in Appendix G4. These results are subsequently used for calculating statistical correlations during validation.

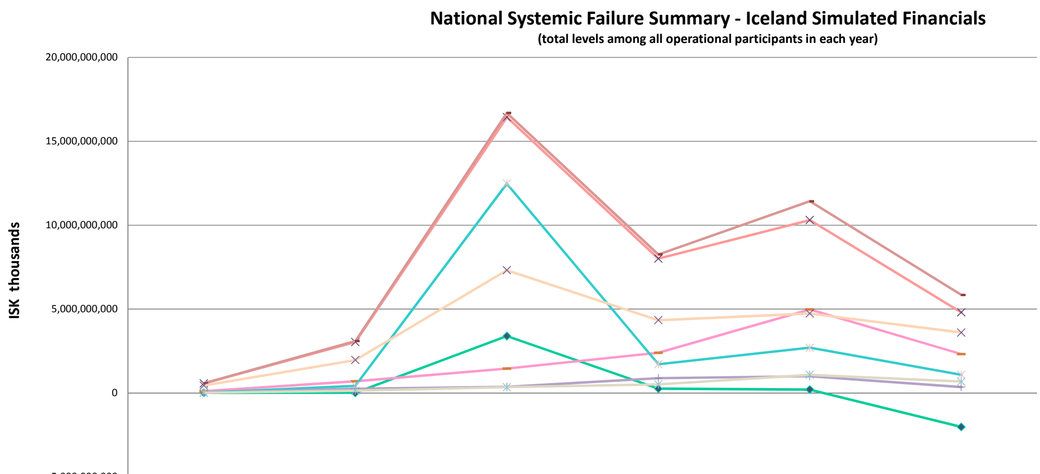
5.6.3.2 Meso-level

The meso-level results presented in Chart 3 are a composite of three separate line-charts, depicting closely related data used for both qualitative and quantitative validity assessment. The top chart shows actual totals for financial reporting variables over the years 2000 to 2009. It is the same as Chart 1 presented in sub-section 5.2.2, reproduced here for easy comparison with the other two charts. Simulated values equivalent to those totals are presented in the middle chart, for the period of interest to this thesis over the years 2003 to 2008. These values were extracted from simulation output at the datapoints given in Appendix G4, and entered into the MS Excel file containing the top chart for comparison using the same charting tool. The two charts appear to match quite well, but the degree of correlation will be determined statistically during validation. Finally, the bottom chart presents the same simulated values as the middle chart, but rendered by the NetLogo charting object in the simulation interface. Changes in sentiment reflected in these charts by the directions and gradients of line-plots were induced by simulation interface parameters, such as 'sentiment-change-on-tick' and 'foreign-acquisitions-on-tick'. References to them were restricted to the rules of individual participation in the micro-level, to ensure that non-linear relationships between the micro- and phenomenal-level would not be compromised.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
tot_profit_act	1,656,700	4,312,100	8,403,100	2,276,100	6,020,600	3,549,845,139	239,599,662	206,412,248	-1,953,841,290	-607,881,900
tot_assets_act	451,393,500	924,935,100	981,676,800	565,522,000	2,939,201,500	15,999,713,336	7,811,197,543	10,435,219,325	4,996,139,748	3,887,703,500
tot_liabilities_act	468,318,500	939,790,100	995,786,700	570,690,500	3,044,863,900	16,654,898,860	8,383,680,300	11,465,867,885	5,574,049,530	4,318,728,400
tot_liquid_act	231,931,800	330,242,100	363,716,300	103,713,500	691,861,200	1,525,669,113	2,581,366,364	4,860,068,189	2,374,534,591	1,734,561,200
tot_securities_act	53,084,900	74,062,800	67,007,000	17,630,800	407,113,000	12,681,175,749	1,712,223,256	2,715,050,572	1,093,228,923	774,386,700
tot_debt_act	202,975,600	557,257,400	572,129,000	437,710,500	1,951,623,900	7,215,230,684	4,429,202,641	4,835,106,317	3,480,337,873	3,811,485,100
tot_loans_act	0	0	0	0	250,700,200	354,177,740	934,168,278	999,915,622	332,978,327	323,283,500
tot_deposits_act	92,725,900	138,312,400	136,906,900	5,807,700	136,177,400	342,577,782	511,286,489	1,081,272,784	688,948,932	362,818,900

Source: Extracted from the reported accounts of all 51 financial institutions in the Iceland database of Bankscope.



	2003	2004	2005	2006	2007	2008
tot_profit_sim	2,288,092	6,181,635	3,385,689,093	249,148,320	197,303,904	-2,028,768,085
tot_assets_sim	565,463,619	3,031,255,287	16,436,266,933	8,000,871,811	10,300,805,545	4,797,072,845
tot_liabilities_sim	568,777,007	3,088,906,629	16,685,274,017	8,249,878,895	11,420,319,044	5,836,406,227
tot_liquid_sim	103,384,474	690,826,769	1,446,451,674	2,390,728,361	4,979,384,503	2,312,876,789
tot_securities_sim	17,649,488	423,267,494	12,476,793,277	1,707,138,211	2,693,061,723	1,075,837,011
tot_debt_sim	437,144,393	1,958,031,151	7,315,991,927	4,333,688,799	4,733,905,672	3,597,576,985
tot_loans_sim	0	245,375,324	359,320,471	878,666,766	993,576,401	348,927,324
tot_deposits_sim	5,801,338	129,829,178	340,840,201	509,252,986	1,075,600,763	674,844,171

Source: Simulated results re-presented in the same charting tool used for actual results presentation (see top chart on this page).

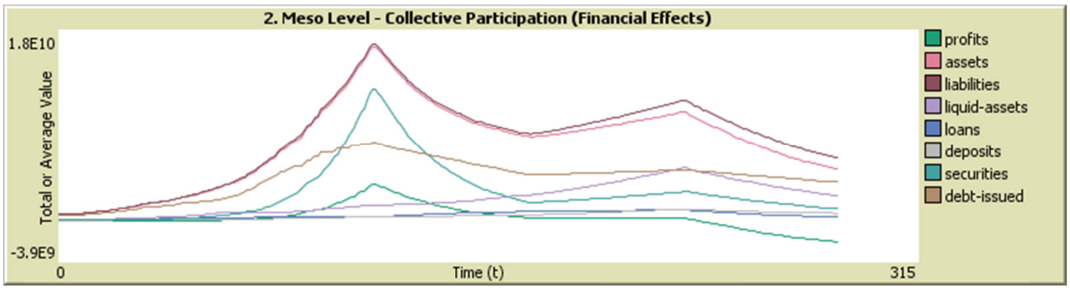


Chart 3: Meso-level financials, actual versus simulated

5.6.3.3 Macro-level

Interplay between exposure and diversity effects in operational state-shifts over time is shown for each simulation tick by the dynamic bar chart representing this level in the simulation interface. The chart is not used directly in validation, but provides useful information for identifying mitigation opportunities. It interprets diversity as the percentage:

$$d = \frac{(p - s)}{p} \times 100, \tag{27}$$

where p is an overall participation count for a tick, and s is its strategic emphasis count (i.e. the number of participations in financial service activity-types identified by participant rules as pertinent to their selected strategy).

Exposure is interpreted as the percentage:

$$e = \frac{l}{i} \times 100, \tag{28}$$

where l is the the total value of losses due to simulated turbulence, and i is total income.

Observed interplay between a lack of diversity in system participation strategies and shared exposure to potential losses as the system approaches a state of systemic failure indicates this may be a key operational mechanism of catastrophic tensions arising in the supply and demand of financial services. During theoretical triangulation (sub-section 5.7) this observation is used to explain how hypothesised phenomena arise, and it is included in theory revisions in section 6.

5.6.3.4 Phenomenal-level

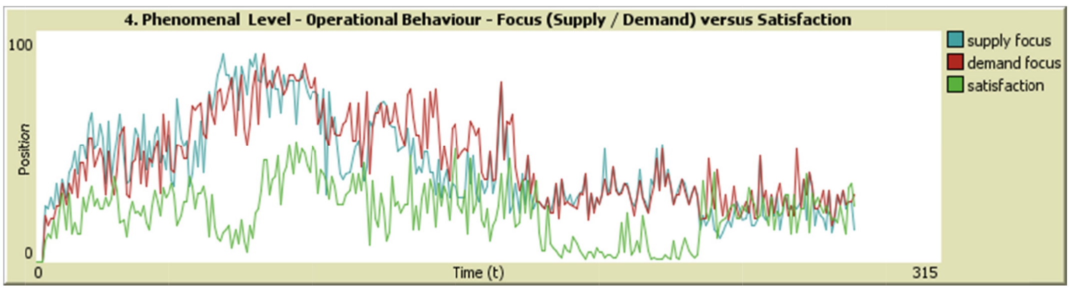


Chart 4: Phenomenal-level, focus versus satisfaction

Operational behaviour at the phenomenal-level is represented in Chart 4 by plotting focus tensions between supply and demand, versus overall satisfaction. When these values are combined in the behaviour space coordinates (x, y, z) they represent operational effectiveness. The simulation results show converging and diverging plots that are nominated as empirical indicators for hypotheses when examined together with phenomena observed in the 3D View (see Figure 32 and Figure 33). They are used for qualitative validation of hypothesised phenomena in sub-section 5.7.

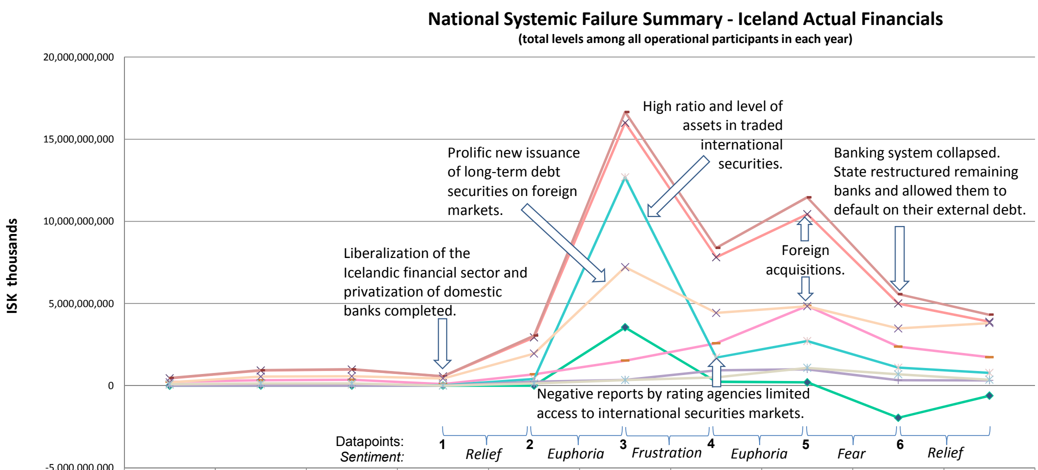
5.6.4 Replication

The final verified and validated simulation experiment can be replicated simply by installing the correct NetLogo version and running the source-code file in NetLogo readable format (.nlogo3d). Installation files and source code are provided on the CD supplied with this thesis (see Appendix I). See sub-section 5.4.2 for further instructions.

5.7 Validation

5.7.1 Objectives

The general approach taken by this thesis to validation is specified in sub-section 3.5.10; whereas this sub-section examines effects that were visible in the interface during simulation, and the results summarised in Table 10.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
tot_profit_act	1,656,700	4,312,100	8,403,100	2,276,100	6,020,600	3,549,845,139	239,599,662	206,412,248	-1,953,841,290	-607,881,900
tot_assets_act	451,393,500	924,935,100	981,676,800	565,522,000	2,939,201,500	15,999,713,336	7,811,197,543	10,435,219,325	4,996,139,748	3,887,703,500
tot_liabilities_act	468,318,500	939,790,100	995,786,700	570,690,500	3,044,863,900	16,654,898,860	8,383,680,300	11,465,867,885	5,574,049,530	4,318,728,400
tot_liquid_act	231,931,800	330,242,100	363,716,300	103,713,500	691,861,200	1,525,669,113	2,581,366,364	4,860,068,189	2,374,534,591	1,734,561,200
tot_securities_act	53,084,900	74,062,800	67,007,000	17,630,800	407,113,000	12,681,175,749	1,712,223,256	2,715,050,572	1,093,228,923	774,386,700
tot_debt_act	202,975,600	557,257,400	572,129,000	437,710,500	1,951,623,900	7,215,230,684	4,429,202,641	4,835,106,317	3,480,337,873	3,811,485,100
tot_loans_act	0	0	0	0	250,700,200	354,177,740	934,168,278	999,915,622	332,978,327	323,283,500
tot_deposits_act	92,725,900	138,312,400	136,906,900	5,807,700	136,177,400	342,577,782	511,286,489	1,081,272,784	688,948,932	362,818,900

Source: Extracted from the reported accounts of all 51 financial institutions in the Iceland database of Bankscope.

Figure 29: Empirical validation datapoints

5.7.2 Quantitative

Simulation results are linked by the 6 datapoints identified in Figure 29 to actual values. They mark year-end reporting for 8 financial variables, and serve as the beginnings and ends of yearly changes in participation sentiment identified by financial analysis during step 7 of the research methodology (see Figure 4). Validation uses these datapoints for reconciling actual and simulated data, by comparing continuously changing simulation values with actual data reported for discrete points in time (i.e. at year end), where 57 ticks are equivalent to one year.

A statistical analysis of experimentation results is presented in Table 10 for quantitative validation. It analyses overall maximum deviations and individual correlations between actual and simulated values for 8 financial variables over six datapoints. Both total and average values are given, to show the effects of differences between numbers of actual and simulated participants.

Variable	Label	Financial Reporting Year (of annual report extracts from Bankscope) 2003	2004	2005	2006	2007	2008	2009				
		Initial simulation values	Simulation Period (represented by 285 ticks) →					Post-simulation				
g-sentiment and 'rules-based tactical response'.	SIPs sentiment and tactical response to overall system challenges *(interpreted from emergent trends in the actual financial reporting data, supported by observations in cited literature. Simulated accordingly).*		***Relief*** following banking de-regulation.	***Euphoria*** generated by securities-driven asset growth .	***Frustration*** over need for securities liquidation due to market denial of debt-financed asset growth.	***Euphoria*** after tactical switch to foreign acquisitions-driven asset growth.	***Fear*** of operational decline.	***Relief*** as the Central Authority intervenes.	Type 1 Bi-Polar Operational Behaviour (see Hypothesis 5).			
year's simulation ends on tick number			57	114	171	228	285		**Time-Series Data Point Deviations** (act versus sim)		**Kolmogorov-Smirnov Test** (N = 6)	
num_SIPs_act	Actual SIPs	22	20	27	27	23	20	13				
num_SIPs_sim	Simulated SIPs	22	21	21	21	21	18	**Pearson Correlation Coefficient**	**Absolute max_dev**	**Absolute max_devp**	**Z**	**Significance** (two-tailed)
		All financial values are in ISK thousands										
Profit	Total …											
tot_profit_act	actual	2,276,100	6,020,600	3,549,845,139	239,599,662	206,412,248	-1,953,841,290	**1.00**			0.873	0.432
tot_profit-sim	simulated	2,288,092	6,181,635	3,385,689,093	249,148,320	197,303,904	-2,028,768,085				0.846	0.471
tot_profit-dev	deviation	11,992	161,035	-164,156,046	9,548,658	-9,108,344	-74,926,795		164,156,046			
tot_profit-devp	deviation%	0.5%	2.7%	-4.6%	4.0%	-4.4%	-3.8%			4.6%		
	Average …											
avg_profit_act	actual	108,386	316,874	136,532,505	9,215,372	9,382,375	-102,833,752	**1.00**			0.809	0.530
avg_profit_asim	adjusted simulation*	108,957	325,350	130,218,811	9,582,628	8,968,359	-106,777,268				0.784	0.571
avg_profit_dev	deviation	571	8,476	-6,313,694	367,256	-414,016	-3,943,515		6,313,694			
avg_profit_devp	deviation%	0.5%	2.7%	-4.6%	4.0%	-4.4%	-3.8%			4.6%		
Assets	Total ...											
tot_assets_act	actual	565,522,000	2,939,201,500	15,999,713,336	7,811,197,543	10,435,219,325	4,996,139,748	**1.00**			0.364	0.999
tot_assets_sim	simulated	565,463,619	3,031,255,287	16,436,266,933	8,000,871,811	10,300,805,545	4,797,072,845				0.398	0.997
tot_assets_dev	deviation	-58,381	92,053,787	436,553,597	189,674,268	-134,413,780	-199,066,903		436,553,597			
tot_assets_devp	deviation%	0.0%	3.1%	2.7%	2.4%	-1.3%	-4.0%			4.0%		
	Average …											
avg_assets_act	actual	26,929,619	139,961,976	615,373,590	300,430,675	474,328,151	262,954,724	**1.00**			0.421	0.994
avg_assets_asim	adjusted simulation*	26,926,839	144,345,490	632,164,113	307,725,839	468,218,434	252,477,518				0.397	0.997
avg_assets_dev	deviation	-2,780	4,383,514	16,790,523	7,295,164	-6,109,717	-10,477,205		16,790,523			
avg_assets_devp	deviation%	0.0%	3.1%	2.7%	2.4%	-1.3%	-4.0%			4.0%		
Liabilities	Total ...											
tot_liabilities-act	actual	570,690,500	3,044,863,900	16,654,898,860	8,383,680,300	11,465,867,885	5,574,049,530	**1.00**			0.334	1.000
tot-liabilities-sim	simulated	568,777,007	3,088,906,629	16,685,274,017	8,249,878,895	11,420,319,044	5,836,406,227				0.307	1.000
tot-liabilities-dev	deviation	-1,913,493	44,042,729	30,375,157	-133,801,405	-45,548,841	262,356,697		262,356,697			
tot-liabilities-devp	deviation%	-0.3%	1.4%	0.2%	-1.6%	-0.4%	4.7%			4.7%		
	Average …											
avg_liabilities_act	actual	27,175,738	144,993,519	640,573,033	322,449,242	521,175,813	293,371,028	**1.00**			0.419	0.995
avg_liabilities_asim	adjusted simulation*	27,084,619	147,090,792	641,741,308	317,303,034	519,105,411	307,179,275				0.448	0.988
avg_liabilities_dev	deviation	-91,119	2,097,273	1,168,275	-5,146,208	-2,070,402	13,808,247		13,808,247			
avg_liabilities_devp	deviation%	-0.3%	1.4%	0.2%	-1.6%	-0.4%	4.7%			4.7%		

Table 10: Summary of validation data for the final simulation

Variable	Label	Financial Reporting Year (of annual report extracts from Bankscope) 2003	2004	2005	2006	2007	2008	Pearson	Absolute max_dev	Absolute max_devp	Z	Significance (two-tailed)
Liquid Assets	Total …											
tot_liquid_act	actual	103,713,500	691,861,200	1,525,669,113	2,581,366,364	4,860,068,189	2,374,534,591	1.00			0.498	0.965
tot_liquid-sim	simulated	103,384,474	690,826,769	1,446,451,674	2,390,728,361	4,979,384,503	2,312,876,789				0.589	0.879
tot_liquid_dev	deviation	-329,026	-1,034,431	-79,217,439	-190,638,003	119,316,314	-61,657,802		190,638,003			
tot_liquid_devp	deviation%	-0.3%	-0.1%	-5.2%	-7.4%	2.5%	-2.6%			7.4%		
	Average …											
avg_liquid_act	actual	4,938,738	34,593,060	63,569,546	112,233,320	255,793,063	139,678,505	1.00			0.418	0.995
avg_liquid_asim	adjusted simulation*	4,923,070	34,541,339	60,268,820	103,944,712	262,072,869	136,051,576				0.447	0.988
avg_liquid_dev	deviation	-15,668	-51,721	-3,300,727	-8,288,609	6,279,806	-3,626,929		8,288,609			
avg_liquid_devp	deviation%	-0.3%	-0.1%	-5.2%	-7.4%	2.5%	-2.6%			7.4%		
Loans	Total …											
tot_loans_act	actual	0	250,700,200	354,177,740	934,168,278	999,915,622	332,978,327	1.00			0.708	0.698
tot_loans_sim	simulated	0	245,375,324	359,320,471	878,666,766	993,576,401	348,927,324				0.688	0.731
tot_loans_dev	deviation	0	-5,324,876	5,142,731	-55,501,512	-6,339,221	15,948,997		55,501,512			
tot_loans_devp	deviation%	0.0%	-2.1%	1.5%	-5.9%	-0.6%	4.8%			5.9%		
	Average …											
avg_loans_act	actual	0	25,070,020	23,611,849	54,951,075	62,494,726	27,748,194	1.00			0.602	0.862
avg_loans_asim	adjusted simulation*	0	24,537,532	23,954,699	51,686,281	62,098,525	29,077,277				0.532	0.939
avg_loans_dev	deviation	0	-532,488	342,849	-3,264,794	-396,201	1,329,083		3,264,794			
avg_loans_devp	deviation%	0.0%	-2.1%	1.5%	-5.9%	-0.6%	4.8%			5.9%		
Deposits	Total …											
tot_deposits_act	actual	5,807,700	136,177,400	342,577,782	511,286,489	1,081,272,784	688,948,932	1.00			0.319	1.000
tot_deposits_sim	simulated	5,801,338	129,829,178	340,840,201	509,252,986	1,075,600,763	674,844,171				0.324	1.000
tot_deposits_dev	deviation	-6,362	-6,348,222	-1,737,581	-2,033,503	-5,672,021	-14,104,761		14,104,761			
tot_deposits_devp	deviation%	-0.1%	-4.7%	-0.5%	-0.4%	-0.5%	-2.0%			4.7%		
	Average …											
avg_deposits_act	actual	387,180	9,726,957	17,128,889	26,909,815	72,084,852	52,996,072	1.00			0.514	0.955
avg_deposits_asim	adjusted simulation*	386,756	9,273,513	17,042,010	26,802,789	71,706,718	51,911,090				0.506	0.960
avg_deposits_dev	deviation	-424	-453,444	-86,879	-107,027	-378,135	-1,084,981		1,084,981			
avg_deposits_devp	deviation%	-0.1%	-4.7%	-0.5%	-0.4%	-0.5%	-2.0%			4.7%		
Debt	Total …											
tot_debt_act	actual	437,710,500	1,951,623,900	7,215,230,684	4,429,202,641	4,835,106,317	3,480,337,873	1.00			0.374	0.999
tot_debt_sim	simulated	437,144,393	1,958,031,151	7,315,991,927	4,333,688,799	4,733,905,672	3,597,576,985				0.415	0.995
tot_debt_dev	deviation	-566,107	6,407,251	100,761,243	-95,513,842	-101,200,645	117,239,112		117,239,112			
tot_debt_devp	deviation%	-0.1%	0.3%	1.4%	-2.2%	-2.1%	3.4%			3.4%		
	Average …											
avg_debt_act	actual	33,670,038	130,108,260	343,582,414	201,327,393	254,479,280	217,521,117	1.00			0.450	0.987
avg_debt_asim	adjusted simulation*	33,626,492	130,535,411	348,380,568	196,985,854	249,152,931	224,848,562				0.406	0.997
avg_debt_dev	deviation	-43,546	427,151	4,798,154	-4,341,539	-5,326,349	7,327,444		7,327,444			
avg_debt_devp	deviation%	-0.1%	0.3%	1.4%	-2.2%	-2.1%	3.4%			3.4%		
Securities	Total …											
tot_securities_act	actual	17,630,800	407,113,000	12,681,175,749	1,712,223,256	2,715,050,572	1,093,228,923	1.00			0.896	0.398
tot_securities_sim	simulated	17,649,488	423,267,494	12,476,793,277	1,707,138,211	2,693,061,723	1,075,837,011				0.894	0.401
tot_securities_dev	deviation	18,688	16,154,494	-204,382,472	-5,085,045	-21,988,849	-17,391,912		204,382,472			
tot_securities_devp	deviation%	0.1%	4.0%	-1.6%	-0.3%	-0.8%	-1.6%			4.0%		
	Average …											
avg_securities_act	actual	881,540	21,427,000	528,382,323	65,854,741	123,411,390	57,538,364	1.00			0.863	0.445
avg_securities_asim	adjusted simulation*	882,474	22,277,237	519,866,386	65,659,162	122,411,896	56,623,001				0.861	0.449
avg_securities_dev	deviation	934	850,237	-8,515,937	-195,578	-999,494	-915,364		8,515,937			
avg_securities_devp	deviation%	0.1%	4.0%	-1.6%	-0.3%	-0.8%	-1.6%			4.0%		
								Overall Absolute Max Deviation %:		7.4%		

* Adjusted for differences in averages calculations between actual and simulated number of SIPs at end of year.

Table 10 (cont): Summary of validation data for the final simulation

In summary, quantitative validation of the final simulation results in Table 10 confirms that simulated values for each of the 8 financial variables at year-end boundaries over the period from 2003 to 2008, when compared as a time-series of data points with their equivalent actual values from the financial analysis of annual reports, all have a Pearson Correlation Coefficient of 1.00 and an overall absolute maximum deviation of 7.4%. As these simulated values are generated at meso-level (also reflected at macro and phenomenal levels), and are derived indirectly in a non-linear way from complex rules-based interactions between participants at micro-level over an extended period of time, they suggest the strategic priority of 'Grow Assets' applied to simulated participation is a reasonable approximation to what actually occurred in the Icelandic failure. This confirms academic commentary from the preliminary financial analysis about possible causes of this particular failure.

Furthermore, changes in the macro-level bar chart over time (not shown here) suggested that the interplay between this lack of diversity in participation strategies versus risk exposures may have been a key operational mechanism of the catastrophic tensions observed. Future research into this effect may confirm the observations of Beale et al (2011).

5.7.3 Qualitative

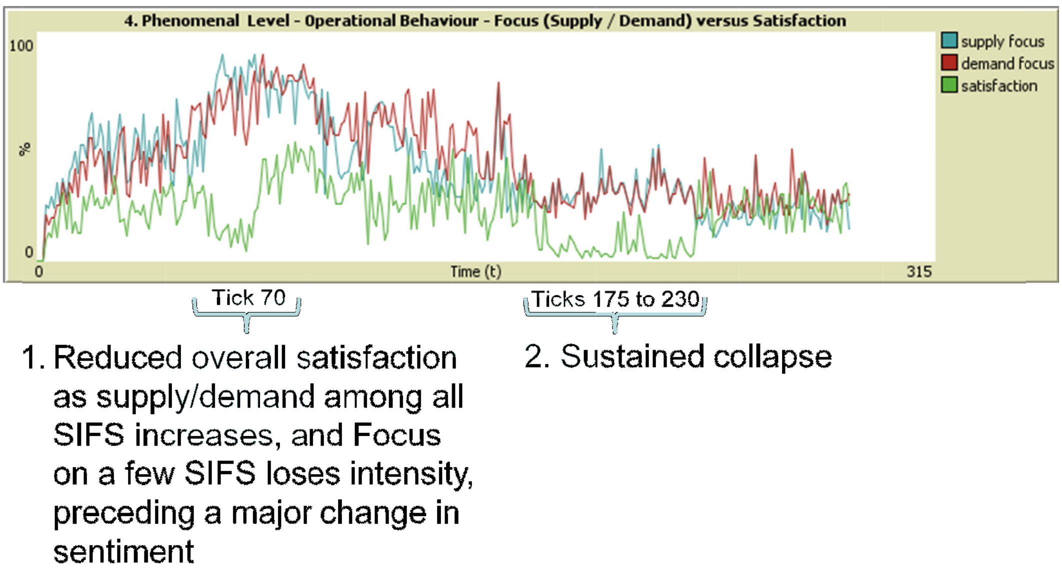


Figure 30: Observed operational behaviour phenomena

At the end of the final simulation, two significant operational behaviours were observed in the phenomenal-level chart of the simulation dashboard (see Figure 30). Around tick 70 a reduction in overall satisfaction preceded a major change in sentiment (see reversal at datapoint 3 in Figure 29). Later, beginning at tick 175, satisfaction collapsed suddenly and bounced along the bottom of the chart for a while. The first behaviour was unexpected, and suggested an extension to proposition 9; whereas the second validated hypothesis 2 with an example of an 'immediate' catastrophic collapse from which the system recovered, until central authority intervention. See theory revision in section 6 for further discussion.

5.7.4 Theoretical Triangulation

5.7.4.1 Principles

In this sub-section, and the following three, the notion of granular pragmatic validity is extended by theoretical triangulation (Denzin, 1970) to corroborate the quantitative and qualitative validations discussed previously by interpreting hypothesised effects through the lens of catastrophe theory (see Figure 31).

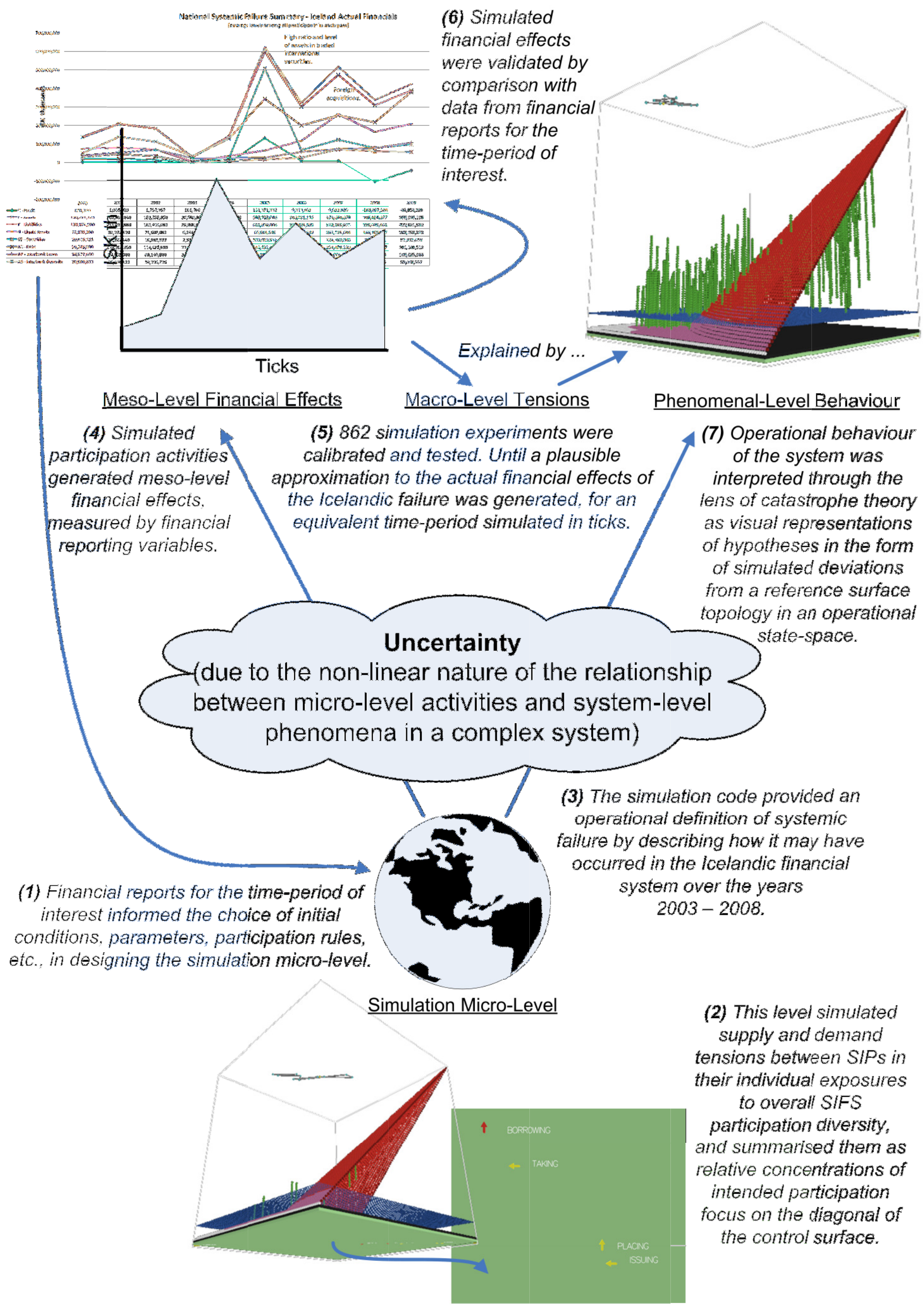


Figure 31: Validation by theoretical triangulation

The computational representation in which the four levels of simulation mentioned in Figure 31 are represented is described in Appendix G. Each of the next three sub-sections explains how simulated effects in the 3D View of that representation were used to corroborate a hypothesis of the proposed theory.

5.7.4.2 Hypothesis 1 corroboration

Empirical indicators of hypothesis 1 were represented by features of a reference manifold (see 5.4.2.2) in the 3D View interpretation of simulation results through the lens of catastrophe theory. Then, as the simulation ran, a clear down-sloping gradient of operational states was observed each time the current operational state approached the region of systemic failure, as predicted. This behaviour confirmed the three coordinates (x, y, z) of the current operational state move in a correlated way as the hypothesis rationale suggested.

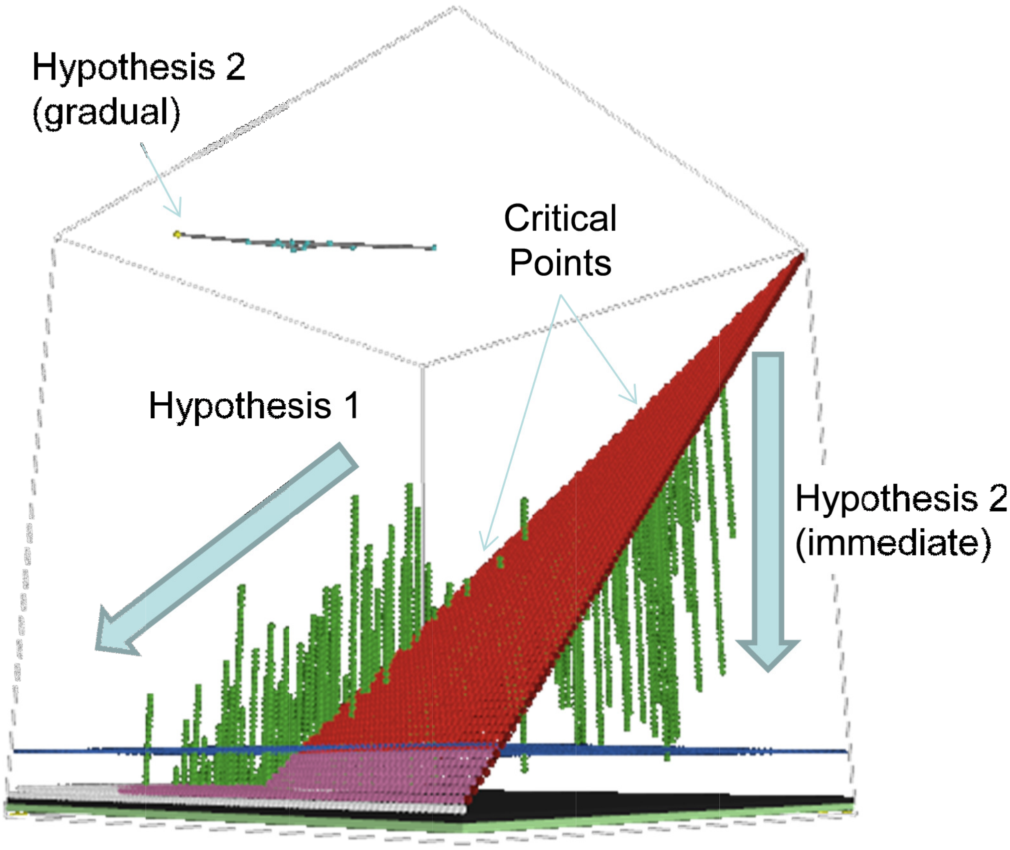


Figure 32: Corroboration of hypotheses 1 and 2

5.7.4.3 Hypothesis 2 corroboration

Empirical indicators of hypothesis 2 were also represented in the 3D View, as for hypothesis 1. Then, as the simulation ran, operational behaviour exhibited catastrophic tendencies resulting in systemic collapse at a critical point on the behaviour manifold, as predicted. At that time, the value of satisfaction either collapsed and then moved down the reference manifold gradually towards the systemic failure region, as the hypothesis rationale suggested, or plunged immediately to zero or near zero for a sustained period of time.

5.7.4.4 Hypothesis 5 corroboration

Empirical indicators of hypothesis 5 were also represented in the 3D View, as for hypothesis 1. Then, as the simulation ran, a loop pattern was observed in operational behaviour around a critical point on the reference manifold that appeared to be induced by operational feedback close to the cusp, as predicted. The cusp was represented by varying degrees of drop in actual satisfaction levels, suggesting a cusp fold discontinuity at those points.

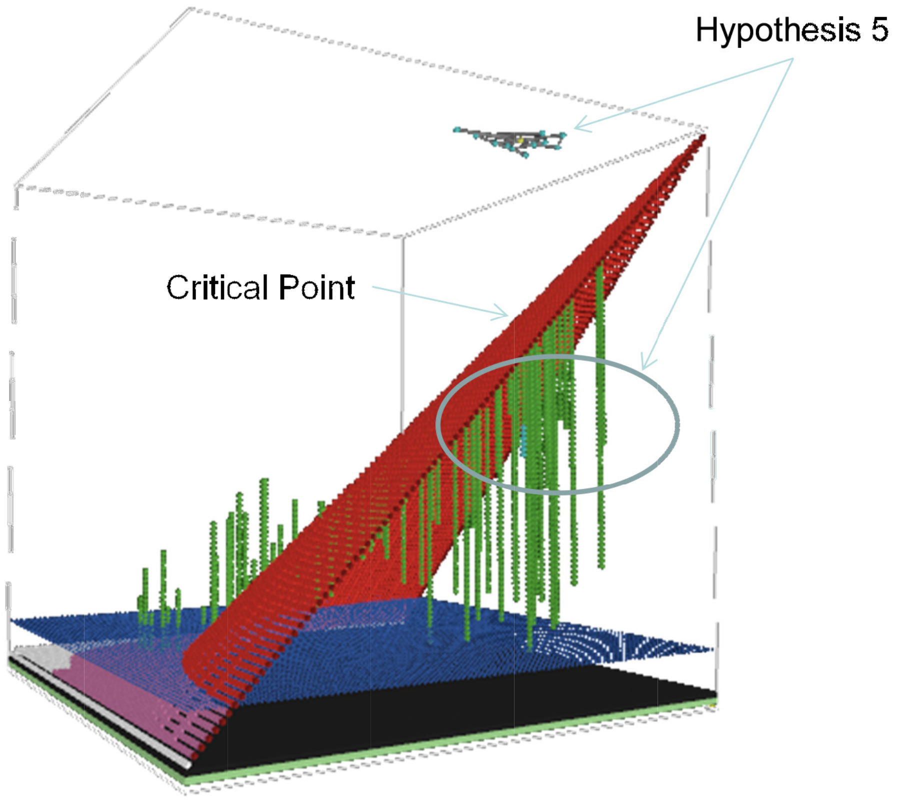


Figure 33: Corroboration of hypothesis 5

5.7.5 A New Conjecture

As phenomena observed in Figure 32 and Figure 33 unfolded, the interplay mentioned in sub-section 5.6.3.3 between a lack of diversity in system participation strategies and shared exposure to potential losses as the system approaches a state of systemic failure in the macro-level dynamic bar chart confirmed this may be a key operational mechanism of catastrophic tensions arising in the supply and demand of financial services. Theory revision in section 6 refers to these observations, and adds a new conjecture to the proposed theory, for validation in future research.

5.7.6 Outcome

After a series of 862 simulation experiments to refine the model's efficacy and improve its results correlation to actual data for the period of interest, attention turned to confirming the null hypothesis that the theory's predictions would not be present. A diagnosis of circumstances in which failure arises in a final simulation experiment that uses this refined computational representation, verified with the proposed theory, then refuted the null hypothesis by showing that a particular set of initial conditions, parameters and rules of participation is capable of generating financial results and emergent phenomena that are highly correlated with actual data, and corroborated by theoretical triangulation with catastrophe theory. It is therefore argued in this thesis that: if alternative sets of parameters and rules, verified with the proposed theory, are shown in future research to also be capable of simulating an approximation of the observed financial effects from the same initial conditions; generating similar emergent operational phenomena corroborated by theoretical triangulation in the same way; they would comprise a solution set of sets that suggests the proposed theory's hypotheses about real financial systems may be valid in more general circumstances. Furthermore, by altering certain configuration parameters of future simulations it should also be possible to generate hypothesised phenomena from the same rules of participation without failure arising, offering further insights for systemic risk mitigation in such systems.

5.8 Critical Assessment

Due to the apparent intractable nature of the research question addressed by this thesis, the scarcity of data for empirical validation, and nonlinear aspects of satisfying its goal assertion, theory testing and validation required an innovative approach. The approach selected was based on realist constructivism combined with agent-based model simulation for the reasons explained; and wherever practical, the expectations of that approach were satisfied according to advice found in the literature. Furthermore, although the goal assertion carefully positioned potential contributions of this thesis on the relevance side of the rigour/relevance debate, this approach nonetheless attempted to maintain rigour in its widest sense, implying thoroughness in the pursuit of relevance. Therefore, the outcome of research is argued by this thesis to have satisfied its goal of making a significant contribution to theory, supported by findings validated according to latest understanding about how to address such research challenges. However, only the first step on a long journey can be claimed to have been made. Much research remains to be done before the proposed theory is shown to be generally applicable, although the outcome presented here is argued to offer a significant contribution to the foundations of that work.

6 THEORY REVISION

6.1 Simulation Experiment Findings

6.1.1 Improvements

Observations made during project 3 of the methodology (see Figure 4) suggested certain amendments and additions to the proposed theory, which are addressed here in the revision section of this thesis together with potential risk mitigation opportunities. They do not materially affect outcomes reported in the previous section, but offer improvements which can be explored in future research. Revising the proposed theory in this way expounds an outline of new theory into a completed theory satisfying the goal assertion of this thesis.

6.1.2 Observations

The following three observations were made over a complete series of 862 simulation experiments. They are not presented in any particular order, but are listed here for reference in following sub-sections.

6.1.2.1 Systemic failure occurrence

Entering a region in the behaviour manifold centred on its origin-coordinates which signifies systemic failure is not the only way to induce that operational state. Figure 32 observes there can be both gradual and immediate shifts into that state. A horizontal criticality plane was therefore added to the 3D View (i.e. the blue plane not originally shown in Figure 18 of the theoretical model), introducing a vertical boundary for satisfaction values, below which the danger of failure is recognized to have become severe. Therefore, in addition to a partial collapse followed by a bounce and gradual decline towards the origin of the behaviour space, systemic failure can also occur vertically through operational states with zero or near zero values of satisfaction.

6.1.2.2 Predicting a change in sentiment

A large fall in satisfaction values observed in Figure 30 preceding a change of sentiment in Figure 29 suggests there may be a predictive relationship between the two phenomena of relevance to risk mitigation efforts.

6.1.2.3 Exposure and Diversity

The interplay between levels of exposure and diversity in collective participation observed in the dashboard's macro-level bar chart, and the dominance of each at particular times under different conditions and sentiments, may offer new risk mitigation potential that can be tested in future research.

6.1.2.4 Implications

Observation 6.1.2.1 indicates experimental support for a proposition extension, while 6.1.2.2 and 6.1.2.3 suggest a new conjecture for further research.

6.2 Extended Proposition

6.2.1 Proposition 13: A definition of systemic failure (extended)

If the satisfaction coordinate z of operational effectiveness drops immediately to a value of 0, or comes down to that value more slowly and eventually lands on the control surface outside the region F_v^{fail} at a time v, the operational state with those coordinates $(x, y, 0)$ is also considered to be a failed current state such that:

$$\xi_v := \left\{ \text{Current}(B_v, \tau, \gamma, \varphi) \in \mathcal{B}_v \,\middle|\, \text{Region}\left(b_v^{(x,y,0)}, \tau, \gamma, \varphi\right) = \rho_4,\ v \in T \right\}. \quad (29)$$

In other words, the entire control surface is an extension of the region F^{fail} for coordinates with $z = 0$. Furthermore, a horizontal plane at some value $z > 0$ can serve as a criticality threshold π, to define satisfaction as being critically low.

6.3 New conjecture

6.3.1 Conjecture 9: Predicting change in systemic risk of failure

Even though proposition 11 outlines a practical definition of systemic risk of failure based on expression 23, quantifying its element of uncertainty remains a challenge for predictive calculations. However, the simulation experiment findings presented in sub-section 6.1 suggest that an operational perspective on how systemic risk occurs may be useful for indicating whether it is likely to increase or decrease, and by how much. A precise probability with its uncertainty qualifier may still be beyond reach, but a combined directional and velocity indicator may be feasible. For example, observations 6.1.2.2 and 6.1.2.3 showed that after a prolonged period of intense participation in a subset of products, during which overall satisfaction values remained low, interplay between overall diversity and exposure intensified before a major reversal in sentiment. Further research may find this particular operational behaviour holds true in general as a mechanism of distress propagation, for which another conjecture is offered:

Conjecture 9 summary – An improved understanding of how participation intensities interact with overall focus diversity, exposure and sentiment can indicate the direction and velocity of change in systemic risk of failure for practical risk mitigation purposes over short and medium range time periods.

6.4 Further research

Conjecture 9 opens up the potential for quantifying systemic risk in some way suitable for policy guidance. This could be achieved by extending the computational representation developed in this thesis to simulate new properties of the trajectory of operational behaviour. Then experimentation could show how proposed techniques for predicting this trajectory at the phenomenal level (having a nonlinear relationship to micro-level participation) perform when initial conditions, values and parameters of Iceland's systemic failure are varied to generate different outcomes. If these techniques perform well, then a simulation tool that calculates the direction and velocity of change in systemic risk of failure for the global financial system could be used in risk mitigation until mathematical techniques mature sufficiently to predict its probability more accurately.

7 DISCUSSION

7.1 The Theory in Current Events

Since submission in 2011 of the original paper on which this thesis is based, and its subsequent presentation at the Global Finance Conference in May 2012, the systemic crisis of 2008 has moved through several phases of emergent operational behaviour involving varying degrees of systemic risk of failure. In what the IMF (2011) refers to as the bank-sovereign feedback loop, the balance between instabilities swung towards increasing risk of multiple sovereign defaults in 2011/12. This was distress propagation on a grand scale, impacting all types of financial institutions and systemically exposed counterparties. Bipolar operational behaviour intensified throughout the global financial system as temporary fixes proved increasingly ineffectual until some massive mitigation initiative, such as another global round of quantitative easing, or the financial bailout of a Eurozone member, once again flipped the catastrophe fold to buy a little time.

In more recent phases there have been many repeating cycles of this bipolar operational behaviour of the global financial system, emerging from a currency crisis centred on the Euro, and a succession of failures among countries including Ireland, Portugal, Spain, Italy, Greece and Cyprus, arguably arising as operational tensions. For example, the Cyprus government allowed its financial system to become so big that figures show banking assets reached 800% of GDP in 2011, which is very reminiscent of Iceland at the end of 2007 . Eurozone politicians who did not understand what they were doing pressurized Cypriot politicians, who knew even less, to respond hastily. They, in turn, leant on Cypriot bankers to inflict losses on deposits, thereby breaking depository guarantees and raising the potential for bank runs throughout that island and well beyond in similarly weak Eurozone economies, providing a clear example of how easy it is to push the entire global financial system over the edge into disaster.

At the time of writing this final thesis, systemic risk of failure appears to have lessened. However, history shows that situation will not continue indefinitely. If another perfect storm develops in the future, will the resources, political support and understanding be available to avert it? More importantly, what additional systemic risk mitigation is there, capable of moving operational behaviour completely away from the cusp of catastrophe? The proposed theory suggests that any lasting solution (until the next crisis) must directly address emergent phenomena in the system through selective interventions in the operational behaviour of systemically important participants (SIPs) by a central authority with sufficient power, expertise and funding. However, care must be taken to avoid unintended consequences that can increase systemic risk.

For example, when the European Central Bank responded to the Eurozone crisis in December 2011 by providing *"… euro 489bn in unprecedented three-year loans to more than 500 banks across the region"* (Alloway and Atkins 2011) without staggering repayment schedules and ensuring the proper use of those funds, ahead of a crucial round of government debt refinancing, it was stimulating a classic concentration of focus in the supply and demand of SIFS. By allowing banks to use this money as they wish, a new threat was created where some banks could ignore refinancing their existing assets in favour of buying higher yielding assets such as more of the sovereign debt that got them into trouble to begin with. If enough of the 500 banks did this, the proposed theory suggests overall operational effectiveness of the global financial system would have been further compromised, and systemic risk would have continued to increase. At the very least a new synchronicity effect would have been created, where many banks would simultaneously require re-financing at similar times in the future, with unknown consequences.

7.2 Implications for Systemic Risk Mitigation

New opportunities for a contribution to practice in systemic risk mitigation arise from this theory by using the correlation between focus and satisfaction from hypothesis 1 to improve and maintain stability in the global financial system. While continuing with the existing practice of introducing new regulations that address perceived causes of the latest crisis to reduce the risk of their recurrence, it would be possible for regulators to manage emergent operational behaviour by dispersing focus (see conjecture 7) and improving overall operational effectiveness to ensure that distress is unable to propagate. Macroprudential initiatives aimed at directing operational behaviour, along with the introduction of suitable regulatory compliance obligations to provide the necessary data for oversight, could change the current reactive stance of crisis intervention to one that is more proactive and pre-emptive. For example, regulatory instruments incorporating the principles of this theory, or derivative models, could be used in monitoring distress as it propagates and simulating intervention effects to identify appropriate actions. These might include creating disincentives for growth in concentrations of participation involving certain SIFS, or using funds that would otherwise be employed in quantitative easing in addressing gaps in demand or supply. Naturally, any such macroprudential initiatives must be aimed at system-wide effects, globally. Otherwise any sub-systemic response would likely be sub-optimal in its effects, potentially becoming a new source of systemic risk.

7.3 Policy Guidelines

Pre-emptive regulation is consequently argued to require improved operational transparency from system participants, and prompt visibility of data about their operational behaviour, in order to prevent positive feedback inducing a failure of the system to operate within required parameters. This translates into changes and additions to policy, which in turn call for new regulatory practices. The policy and practices recommendations of this thesis are:

i. Operational performance parameters should be identified, communicated, and required to be maintained by systemically important participants; and performance confirmation data should be provided by them; to enable constant prudential monitoring of the system's operational behaviour; and continual updating and publication of operational behaviour assessments of the global financial system and all regional and national financial sub-systems; for all system participants.

ii. Then a policy of pre-emptive operational intervention must be assigned ownership among senior regulators, for ensuring positive feedback from emergent operational behaviour is prevented from inducing a failure of the system to operate within the parameters established in policy ‘i’.

8 CONCLUSIONS

8.1 Plausibility Assessment

The outcome of theory development is presented, from research into a gap in knowledge about how systemic risk arises and materializes in the global financial system. It takes a systems-theoretic approach (Dubin, 1978), incorporating a simulation-constructivist orientation towards the meaning of theory and theory development (Davis, Eisenhardt and Bingham, 2007), within a realist constructivism epistemology for knowledge generation about complex social phenomena (Crnkovic, 2010).

An assessment of the proposed theory's plausibility refers back to the following:

Research Question ***"How does instability of the global financial system become operationally catastrophic, and how could that outcome generally be avoided?"***

Goal Assertion ***"To describe how instability of the global financial system becomes operationally catastrophic, and explain that operational behaviour, in order to diagnose when it approaches a state of operational crisis and understand how that outcome could generally be avoided"***.

Null-Hypothesis ***"A plausible (verified and empirically validated) simulation of a real financial system collapse, corroborated by theoretical triangulation with catastrophe theory, will not confirm the predictions of hypotheses 1, 2 and 5."***

An original research question gave rise to a narrower-scoped goal assertion, adapted from suggestions in multiparadigm perspectives on theory building for organizational studies (Gioia and Pitre, 1990), 'to describe and explain in order to diagnose and understand.' That places this mixed-methods research on the relevance side of the rigour/relevance debate (see 'evaluating mixed methods', Creswell and Plano Clark, 2007: page 162). Nonetheless, it also responds to the call for more rigour in agent-based simulation as an experimental method (Bankes, 2002).

In this context, research results show there is a non-empty class of computational representations, verified with the proposed theory (see sub-section 5.5); that confirms the predictions of hypotheses 1, 2 and 5 by simulation experiment results (see sub-section 5.6.3); which are empirically validated by data from Iceland's financial system failure (see sub-sections 5.7.2 and 5.7.3); and further corroborated by theoretical triangulation with catastrophe theory (see sub-section 0); to demonstrate a 'granular' form of pragmatic validity (Worren, Moore and Elliott, 2002; Davis, Eisenhardt and Bingham, 2007). Therefore, the null-hypothesis is refuted by demonstrating the proposed theory is a plausible description and explanation for how systemic failure may have been operationalised in the specific real world case of Iceland.

General applicability of this theory would require further demonstration of its plausibility for other cases of systemic failure, including failure of the entire global financial system. However, thankfully, there are no other cases in recent history that can be taken as reasonable examples of modern operational practices in the financial services industry.

Nonetheless, useful propositions are offered in this thesis for policy guidance in diagnosing when the global financial system is approaching a state of operational crisis, and understanding how that outcome could generally be avoided.

8.2 Limitations

8.2.1 Use of Catastrophe Theory

Although much progress has recently been made by the field of mathematical topology in exploring how shapes can be used to visualize how an entire multi-dimensional dynamical system behaves as a single entity, this thesis has chosen to apply the 'Big tent' notion of complexity (Rosser Jr, 2009; Rosser Jr, 2000) encompassing a dynamic definition based on non-axiomatic foundations. This is argued in bifurcation theory to be the most promising approach to addressing structurally stable, generic singularities of dynamical systems (Rosser Jr, 2000). Within that notion, catastrophe theory is considered by this thesis to offer the best fit with its constructivist interpretation of the operational behaviour paradigm for systemic risk of failure. However, a lack of axiomatic foundations may limit the potential for developing mathematical predictions.

8.2.2 Findings emphasis on final simulation

Empirical validation of the theory is based solely on the data generated by the final simulation of a series of 862 simulation experiments conducted for calibration and testing. This is considered justifiable because the size and medium-scale of simulation complexity attempted by this thesis is argued in the literature to require a departure from the normal standards of small-scale simulations (Post and Votta, 2005), in which results were previously validated by many simulation runs using different initial conditions and run parameters.

8.2.3 Simulated time steps

An important consequence of the single-run validation mentioned in the previous sub-section is that findings are based on only one number of ticks used to interpret the time-steps of a simulation (i.e. 57 ticks equate to a simulated elapsed time of one year). Although the tick equivalence selected for validation was determined by the 862 calibration and testing experiments of this thesis as being optimal, as confirmed by corrolation statistics, further research would benefit from exploring the effects of using other values to see how the validation results may vary.

In general, when simulating economic systems in this way, the choice of time steps and tick equivalence is driven by the granularity of the phenomenon being observed. For example, if a systemic failure can occur within one or two days then the number of ticks simulated per time step should be sufficiently large for the failure to be observed over that time. In the case of 57 ticks per simulated year, any phenomenon that takes less than one week would not be observable. However, calibration and testing experiments demonstrated the phenomenon of interest to this thesis did indeed appear within the selected timeframe.

8.2.4 Price Theory relevance

The operational behaviour paradigm of systemic risk of failure explains how shifts in focus between the supply and demand of financial services influence the operational effectiveness of the global financial system. Participation is modelled as bids and offers on a 'global exchange', where trading occurs in aggregate values and aggregate profits or losses are simulated by random allocation rules. This makes pricing theory irrelevant, and the simulation of pricing activity becomes unnecessary.

8.3 Contributions

8.3.1 Overall Impact

The claimed multi-disciplinary contribution of theory adds to economic thinking evolving out of a combination of neoclassical and other less orthodox work, described by Holt, Rosser and Colander (2011) as comprising a shift to *"the complexity era in economics"*. The theory applies philosophical insights from risk literature, notions of uncertainty from information science and physics, a perspective on change from evolutionary economics, insights about dynamical systems and catastrophes from complexity science, and combines them with a new operational behaviour paradigm, to open new conversations in the literatures of risk and behavioural economics.

In particular, it explains how systemic failure arises in the operations of the global financial system, which is used as the basis for an improved definition of systemic risk of failure incorporating an interpretation of entropy as risk uncertainty. However, it does not specify how that risk may be calculated, or how systemic failure may be predicted. Nonetheless, it discusses opportunities for future research to do so by building on these foundations.

8.3.2 Contribution to Theory

8.3.2.1 A new paradigm

An operational behaviour paradigm of systemic failure is introduced for the global financial system, extending current theory about systemic risk of failure to explain how instability becomes operationally catastrophic, and how that outcome could be avoided (see Figure 1). It uses the notion of operational distress from proposition 12 to explain how execution-level supply and demand activities of collective participation behaviour emerge as operational behaviour at system level, potentially leading to systemic failure, encapsulated in the transformation:

$$\text{Distress: Conditions}(\mathit{\Delta}_{t+1}) \ \mapsto \text{Current}(B_{t+2}, \tau, \gamma, \varphi), \tag{26}$$

(see full explanation in sub-section 4.9.5).

8.3.2.2 A definition of systemic failure

Explanation of that paradigm begins with a series of propositions leading to a definition of systemic failure in proposition 9, outlined as:

$$\text{Ⅎ}_t \coloneqq \left\{ \{\xi_{v,}\xi_{v+1,} \dots, \xi_{v+(\mu-1)}\} \,\middle|\, \xi_t \in \text{Ⅎ}_t,\ v \in T,\ \mu > 1,\ t = v + (\mu - 1) \right\}, \tag{19}$$

(see full explanation in sub-section 4.9.2).

8.3.2.3 A formal definition of entropy in systemic risk

Then applying the concept of entropy to the uncertainty implicit in any determination of the probability of systemic failure over some useful future time-span, produces the new interpretation:

$$\text{Entropy}(p_{t:u}) \ = \ - \sum_{i=t+1}^{u} p_t^i \log p_t^i. \tag{22}$$

(see full explanation in sub-section 4.9.4).

8.3.2.4 A formal definition of systemic risk of failure

Ultimately, this leads to the proposal of a probability metric for systemic risk of failure incorporating entropy as a measure of uncertainty, expressed as:

$$\text{Risk}(\text{Ⅎ}_u, t) \coloneqq \{\, p_t^u, \text{Entropy}(p_{t:u})\}, \tag{23}$$

(see full explanation in sub-section 4.9.4).

Although this definition satisfies the thesis goal assertion of describing and explaining systemic risk of failure, calculating a precise probability with its uncertainty qualifier is still be beyond the reach of nonlinear mathematical analysis. However this thesis suggests that a combined directional and velocity indicator of that risk may be feasible if it is based on simulated predictions.

8.3.2.5 Relevance to the programme research problem

The main contributions to theory summarised in the preceding sub-sections are operationalised in a way that can be traced back to the programme research problem by refuting a null hypothesis, and linking hypothesised predictions to a goal assertion derived from that problem (see sub-section 8.1).

8.3.3 Contribution to Practice

8.3.3.1 A practical definition of systemic risk of failure

For practical purposes, the formal definition in expression 23 can be restated in less formal terminology as: *"a measure of the overall probability at a current time of the system entering an operational state of systemic failure by a specified time in the future; qualified by a measure of uncertainty determined by the system's entropy for a series of probabilities about a succession of future operational states considered to be (e.g. by simulation) capable of that outcome by the specified time; in the absence of new mitigation efforts"*.

8.3.3.2 Recommended changes to practices

Macroprudential tools incorporating the principles of this theory, or derivative models, could be used in monitoring distress as it propagates and simulating intervention effects to identify appropriate actions. These might include creating disincentives for growth in concentrations of participation involving certain SIFS; or using funds that would otherwise be employed in quantitative easing in addressing gaps in demand or supply; or influencing the interplay between diversity and exposure. Naturally, any such macroprudential initiatives must be aimed at system-wide effects globally, otherwise any sub-systemic response would likely be sub-optimal in its effects, potentially becoming a new source of systemic risk.

8.3.4 Contribution to Policy

Macroprudential oversight is therefore argued to require improved operational transparency from system participants, and prompt visibility of data about their operational behaviour, in order to prevent positive feedback inducing a failure of the system to operate within required parameters. This translates into changes and additions to policy, which in turn call for new regulatory practices. The policy and practice recommendations of this thesis are:

i. Operational performance parameters should be identified, communicated, and required to be maintained by systemically important participants; and performance confirmation data should be provided by them; to enable constant prudential monitoring of the system's operational behaviour; for continual updating and publication of operational behaviour assessments of the global financial system, and regional or national financial sub-systems; for the benefit of all system participants.
ii. Then a policy of pre-emptive operational intervention should be assigned ownership among senior regulators, for ensuring positive feedback from emergent operational behaviour is prevented from inducing a failure of the system to operate within the parameters established in policy 'i'.

8.4 Research Implications

8.4.1 Economic theory

An evolutionary economics theory of the type outlined in this thesis takes a constructivist approach to modelling the global financial system as a behavioural topology for an operational behaviour paradigm, derived from the participation actions of a simple set of agents, with operating parameters and rules. While it does not intended to explain the full richness of that system's nature, the theory does aim to throw some light on how systemic failure materializes out of systemic risk in the way the system operates.

The implications of this foundational research are nonetheless broad in scope, offering the potential for advances in understanding how the global financial system operates as a dynamical complex system by stimulating improvements in related areas of research such as the realism of simulations, and helping to focus developments in nonlinear mathematical analysis on new properties of emergent phenomena observed during experimentation.

8.4.2 Wider Applicability

However, the theory may also have applicability to a wider class of systems in economics and other disciplines for which catastrophe theory is similarly relevant, such as the operational behaviour of medical aid distribution systems during an epidemic, the practicalities of services provision in social systems under distress, the behavioural effects of world population demographics on economic systems, or the potential effects of incursions in large-scale military command and support infrastructures. The strengths of the proposed new theory are in its concise treatment of the complexities of systemic risk, its use of an operational paradigm of supply and demand, its focus on isolating and outlining the mechanism of distress propagation instead of attributing causality, and its end objective of identifying new opportunities for systemic risk mitigation. Furthermore, it is not limited to the causes and effects of specific events from the past, and the theory's suitability for computational methods of research is useful for aligning with new ways of addressing this intractable problems. With insights from multiple academic disciplines embedded in the theory's model, there can furthermore be a reasonable expectation for generalizations to be discovered that are applicable to cross-disciplinary fields such as critical phenomena and behavioural science.

8.5 Further Research Opportunities

When looking back to the stated purpose of this research in sub-section 1.2, this thesis feels able to conclude that significant success has been achieved. A better explanation of systemic risk of failure is contributed to current understanding, along with more clarity in response thinking.

Although, given the normal slow rate of adoption of new thinking in the global financial services industry amongst regulatory authorities and those they regulate, it seems unlikely that the benefits of this research will be realized quickly. It will take a concerted and organized promotion of the concepts presented here, translated into a form that is acceptable to practitioners, before any benefits they offer for improved global financial stability can be realized over the medium-to-long term. Even so, further academic research would enhance those prospects tremendously, until the next crisis inevitably focuses practitioner attention.

Larger and more realistic simulations probably offer the greatest potential for improvements in systemic failure predictions, much as they have already improved weather forecasting. In this 'complexity era' of economics, they can address the need to explain how various types of unexpected behaviour emerge in economic systems and the consequences of ill-considered responses, and generate exciting new opportunities for research. Ironically, perhaps the most likely short-term benefactors of this research would be other industries. For example, the defence industry has an urgent need to understand the potential systemic impacts of cyber attacks on vulnerable organizations and infrastructures during bouts of cyberwarfare (Osawa, 2013). The direction of future research based on this thesis would answer many of those questions.

8.6 Summary

In response to the research problem of project 1, this thesis describes how a gap in theory identified in project 2 was addressed in projects 3 and 4 by showing how an operational behaviour perspective on complexity theory and evolutionary economics can provide useful insights for outlining a new general theory of systemic risk of failure and its mitigation for the global financial system, capable of unifying and clarifying existing concepts of that risk.

Explanations based on the findings of simulation experiments are offered for how it may be possible to recognize, avoid and respond to potential failures of this system wherever they may emerge in the future. Although further research is recommended for remaining questions about predictability, the fecundity and generalizability of the theoretical model presented is argued to be evident in the results obtained so far.

It is therefore the overall conclusion of this thesis that the theory presented offers a credible contribution to current understanding, by advancing theory in this field of knowledge, and supplementing existing policy guidance for systemic risk mitigation.

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(core contributions are in **bold**, and exploratory contributions are <u>underlined</u>).

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APPENDICES

Appendix A. AWARD

Global Finance Conference

19th Annual Global Finance Conference

Hosted by DePaul University | Chicago, IL, USA

• Best Paper Award •

Paper Title:

An evolutionary theory of systemic risk and its mitigation outlined for the global financial system

Presented to:

PhD Student Thomas Ilin

Manuchehr Shahrokhi, PhD
2012 GFC Program co-Chair

Karim Pakravan, PhD
2012 GFC Program co-Chair

Appendix B. LITERATURE REVIEW METHODOLOGY

B.1 Process

Project 1 of this programme of research implemented the first three stages and seven steps of the prescribed Cranfield University process for a systematic review of literature (see Figure 34 below), within a customized review methodology (see Figure 6). The following sub-sections outline each step, and the review protocol of Appendix C provides further detail.

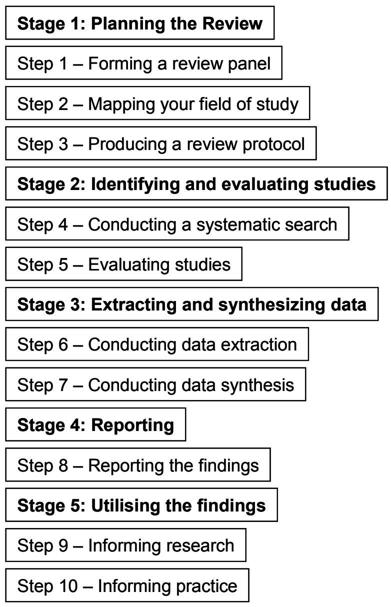

Figure 34: The Cranfield Systematic Review of Literature Process

B.2 Artefacts

A review methodology is a set of methods, techniques and tools selected for implementing a review process. It describes the way they can generally be used together in producing planned outcomes. Whereas, a protocol pre-determines the details of how a particular review will be conducted using that process and methodology, and specifies the type and nature of planned outcomes. This appendix provides a generic overview of the process followed. Then the protocol is outlined in Appendix C, and Appendix D describes how the systematic review was actually conducted.

B.3 Implementation

Output from the scoping study formed the primary input to the methodology, for use in review process steps such as: mapping the field of study and producing a review protocol. The top swim-lane of Figure 6 shows that input feeding into the protocol at flowpoint 1. In a similar way, each step of the systematic review process has equivalent features in the methodology. The next two swim-lanes show how literature is searched, collected, organized and screened to produce a set of approved contributions. A complete audit trail is maintained, with summary statistics (see Table 2) organized by retention criteria, for tasks T2 to T4 in the methodology. Then approved contributions are evaluated against quality criteria in task T4, and excluded or graded; and subsequently selected for data extraction and synthesis in tasks T5 and T6, also with a complete audit trail. Finally, in task T7 analysis is performed on the data extracted, and synthesis results are assimilated for subsequent interpretation.

The methodology diagram in Figure 6 also shows the technology environment used to implement this review, along with actual results statistics. It was the first design artefact produced by the project, and provides an overview of the process to be followed, methods to be applied, and tools to be used in sufficient detail that, when combined with further explanations in the following sections, also shows how to replicate, verify and independently assess the plausibility of literature findings presented in this thesis. Apart from general functionality available on a personal computer running Microsoft Office applications under the Windows operating system, with an internet browser and broadband internet access, the implementation also used: RefWorks 2.0 for bibliography collection and management; NVivo9 to organize, analyse and visualize the literature; and JabRef for reference formatting. The university library's Shibboleth on-line literature search facility provided access to academic databases, and occasional use of

GOOGLE Scholar enabled ad-hoc searches for supplementary material such as missing full-text versions of papers and grey literature.

A full set of reference data about articles gathered has been retained, and is available as soft-copy in the formats of the tools used (provided on a companion zip-file submitted with this thesis). This can be used for literature results verification if required. In addition, complete reference lists for all core and selected literature contributions reviewed are given in the reference section of this document. The following sub-sections describe steps 1 to 7.

B.4 Steps

B.4.1 Step 1: Forming the Review Panel

The first step in the Cranfield Systematic Review Methodology requires that an academic review panel is established for the review process. This panel provides the necessary oversight and guidance to ensure the quality of research produced, and its relevance.

Person	Title / Organisation	Involvement
Prof. Joe Nellis	• Director of School of Management • Director of Policy, Strategy & Performance Community • Professor of International Management Economics	• Co-Supervisor • Sense check on output at each stage • Economics Literature • General guidance
Dr. Liz Varga	• Director, Complex Systems Research Centre • Senior Research Officer	• Co-Supervisor • Sense check on output at each stage • Complex Systems Literature • Computational Modelling Practicality • General guidance
Dr. Colin Pilbeam	• Senior Research Fellow, Management Research	• Panel Chairman • Research Evaluation • Systematic Review methodology
Heather Woodfield	• Kings Norton Library • Cranfield	• Library support

Table 11: The Review Panel

After the scoping study, the proposal for this systematic review of literature was discussed by Cranfield University faculty members of the School of Management. Initially, Prof. Alan Harrison assumed the Lead Supervisor role, with Dr. Colin Pilbeam taking the Panel Chair, and Dr. Liz Varga taking the additional Panel Member role. Prof. Joe Nellis later kindly agreed to take on a subject matter advisory role. Then, after the retirement of Prof. Harrison, Prof. Nellis and Dr. Varga agreed to jointly assume the supervisory role as Co-Supervisors. Heather Woodfield also agreed to provide library support.

The Review Panel so formed advised on all matters of review procedure, conducted panel meetings to examine progress, and generally supervised the direction of this research. In regards to matters such as Protocol development, they were also actively involved in challenging and guiding the nature of its contents, and fulfilling the role of research observers to ensure the claims made by this systematic review of literature were consistent with Cranfield University's Systematic Review Process and standards. While performing their assumed duties, they nevertheless showed every personal kindness and consideration for the conflicting academic and professional demands on this researcher's time.

B.4.2 Step 2: Mapping the Field of Study

The boundaries, findings, conclusions and proposals of the scoping study paper preceding this review are assessed in this step.

In that study, a general business issue is used to: scope, search and collect a literature sample; identify the central and peripheral contributions to addressing that issue; draw a venn diagram of the in-scope domains and themes of literature (see see Figure 8); select the most important contribution of literature for each overlapping area in that diagram (see Table 12); analyse the research approaches and philosophies in this sample (see Table 13 and Table 14); identify and appraise the topics of research conversation found, and develop assertions about a gap in knowledge related to the business issue (see Figure 35); conceptualise that gap (see Table 15); and build a categorisation of the significant conversations at the boundaries of knowledge about that gap (see Table 16). Finally, out of this set of artefacts a literature hypothesis, research focus, and research problem are developed.

Domains {Themes}	**Literature number / reference**
4 {(a∩b)\c}	1. Acharya, Viral V. (2009) "A Theory of Systemic Risk and Design of Prudential Bank Regulation", *Journal of Financial Stability*, 5, pp 224-255
1+3 {(a∩b)\c}	2. Arthur, W. Brian (2006) "Out-of-Equilibrium Economics and Agent-Based Modelling", In *Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics*, K. Judd and L. Tesfatsion, eds, Chapter 32, pp 1551-1564
3+1 {(a∩b)\c}	3. Beinhocker, Eric D. (2010) "Evolution as Computation: Implications for Economic Theory and Ontology", *Journal of Institutional Economics*, Accepted for the special issue on evolution and institutions, Cambridge Science Journals.
3+1 {(a∩b)∩c}	4. Buchanan, Mark (2009) "Meltdown Modelling – could agent-based computer models prevent another financial crisis?", *Nature, 460*, pp 680-682.
1+4 {(a∩b)\c}	5. Colander, David; Föllmer, Hans; Haas, Armin; Goldberg, Michael; Juselius, Katrina; Kirman, Alan; Lux, Thomas and Sloth, Brigitte (2008) "The Financial Crisis and the Systemic Failure of Academic Economics", *Kiel Working Papers No 1489*, Kiel Institute for the World Economy.
1+3 {(a∩b)\c}	6. Farmer, J. Doyne and Geanakoplos, John (2008) "The virtues and vices of equilibrium and the future of financial economics", *Complexity, Special Issue: Econophysics*, 14(3), pp 11-38.
1+4 {(a∩b)\c}	7. Helbing, Dirk (2010) "Systemic Risks in Society and Economics", Part of IRGC report on *The Emergence of Risks: Contributing Factors*, International Risk Governance Council.
4+1 {(a∩b)∩c}	8. Hoogduin, Lex (2010) "Macroprudential instruments and frameworks: a stocktaking of issues and experiences", CGFS Papers No 38, BIS.
1*	9. Hodgson, Geoffrey M. (2007) "Evolutionary and Institutional Economics as the New Mainstream?", *Evolutionary and Institutional Economic Review*, 4(1), pp 7-25.
2+3+5 {(b∩c)\a}	10. Lustick, Ian S. (2000) "Agent-Based Modelling of Collective Identity: Testing Constructivist Theory", *Journal of Artificial Societies and Social Simulation*, 3(1).
2*	11. Schmenner, Roger W. and Swink, Morgan L. (1998) "On theory in operations management", *Journal of Operations Management*, 17, pp 97-113.
2*	12. Wacker, John G. (1998) "A definition of theory: research guidelines for different theory building research methods in operations management", *Journal of Operations Management*, 16(4), pp 361-385.

* Peripheral contributions without thematic allocations.

Table 12: 12 contribution examples from the scoping study literature sample

	Year														
Discipline	Earlier	1900 -1909	1910-1919	1920-1929	1930-1939	1940-1949	19501959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	Grand Total	
Economics	5	1			3		2	1	3	5	8	27	4	**59**	**Scoping study - sample academic literature**
Operations Management								1	1		3	2		**7**	
Complex Systems	1						2		2	1	3	6	1	**16**	
Risk Management												6		**6**	
Grand Total														**88**	

Table 13: Scoping Study - Discipline Contribution by Decade

	Theme				
Research Approach of Contribution	Systemic Risk	Operational Behaviour	Systems (Global Financial)	Grand Total	
Ontology					
Realism	30	24	24	**78**	
Interpretivism	2	3	5	**10**	
Pragmatism					
Epistemology					
Constructivist	2	3	5	**10**	
Participatory					
Positivist	30	24	24	**78**	
Method					
Action					
Archival					
Case		1		**1**	
Experimental Design					
Theory Building	14	19	12	**45**	
Narrative					
Participant Observation					
Review	17	7	17	**41**	
Survey	1			**1**	
Methodology					
Discovery					
Exposure	18	8	17	**43**	
Invention	14	19	12	**45**	
Technique					
Content Analysis					
Event Analysis					
Focus Groups					
Interviews					
Modelling	14	18	12	**44**	
Observations	18	8	17	**43**	
Questionnaires					
Simulation		1		**1**	
Contribution Niche					**Scoping study - sample academic literature**
New Data					
New Methods					
New Perspective	18	8	18	**44**	
New Theory	14	19	11	**44**	

Table 14: Scoping Study - Research Approach by Literature Domain Theme

A comprehensive explanation is yet to be provided for:

i. the fundamental nature of systemic risk in the Global Financial System;
ii. 'How' systemic risk evolves in that system;
iii. 'How' it operationally materializes as systemic failure;
iv. 'How' that materialization could be prevented.

Figure 35: Scoping study Gap Assertions

	Theme / Key Relevant Concepts			
Topic	**Systemic Risk**	**Operational Behaviour**	**Systems (Global Financial)**	
Financial Crisis	• General equilibrium theory • Theory of systemic fragility • Financial stability hypothesis • Anatomy of Financial crises • Systemic risk measurement • Leading indicators for prediction	• General theory of employment, interest and money • Behavioural Finance • Operational agility	• Business Cycles	
Complexity	• Non-cooperative game theory	• Non-equilibrium and complex behaviour	• Financial globalization • Operations management systems • Agent-based computational economics	
Collective Behaviour	• Vested interests in euphoria • Crises following innovations • Speculative bubbles • Irrational exhuberance	• Contagion theory • Theory of collective behaviour • Emergent norm theory • Threshold models of behaviour • Cognitive dissonance • Herd behaviour	• Behaviour of complex phenomena • Kinship Theory • Reciprocation Theory • Sociology + new systems theory • Agent-based models	
Evolution	• Evolutionary epistemology • Evolutionary economics • Macroeconomic resilience	**x** **w** ? **y**	• Evolutionary theory of economic change • Epistemics of operational risk • Innovation and regulatoty constraints	
Theory	• Theory of systemic risk - based on equilibrium economics, risk shifting phenomena and correlations on returns on assets.	**v** ? **z**	• Operational framework for financial stability	**scoping study - sample academic articles**

Table 15: Conceptual gap in the literature

Significant Conversations: Re-stating the Conceptual Gap Participation in each conversation is illustrated by references to one or more of the 12 example contributions identified in the Example Contributions column, together with an indication of their originating topic or boundary.			
Num	**Conversation**	**Example Contributions** (Literature numbers from Table 12)	**Topic or Gap-Boundary** (from Table 15)
S01	Discussions: about theory development	3, 11, 12	Theory
S02	Assessments: of a potential gap in theory informing the research problem	3, 4, 5, 7	v, w, y
S03	Theories: about systemic risk	1, 2, 8, 10	v, z
S04	Perspectives: on the system	6, 7, 9	w, y
S05	Definitions: of systemic risk	1, 7, 8	v, y, z
S06	Forms: of distress in the system	7, 9	w, y
S07	Mechanisms: of systemic failure	2, 7, 10	w, x, y
S08	Recognition: of the potential for systemic failure	2, 4, 8	y, z
S09	Responses: to the potential for systemic failure	8	y
S10	Effects: of systemic failure	7	w, x
S11	Recovery: from systemic failure	7	w, y
S12	Involvement: in the system	4, 10	x, y
S13	Operations: of the system	9	w, y
S14	Reviews: of systemic crises and failures	4	x, y

Table 16: Significant Conversations

B.4.3 Step 3: Producing the Review Protocol

Then a protocol is developed and documented for subsequent reference (see Appendix C).

B.4.4 Step 4: Conducting the Systematic Search

After preliminary work in developing the protocol and its artefacts is completed, the search begins (see Figure 6).

B.4.5 Step 5: Evaluating Studies

Titles and abstracts of search results from the previous step are then negatively screened against relevance discard criteria (i.e. relevant contributions are retained), and then full texts of relevant contributions are positively screened against significance criteria (i.e. approved contributions are retained). Finally, approved contributions are evaluated and graded according to quality criteria.

B.4.6 Step 6: Conducting Data Extraction

Contributions evaluated as being of acceptable quality are then analysed for synthesis data. The type of data required depends entirely on the type of synthesis proposed (see Appendix C.8).

B.4.7 Step 7: Conducting Data Synthesis

The final step of the prescriptive stages of this methodology then synthesizes findings from selected literature (see example in Figure 36 and Appendix C.9). The review conducted for this programme of research involved thematic synthesis of conjectures for theory development.

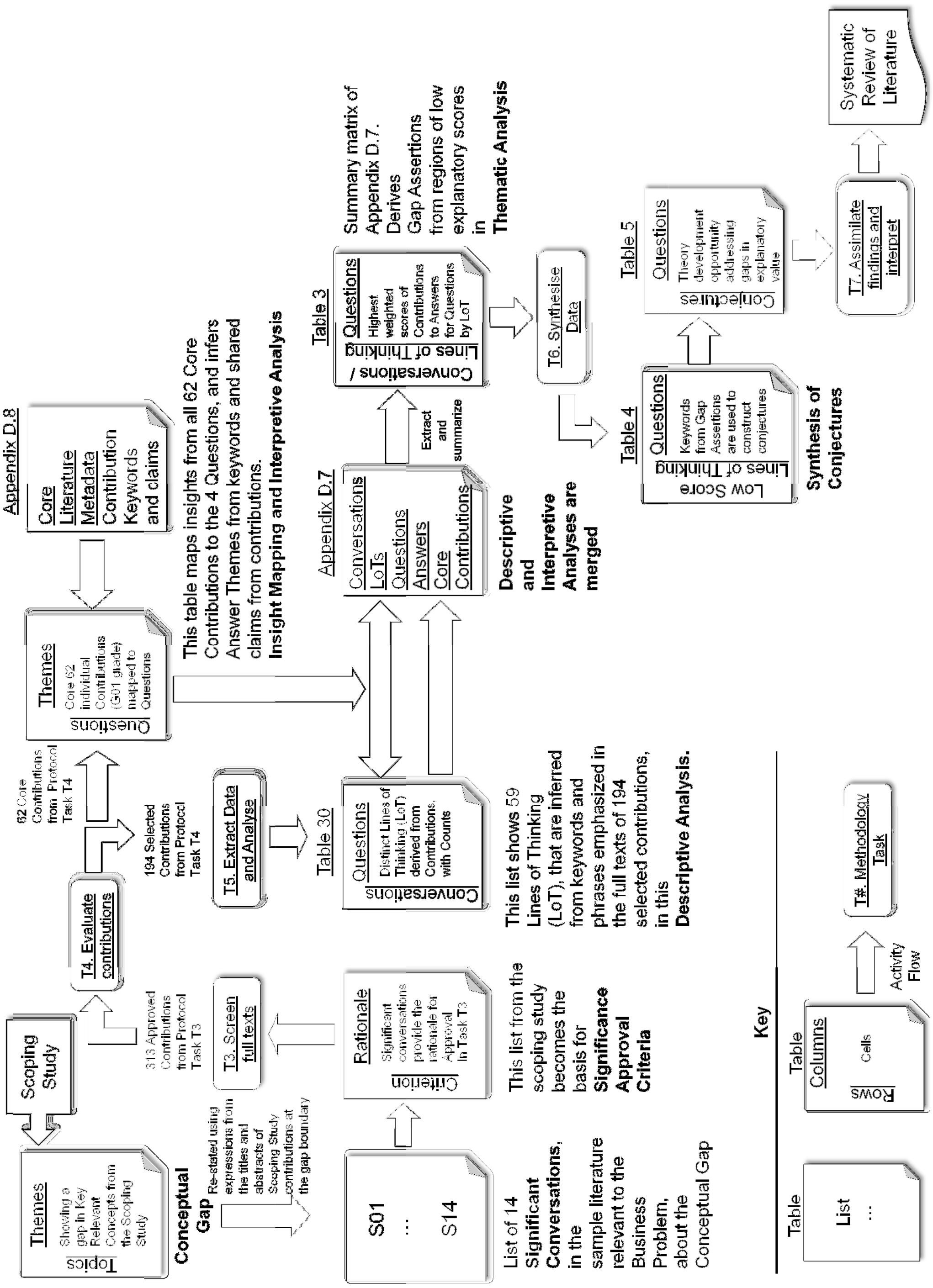

Figure 36: Thematic Synthesis Process

Appendix C. LITERATURE REVIEW PROTOCOL

C.1 Title:

Exploring a potential gap in theory about catastrophic instability of the global financial system, and mitigation of its systemic risk of failure.

C.2 Literature Review Questions:

With reference to the Global Financial System …

Q1. What is the nature of catastrophic instability or total collapse of this system ?

Q2. What is meant by the risk of such an occurrence ?

Q3. How does that risk materialize ?

Q4. What can be done to mitigate that risk ?

Figure 37: Systematic Review literature questions

C.3 Search Strings:

Systematic Review Questions (with reference to the global financial system)		Literature Domain Themes		
		a **Systemic Risk**	**b\a** **Systems (Global Financial)**	**c\a** **Operational Behaviour**
	Base string for each theme ⇨	TITLE (systemic risk)	TITLE (bank OR banks OR banking OR financial)	TITLE (operat* OR behav*) AND TITLE (bank OR banks OR banking OR regulat* OR firm*)
			AND	AND
Q1	**Nature:** What is the nature of catastrophic instability or total collapse of this system?		TITLE (cris* OR fail* OR crash* OR collaps* OR vulnerab* OR instability OR stability)	(breakdown OR mania* OR panic*)
Q2	**Meaning:** What is meant by the risk of such an occurrence?		AND (risk*)	(OR threat* OR expos*)
Q3	**Materialization:** How does that risk materialize?			(OR exuberan* OR greed* OR appetite* OR fear* OR hazard* OR collect* OR evol* OR bubble OR subprime OR sub-prime OR suppl* OR demand*)
Q4	**Mitigation:** What can be done to mitigate that risk?			(OR mitiga* OR risk*)
			AND NOT (systemic risk)	AND NOT (systemic risk)
	Complete string for each theme ⇨	TITLE (systemic risk)	TITLE (bank OR banks OR banking OR financial) AND TITLE (cris* OR fail* OR crash* OR collaps* OR vulnerab* OR instability OR stability) AND (risk*) AND NOT (systemic risk)	TITLE (operat* OR behav*) AND TITLE (bank OR banks OR banking OR regulat* OR firm*) AND (breakdown OR mania* OR panic* OR threat* OR expos* OR exuberan* OR greed* OR appetite* OR fear* OR hazard* OR collect* OR evol* OR bubble OR subprime OR sub-prime OR suppl* OR demand* OR mitiga* OR risk*) AND NOT (systemic risk)

Table 17: Derivation of search strings from review questions

C.4 Quality Appraisal:

T4: Quality Score Definitions			
Criterion	**0 - Unacceptable**	**1 - Acceptable**	**2 – Applicable** (to review)
Thinking	Contributions in which claims are unclear or not grounded in the literature.	Contributions in which claims and their relationship to the literature can be determined, but some concepts remain vague.	Contributions in which claims are clear and well grounded in the literature, with applicable concepts declared and explained where necessary.
Certainty and legitimacy	Contributions in which plausibility or proof for arguments is not established.	Contributions in which plausibility or proof for arguments is weak, or without relevant empirical evidence.	Contributions in which plausibility or proof for applicable arguments is convincing, with empirical evidence where relevant.
Kinds of knowledge	Contributions that make assertions based on unjustified assumptions.	Contributions that present tentative findings or concepts based on incomplete research, flawed analysis, or simply offer reasoned conjectures.	Contributions that present fully developed findings or concepts based on good research practices, and/or analysis that provides applicable insights.
Type of literature	Contributions from literature sources that have undetermined or low academic credibility.	Contributions from credible sources of literature that provide practice or policy perspectives (e.g. from government agencies, professional journals).	Contributions from approved academic sources that provide peer-reviewed research content with clear aims and well reasoned applicable conclusions.
Suitability for purpose	Contributions in which implications or claims cannot be determined or applied.	Contributions in which claims have limited or peripheral bearing on the review purpose.	Contributions which claims to inform theory or introduce applicable knowledge-for-action and instrumentalism.

Table 18: Quality Score Definitions

T4: Quality Criteria	
Criterion/ Grade	**Rationale**
G01	***Good quality exemplar having a direct bearing on the research focus*** ***(***at least three score two, including for the Suitability criterion).
G02	***Good or adequate quality exemplar for a distinct line of thinking*** (but not G01, due to only having an adequate quality or an indirect bearing on the research focus)***.***
G03	***Supporting contribution*** (at least two score 2, with special relevance)***.***
G04	***Unacceptable*** (score 0 for any criterion).
G05	***Low quality*** (less than two score 2).
G06	***At least adequate quality*** (two or more score 2) ***but not exemplar or support*** for a distinct strand of thinking.

Table 19: Quality Criteria

<table>
<tr><th colspan="7">Evaluation Scores Summary for Approved Contributions</th></tr>
<tr><th rowspan="2"></th><th colspan="3">Exclusions</th><th colspan="3">Graded Selections</th></tr>
<tr><th>G06</th><th>G05</th><th>G04</th><th>G03</th><th>G02</th><th>G01</th></tr>
<tr><td rowspan="2">Contributions</td><td colspan="3" rowspan="2">Discard</td><td colspan="3">Use in Descriptive Analysis</td></tr>
<tr><td colspan="2"></td><td>Use in Interpretive Analysis and Thematic Synthesis</td></tr>
</table>

Table 20: Approval Evaluation Results

C.5 Search Engines to be used:

- ABI/ProQuest
- EBSCO
- SCOPUS
- Google Scholar (for grey literature, theses, etc)
- SSRN
- Regulatory authorities (Bank of England, BIS, IMF, etc)
- Professional Literature and Web-sites
- Personal Reading Materials

C.6 Primary Research Formats:

Format	Prescribed Use
Journal articles	Peer-reviewed articles from quality journals are the primary source of information about relevant primary research.
Conference Papers	Conference presentations inform this review about relevant key conversations of interest to research communities, and possible future directions.
Books	Recent major contributions from respected academics serve as useful summaries of relevant current thinking, either for the work of those authors or about a scoped-in field of knowledge.
Doctoral theses	Provide another source of peer-reviewed contributions, if they are relevant but not summarised elsewhere in journal articles, conference papers or books.
Working papers	Provide a perspective on latest thinking in relevant research, and emerging conversations. However, selection should be limited to papers claiming publication acceptance which have not yet appeared in other formats.
Literature reviews	Book reviews are not included, but journal articles contributing reviews of relevant research literature should be collected in that format (see 'Journal articles' above). Books of interest were reviewed directly (see 'Books' above).
Institutional Reports	Publications from such sources as the Bank for International Settlements (BIS) on relevant topics should provide practitioner and regulatory perspectives.
Professional papers	Academic quality contributions from such sources as consultancy practices should be used to collect evidence of relevant industry trends.
Documents on the internet	Should be collected for background information, such as MS Powerpoint presentations from company websites.
Reference/ Bibliography lists	Citation lists from the above formats should be used to cross-check for any contributions otherwise missed.

Table 21: Primary research formats

C.7 Selection Criteria Guidelines:

T1: INCLUSION CRITERIA (ALL) A contribution must be included if it satisfies all criteria.	
Criterion	**Definition / Rational**
I01	***A primary contribution published in the formats given in Table 21.*** See rational in 3.6.5(a).
I02	***Published in the English language***. As this language is the standard for international communications in the global financial system, and the preliminary sample from the scoping study confirms that researchers in this field dispersed globally among academic institutions also appear to follow this standard when publishing their findings, literature in other languages has not been searched.
I03	***Published on any date before collection***. Although the age of a contribution may diminish its relevance in later filtering. Sources vary in their earliest publications retained for each academic field. Historical reviews provide a cross-check on completeness when long timelines of research are necessary.
I04	***Belonging to any academic or professional discipline represented in the data sources***. This is to ensure a multi-disciplinary research approach is taken. Irrelevant inclusions will be discarded during title and abstract screening after a deliberate assessment of potential opportunities for using existing insights from other disciplines in this field of study.
I05	***Collected on the dates of 16th and 17th August 2011***. This is to ensure that accurate verification of the evidence presented is possible than could otherwise be the case if searches were conducted over an extended period of time. Includes three papers written by this author that have a combined total of more than 450 downloads logged against them on SSRN at the time of search, which may indicate that some awareness of the contributions already made by this programme of research may influence current academic thinking by the time the final thesis is submitted.

Table 22: Inclusion Criteria

T2: RELEVANCE DISCARD CRITERIA (assign to first applicable) A contribution must be discarded if any of the below criteria applies to it. The first applicable criterion must be allocated to it in the ascending hierarchy: D01 to Dupl. See sub-section 6.1.2 for a discussion of contribution examples filtered by each criterion.	
Criterion	**Rationale**
D01	***From out-of-scope literature domains:*** that is, other than Economics, Operations Management, Complex Systems, or Risk Management, and offering no compensating insight that is applicable to the research problem.
D02	***Unrelated to any of the three themes***: that is, other than Systemic Risk, Systems (Global Financial), or Operations Management, and offering no compensating insight that is applicable to the research problem.
D03	***Not pertinent to the research problem:*** as in using some key words but not addressing the systematic review questions, such as providing

	investment advice during crises, or analysing returns on risk-taking under turbulent conditions.
D04	***Unlikely to inform the systematic review questions:*** as in addressing some of the systematic review questions, but offering irrelevant insights such as for pricing improvements.
D05	***Inconclusive***: as in simple commentary, unsupported opinions or book reviews.
D06	***Relevant insights expressed better in other contributions:*** as in confirmations or re-statements of general insights presented in other papers.
D07	***Superseded, disproven or outdated notions:*** as in contexts where regulations, conditions or definitions have evolved, or new facts have emerged.
D08	***Missing data:*** for example, author, year, publication name etc.
Dupl	***Duplicate:*** Not found previously by auto de-duplication in RefWorks.

Table 23: Relevance Discard Criteria

T3: SIGNIFICANCE APPROVAL CRITERIA (assign to all applicable) A contribution is approved for significance if it belongs to at least one of the conversations (S01 to S14) in this literature, converted from Table 16 into the below rationale for significance approval.	
Criterion	**Rationale** (significance is approved if a contribution is made to …)
S01	Discussions about suitable theory development and testing approaches.
S02	Assessments of the state of systemic risk theory.
S03	Theories, models, frameworks and simulations about systemic risk.
S04	Different perspectives on the system.
S05	Definitions for systemic risk of failure, or similar terms.
S06	Observed forms of distress in the system.
S07	Explanations of how systemic failure arises out of distress in the system.
S08	Explanations of how to recognize the potential for systemic failure.

S09	Explanations of how to respond to the potential for systemic failure.
S10	Descriptions of the effects of systemic failure.
S11	Explanations of how to recover from systemic failure.
S12	Examples of involvement in the system.
S13	Explanations of the system's operations.
S14	Reviews of systemic crises and failures.

Table 24: Significance Approval Criteria

C.8 Data Extraction Method:

Reference Type; Author; Year; Title; Secondary Author; Secondary Title; Place Published; Publisher; Volume; Number of Volumes; Number; Pages; Section; Tertiary Author; Tertiary Title; Edition; Date; Type of Work; Subsidiary Author; Short Title; Alternate Title; ISBN/ISSN; DOI; Original Publication; Reprint Edition; Reviewed Item; Custom 1 - Discipline; Custom 2 - Ontology; Custom 3 - Epistemology; Custom 4 - Method; Custom 5 - Methodology; Custom 6 - Technique; Custom 7 - Contribution Niche; Keywords; URL; Author Address; Name of Database; Database Provider; Added to Library; Last Updated.

Table 25: Data Extraction Base Specification

C.9 Thematic Synthesis Method:

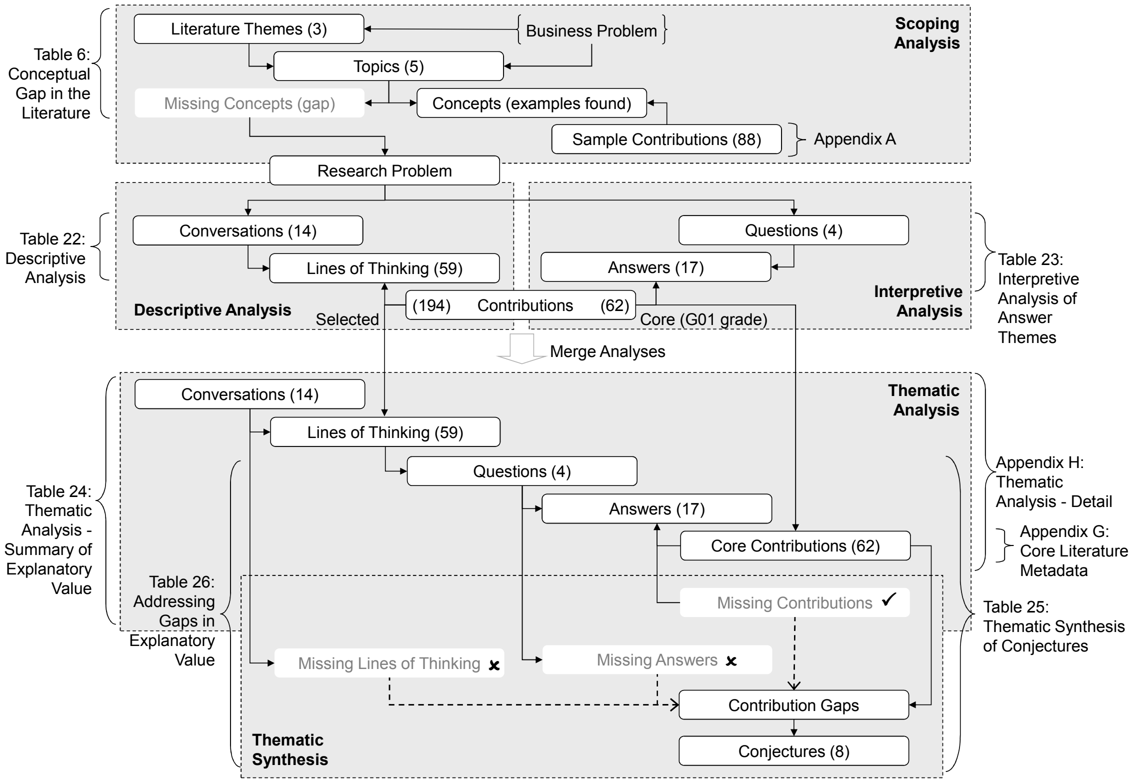

Figure 38: Thematic Synthesis Method

C.9.1 Aims

Selection of an appropriate synthesis method is vitally important, but all such methods are known to have major weaknesses when they are applied to an evidence-base requiring consideration of such matters as diversity in research traditions, a wide spectrum and controversial mixtures of applied methods, differences in accepted formalisms and levels of empirical support, paradigm incompatibilities, and so on. When attempting to establish evidence for a gap in theory, to offer new insights about what is missing, such problems are compounded by conventional methods of theory-driven synthesis that aim to 'go beyond' existing primary research by introducing a 'higher order' theoretical structure equivalent to 'third order interpretations' from meta-ethnography (Britten et al, 2002; Campbell et al, 2003). This aim works well if new theory is likely to be synthesised out of existing primary studies, as in realist synthesis (Dixon-Woods et al, 2005), and when synthesising from an evidence-base in a state of general accord with a dominant theoretical paradigm. However, it fails to be productive when a shift to a new paradigm may be required, and where the review strategy calls for a large scope of fertile but disparate evidence-base, possibly including unconventional combinations of academic disciplines, to solve a previously intractable problem.

C.9.2 Terms

Key terms used to explain this synthesis are defined as follows:

Conversations

Descriptive themes in the literature, identified as discussion topics of common interest relevant to some aspect of the literature hypothesis.

Lines of Thinking

Thematic ideas or opinions debated within conversations around which a consensus is formed in the literature.

Exemplars

A grade G01 quality contribution to the literature considered to represent a distinct expression or strand of a line of thinking.

Answer Theme

A consensus formed between exemplars, expressed as an interpretive theme, for responding to a literature search questions, derived from shared claims and commonly declared keywords.

C.9.3 Method

The qualitative method selected by this review combines both descriptive and interpretive thematic synthesis (Thomas and Harden, 2007; Barnett-Page and Thomas, 2009) to produce a weighted scoring of the explanatory value of current primary research for a pre-defined set of literature questions, using a descriptive scheme, declared interpretations, and a weighted scoring method.

After identification, collection, screening and evaluation of the initial literature, to establish an evidence-base of selected contributions as prescribed earlier in this protocol for subsequent descriptive analysis, a core subset of exemplar literature would then be extracted from top-quality (G01) selected contributions for synthesis in Task T5. The purpose of descriptive analysis would be to identify lines of thinking in the selected literature from research conversations revealed by the scoping study. Then each contribution would be assigned to one or more line of thinking, and mapped to the literature questions for which it provides insights.

At a collective level, common insights of the contributions mapped to each question would then be interpreted as themes, in the form of answers inferred from that literature using keywords and explicit claims from abstracts. Then each contribution would be assigned to one or more of these answer themes, according to the insights they offer the literature questions, from the perspective of each line of thinking to which they contribute, and they would be scored for explanatory value as described in the next sub-section, to produce a detailed thematic analysis (see Appendix D.5). The lines of thinking with low explanatory score values (3 or less) would then be determined to offer the greatest potential for significant new contributions to knowledge and practice; a key assumption being that sufficient opportunity can be found for new contributions to existing lines of thinking without the need for creating another.

Then a summary matrix of explanatory value would be constructed from that detailed thematic analysis, showing the sub-set of lines of thinking having scores of mostly 3 or below for contributions to the answers of a literature question (see Table 3). Gap assertions would then be derived from keywords in the text of associated questions, answers and lines of thinking, for use in the thematic synthesis of conjectures for theory development.

C.9.4 Scoring

Weighted scoring was determined to be calculated from core contributions by the following process:

i. In Appendix D.5, core contributions are assigned to answer themes within literature questions within conversations or lines of thinking, according to their insight contributions. Then a score is selected for each contribution to this context, indicating that it either 1=implies, 2=supports or 3=introduces insights.

ii. Next, these scores are weighted for coverage at answer theme levels for each context. A judgement is made regarding whether there are sufficient numbers and depth of contributions to the answer theme, providing a 1=partial or 2=broad coverage for this context. A coverage weighting is attributed to each answer theme, and each theme's weighted score is the product of its coverage weighting and the highest contribution score among the contributions associated with that answer.

iii. Finally, the weighted score calculated for each answer theme in this way can be transferred to its context placement in Table 3, if the line of thinking it relates to is shown in that matrix.

Appendix D. SYSTEMATIC REVIEW OF LITERATURE

D.1 Purpose of Review

The purpose of this review was to examine four assertions about a gap in theory identified in a preliminary appraisal of relevant literature from a research scoping study, and inform recommendations for a potential programme of theory development research. Consequently, the review protocol aimed to explore a large, multi-disciplinary evidence-base of literature to ensure the gap assertions were valid, to avoid re-discovering existing knowledge, and to collect applicable insights from diverse sources. This was collected over a two-day period (on the 16th and 17th of August, 2011), using database search strings constructed from keywords and phrases found among significant conversations at the boundaries of the gap appraisal in the scoping study literature. The core literature filtered from this initial collection of 4076 contributions proved useful for synthesizing 8 conjectures about the asserted gap in theory, to inform subsequent theory development.

D.2 Evidence base

A summary of the data statistics from tasks T1 to T4 of the methodology is presented in Table 2, and explained in the following sub-sections. The database files from which these statistics have been derived were submitted with this thesis, and copies can be requested from Cranfield University School of Management.

D.2.1 Search Results Data

D.2.1.1 Task T1 – Search

In task T1, the three key databases queried were ABI/INFORM, EBSCO, and SCOPUS, with GOOGLE being used as an additional source for grey literature, etc. Table 2 shows that the most productive among them was SCOPUS, particularly when dropped duplications were taken into account (see the first column under 'Discarded as not relevant'). All of these literature sources had an 'export to RefWorks' feature, enabling 4069 references to be automatically imported into that tool, and organized in folders by theme subsets from scoping study literature domains.

After using the de-duplication feature within RefWorks, 2761 references were retained for export to an '.xml' file. During subsequent import into NVivo9, 47 records were found to be corrupted. These records are accounted for in the 'Drop' column under 'Task Literature' against 'Corrupted records'. They represent a 1.2% level of data corruption, which was considered acceptable. Then 7 other contributions were manually entered into NVivo9, resulting in a total of 2721 unique references loaded into that tool, representing 67% of the 4069 references originally collected.

D.2.2 Screening Data

D.2.2.1 Task T2 – Screen Titles and Abstracts

During title and abstracts screening, 1048 references were retained as relevant while 1673 were discarded. A breakdown of the number of references discarded by reason for discard is given in columns 'Dupl to D08' (see Table 23 for an explanation of each discard criterion) under 'Discarded as not relevant' in Table 2, and a full list of these references can be found in the supplementary document titled 'References Not Retained', under Titles and Abstracts - Discarded (organized by discard code). The relevant literature count represents 26% of the 4069 references originally collected.

D.2.2.2 Task T3 – Screen Full Texts

During full texts screening, 313 references were retained as approved while 735 were rejected. A breakdown of the number of references approved by reason for significance is given in columns S01 to S14 (see Table 24 for an explanation of each significance criterion) under 'Approval by Significance' in Table 2.

It should be noted that a single contribution to literature can be mapped to multiple reasons for significance. A full list of rejected references can be found in the supplementary document titled 'References Not Retained', under Full Text - Rejected. The approved literature count represents 8% of the 4069 references originally collected.

D.2.3 Evaluation Data

D.2.3.1 Task T4 – Evaluate Contributions

Evaluation occurred in two parses. First, each approved contribution was scored according to the definitions of five criteria and three score levels given in Table 18. Then, depending on the scores allocated, each contribution was either dropped as excluded, or selected and given a grade, according to rationales of Table 19. A summary of the scores allocated to all approved contributions is given in Table 26 below. The breakdown of exclusions and graded selection is given in Table 27.

Quality Scores Summary for 313 Approved Contributions			
Criterion	**0 - Unacceptable**	**1 - Acceptable**	**2 – Applicable** (to review)
Thinking	*8*	*35*	*270*
Certainty and legitimacy	*1*	*131*	*181*
Kinds of knowledge	*3*	*144*	*166*
Type of literature	*6*	*72*	*235*
Suitability for purpose	*19*	*15*	*279*

Table 26: Quality Scores Summary for 313 Approved Contributions

Out of 313 approved contributions, 119 were excluded for being below protocol quality criteria, and 194 were selected for grading according to protocol grading criteria. The selected count represents 5% of the 4069 references originally collected.

Evaluation Scores Summary for 313 Approved Contributions						
	Exclusions			Graded Selections		
	G06	G05	G04	G03	G02	G01
Contributions	*26*	*8*	*85*	*23*	*5*	*166*

Table 27: Evaluation Scores Summary for 313 Approved Contributions

D.2.4 Extraction Data

D.2.4.1 Task T5 – Extract Data

From the 194 selected references, a core subset of 62 references were identified as 'exemplars' of the insights from distinct lines of thinking in this literature, drawn exclusively from top grade (G01) contributions. The notion of using both literature sets was prescribed in the protocol, and intended as a means of reviewing a wider evidence-base of selected contributions while at the same time synthesizing a more manageable evidence-base of core contributions. Therefore, all synthesis, assimilation and interpretation beyond the first step of descriptive analysis used this core evidence-base as a high-quality representation of the literature under review. Appendix D.8 analyses the metadata extracted from that core literature by coding the abstracts, keywords and phrases from the full-texts of each contribution. However, some metadata attributes were difficult to classify in many contributions because they generally failed to declare their research philosophy and approach. This often had to be construed from the material, and therefore may increase the subjective nature of some extracted data.

D.2.4.2 Task T5 – Data Analysis

A longitudinal analysis is given in Table 28, showing contributions from this core literature by discipline over time. When compared with a similar analysis from the scoping study (see Table 13), two key differences can be seen. The complex systems discipline is not as well established within the scope of selected domain themes as it appeared to be in the sample literature, but the risk management discipline has suddenly begun to join research conversation of interest. This interest from risk management is probably due to the 'great recession' currently being experienced in most regions of the world, arising from the sub-prime credit crisis and subsequent sovereign debt problems.

	Year														
Discipline	Earlier	1900 -1909	1910-1919	1920-1929	1930-1939	1940-1949	19501959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2011	Grand Total	
Economics									1		6	17	3	**27**	**Systematic Review - academic literature**
Operations Management														**0**	
Complex Systems										1		3	2	**6**	
Risk Management											1	14	14	**29**	
Grand Total														**62**	

Table 28: Review – Discipline Contribution by Decade

	Theme				
Research Approach of Contribution	Systemic Risk	Operational Behaviour	Systems (Global Financial)	Grand Total	
Ontology					
Realism	29	27	2	**58**	
Interpretivism	2	1	1	**4**	
Pragmatism					
Epistemology					
Constructivist	2	1	1	**4**	
Participatory	2			**2**	
Positivist	27	27	2	**56**	
Method					
Action					
Archival					
Case					
Experimental Design	4	1		**5**	
Theory Building	10	12		**22**	
Narrative					
Participant Observation					
Review	16	14	3	**33**	
Survey	1	1		**2**	
Methodology					
Discovery					
Exposure	17	15	3	**35**	
Invention	14	13		**27**	
Technique					
Content Analysis					
Event Analysis		1		**1**	
Focus Groups					
Interviews					
Modelling	13	16		**29**	
Observations	18	11	3	**32**	
Questionnaires					
Simulation					
Contribution Niche					
New Data		1		**1**	**Systematic Review - academic literature**
New Methods	3	1		**4**	
New Perspective	18	14	3	**35**	
New Theory	10	12		**22**	

Table 29: Review - Research Approach by Literature Domain Theme

When the research philosophies and approaches of the 62 exemplar contributions are analysed, as shown in Table 29, more implications emerge for this review. Although, as explained in the previous sub-section, this analysis may be too subjective, the strong presence of realism identified in the scoping study sample is confirmed in this core literature. As before, it seems to be linked to a constructivist epistemology that is employed in circumstances where: data is missing; the mathematics of a problem is non-linear and complex; or where erratic behaviour requires the use of simulation techniques. However, in this literature, simulation techniques are still at the stage of being recommended, with few signs of actual non-trivial use.

The contribution niches of ‘new perspective’ and ‘new theory’ are also clearly present, as before (see Table 29). Indicating that theorising and theory development is prevalent in this multi-disciplinary academic field, reinforcing the scoping study conclusion that this literature represents a nascent field of research in which there may still be gaps in theory.

D.3 Description of the Literature Not Selected

The literature not selected for review is briefly described here. A full account of it is given in a supplement to this document, sub-titled: ‘References Not Retained’, in a compilation of bibliographical reference lists for the 1673 discarded contributions from task T2 (see Figure 39), the 735 rejected contributions from task T3, and the 119 excluded contributions from task T4 (see Figure 40). In that supplement, discards are grouped by criteria for discard, and exclusions are grouped by quality exclusion criteria, reflecting their reasons for non-retention determined by negative screening; whereas, rejections are not grouped because they are the non-retentions of positive screening which uses alternative criteria for retention (see screening explanations in the protocol).

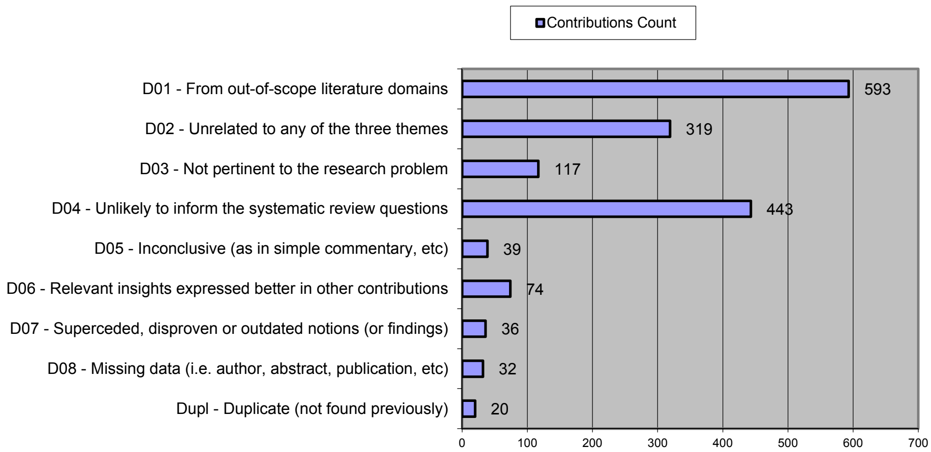

Figure 39: Discards Analysis

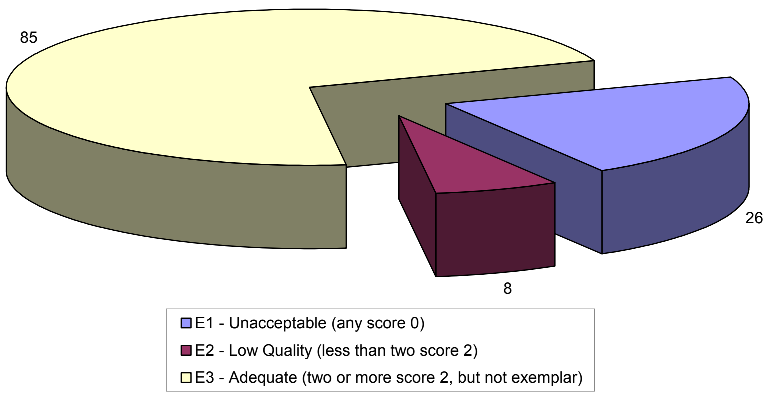

Figure 40: Exclusions Analysis (by number of contributions)

D.4 Thematic Synthesis

D.4.1 Inputs

Four fundamental analysis artefacts were derived out of the data extracted from this literature, and used to develop a categorisation of the evidence-base: two descriptive theme-types (conversations, and lines of thinking), one contribution property (exemplar) and one interpretive theme-type (answers). They were used to identify core contributions from multiple scoped-in academic disciplines, which were assimilated into a generalized, descriptive/interpretive model of the ability of existing theories to answer the literature review questions derived from the research problem. This model formed the basis for outlining a new theory development opportunity through thematic gap analysis, leading to synthesis of unexplored conjectures in that literature. 'Going beyond' the content of current literature in this way is considered a defining characteristic of synthesis (Britten et al, 2002). The rationale for selecting a qualitative approach to synthesis for this systematic review was explained in Appendix C.9.

However, the interpretive nature of qualitative synthesis, with its dependence on the judgements and insights of a reviewer, is widely perceived as a weakness in rigour. For that reason, this review includes a complete audit trail of reasoning and choices made at every step of the systematic review methodology in the form of:

iii. summary statistics, provided in Table 2;
iv. complete reference lists in a supplement to this document, titled 'References Not Retained', of contributions from the search results that were not retained in this synthesis, categorised by their reason for non-retention in the systematic review methodology; and,
v. further details of thematic coding and analysis in the NVivo 9 database used throughout this review, available in soft-copy on CD, together with all supporting import and export files from various software tools.

This audit trail removes uncertainty about the subjective nature of conclusions reached by ensuring complete transparency throughout the systematic review process, particularly with regard to the synthesis outcome. It furthermore reduces the scope for challenges down to differences in literature assessment. Given the multi-disciplinary nature of that literature, and the focus of this review on the potential existence of a gap in theory, it is argued here that a more quantitative approach to synthesis would be even more exposed to challenges of a lack of applicability to notions that cannot be adequately quantified.

Therefore, the objective of this section is to present a thematic rationale for the qualitative sythesis of an opportunity to address a gap in theory about systemic risk of failure and its mitigation for the global financial system.

D.4.2 Analysis

This sub-section should be read in conjunction with Appendix C.9, which outlines the aims and method of thematic synthesis, and how it was conducted in this review. Here, the findings of synthesis are explained and discussed.

D.4.2.1 Descriptive Analysis

The results of descriptive analysis are presented in Table 30. It shows the 14 conversations identified by the scoping study, extended by 59 lines of thinking (LoT), with contribution counts, and is represented by the two left-most columns of that table. The other columns are added when insight mapping is completed and merged with this analysis, to provide the insight numbers shown here. However, in this sub-section, Table 30 will be considered in its entirety as 'finished' descriptive analysis, and discussed as it is.

The table shows how conversations from 'approved', 'selected' and 'core' literature-sets map to relevant insights. However, 3 conversations are marked as 'na', designating 'not appropriate', for insight mapping. In the case of the S01 this is because it relates to literature that is about the process of developing insights only relevant to critical analysis later in this review. Similarly, S02 discusses a potential gap in theory for critical analysis, but offers no new insights. However, S10 is also considered 'not appropriate' because it is a conversation in the broader literature about the effects of systemic failure, which is not relevant to any of the literature questions and therefore not represented in the core set (i.e. its contributions were not retained during screening). Two LoTs also have 'not appropriate' designation in the S03 conversation about systemic risk theories, because they represent contributions that are peripheral to this conversation, but frequently referenced within it, or their insights have been superceded in some way (and therefore not retained during screening).

Where insight mapping gaps appear in question columns, against some conversations and LoT such as the gap under Q2 for S06 (forms of distress), this is generally an indication that the associated literature does not consider those questions. However, it would not have been correct to also designate mapping in these gaps as 'not appropriate' because they may be an indication of missed research opportunities that are collectively being overlooked for some reason. Interestingly, the conversations attracting least insight contributions in this literature are about definitions for systemic risk (S05) and recovery from systemic failure (S11). Among the rest, if 'reviews' (S14) are not counted, recognition of the potential for systemic failure (S08) is also fairly low.

The following sub-sections take these high-level observations about this literature and begin to infer new knowledge, assertions and conjectures.

Contributions to (any) Research Conversations of the Approved, Selected and Core Literature						
Descriptive Analysis: **Conversation** (from Table 16) **Line of Thinking** (LoT)	**Approved, Selected, Core Contrib-utions**	**Insight Mapping to Literature Questions**				
		Q1	**Q2**	**Q3**	**Q4**	**Total**
S01 Discussions: about theory development.	**23, 23, na**	**na**	**na**	**na**	**na**	**na**
S01.1 - The nature of theory	7					
S01.2 - Theory development	7					
S01.3 - Theory testing	3					
S01.4 - Theory in Economics.	6					
S02 Assessments: of a potential gap in theory informing the research problem.	**17, 16, na**	**na**	**na**	**na**	**na**	**na**
S03 Theories: about systemic risk.	**117, 85, 49**					
S03.1 - Candidate theories of systemic risk	**8**	8	4	14	9	35
S03.2 - Other insights	**48**					
S03.21 - Catastrophe	3	3				3
S03.22 - Evaluation	19			14	17	31

S03.23 - Propagation	9	10		9		19
S03.24 - Network	1	1		2		3
S03.25 - Criticality	5	5		2		7
S03.26 - Operations	8	3		8	1	12
S03.27 - Behaviour	38	9		49	22	80
S03.3 - Related concepts	**na**					
S03.4 - Foundational contributions	**na**					
S04 Perspectives: on the system.	**84, 73, 53**					
S04.1 - Banking	18	9		24	13	46
S04.2 - Complex	7	6		3	1	10
S04.3 - Economic	29	11		29	18	58
S04.4 - Financial	49	24		48	28	100
S04.5 - Insurance	3			2	1	3
S04.6 - Market	13	4		8	7	19
S04.7 - Operational	27	4		12	25	41
S04.8 - Regulatory	15	2		12	14	28
S05 Definitions: for systemic risk.	**18, 17, 16**					
S05.1 - Causal	6		6			6
S05.2 - Consequential	1		1			1
S05.3 - Combined	5		5			5
S05.4 - Similar terms and meanings	5		5			5
S06 Forms: of distress in the system.	**118, 82, 59**					
S06.1 - Banking	27	12		35	13	60
S06.2 - Economic	23	8		27	14	49
S06.3 - Financial	50	22		66	19	107
S06.4 - Market	38	24		25	7	56
S06.5 - Monetary	23	6		17	11	34
S06.6 - Operational	8	4		5		9
S06.7 - Regulatory	28	4		14	15	33
S06.8 - Sudden shock	6	3		7	5	15
S07 Mechanisms: of systemic failure.	**63, 50, 32**					
S07.1 - Contagion	3	3		1		4
S07.2 - Emergence	9	6		12	7	25
S07.3 - Collapse	26	10		15	11	36
S08 Recognition: of the potential for systemic failure.	**56, 34, 19**					
S08.1 - Early warning systems	5			5		5
S08.2 - Criteria	7			7		7
S08.3 - Stress testing	2			2		2
S08.4 - Measuring Implications	1			1		1
S08.5 - Concentrations	10			10		10

S09 Responses: to the potential for systemic failure.	**85, 52, 22**					
S09.1 - Governance	0					
S09.2 - Intervention	12				12	12
S09.3 - Regulation	11				11	11
S09.4 - Risk Management	4				4	4
S10 Effects: of systemic failure.	**13, 5, na**	**na**	**na**	**na**	**na**	**na**
S11 Recovery: from systemic failure.	**8, 4, 2**				2	2
S12 Involvement: in the system.	**76, 54, 28**					
S12.1 - Collective	4			4		4
S12.2 - Deliberate (Strategic or Tactical)	9			9		9
S12.3 - Dysfunctional	12			12		12
S12.4 - Ignorant	2			2		2
S12.5 - Procedural	8			8		8
S13 Operations: of the system.	**42, 31, 20**					
S13.1 - Cycles	6			6		6
S13.2 - Innovation	3			3		3
S13.3 - Interconnectedness	7			7		7
S13.4 - Fragility or Resilience	7			7		7
S13.5 - Visibility	6			2	4	6
S14 Reviews: of systemic crises and failures.	**22, 20, 6**					
S14.1 - Current crisis	3	3				3
S14.2 - Other specific crises	0					
S14.3 - General crises	3	3				3
Insight Totals		**207**	**21**	**544**	**291**	**1063**

Table 30: Descriptive Analysis of Insight Contributions

D.4.2.2 Lines of Thinking Appraisal

The ‘selected’ literature count of 16 from column 2 of Table 30 for the S02 conversation confirms there is interest in a potential gap in theory relevant to this review. However, only 8 candidate theories were found in the S03.1 LoT. On closer examination, most of these could barely be described as fully developed theories, although other contributions (in S03.2) offer a wide spectrum of less formal theorising to fill part of that void. Nevertheless, a lack of coherence among this literature could be argued, due to many conflicting LoTs about the nature of the global financial system (S04.1 to 8), and its instability (S06.1 to 8).

Diversity is not so evident among attempts to define systemic risk (S051 to 4), but that should not be assumed to indicate that a consensus exists (see discussion in 6.3.2). There appears to be a preference in this literature for offering fragments of explanations about how systemic risk arises, propagates and becomes identifiable (S05.1 to 4, S07.1 to 3, and S08.1 to 5), without much evidence of thinking about foundational concepts or unifying theories. Systemic risk mitigation also receives a lot of attention, regarding what is mitigated (S04.1 to 8, and S06.1 to 8) and how to respond (S09.1 to 4). However, with regards to the research problem of interest, operational ideas are less well represented (S13.1 to 5), both explicitly and implicitly among the LoTs found, as are behavioural ideas (S12.1 to 5). Therefore, when considered as a whole, this literature seems fairly similar to the sample collected during the scoping study, and has the same conceptual gaps.

D.4.2.3 Insight Mapping

A more detailed picture emerged after insights were inferred from keywords and shared claims found during the full text screening of core contributions, enabling each contribution to be associated with one or more of the literature questions by the relevance of its insights. The 2 left-most columns of Table 31 show the output of that association. Then, by merging this result with the descriptive analysis in Table 30, an insight mapping to the literature questions could be determined for each LoT, represented by the numbers in the 5 right-most columns in that table.

From the perspective of literature questions, the insight totals at the bottom of Table 30 suggest that research attention in this literature is focused on how systemic risk materializes (Q3), not on the fundamental nature of catastrophic instability (Q1), or how the risk of systemic failure could be mitigated (Q4).

The low insights total for Q2 can partially be explained as the result of a specific correspondence between that question and the S05 conversation. All other questions correspond to multiple conversations. That difference in proportion to average insights by question is a natural effect of independently chosen descriptive analysis categories (derived from conversations observed in a preliminary sample of this literature) and literature questions (derived from a research problem). Sometimes equivalent notions are independently derived from different sources. However, the low count for insights could also be argued as confirming a lack of attention to foundational concepts in this literature.

D.4.2.4 Interpretive Analysis

To establish the explanatory values of LoTs, as mapped to literature questions in Table 30, it was first necessary to organize individual contribution insights for each question by assigning them to insight themes. The third column from the left in Table 31 describes how insight themes were interpreted by clustering insights according to particular insight affinities found among the contributions relevant to each question. Then the insight clusters for each question were labelled in the style of answer statements, as shown in the right-most column of that table.

The choice between potential insight affinities for clustering was based on their suitability for interpreting answer themes that could be assigned credible explanatory values for a question. The key objective was to establish a set of interpreted answer themes for each question that could be used to analyse gaps in the explanatory values of contribution insights, mapped to those questions from LoTs as answers at a manageable level of granularity for thematic analysis and synthesis (see Table 31).

If gaps in explanatory value exist, it is argued they would be apparent no matter which insight affinities were selected. However, using 'credibility in assigning explanatory value' as the basis for selection helped to focus the search for candidate affinities.

Question	**Counts for Core Contributions, Insights**	**Interpretation of Common themes for Insights** (inferred from keywords and shared claims in the full-texts of contributions)	**Interpreted Answer Themes**
Q1. Nature?	35, 207	Insights for this question in the core literature can be clustered by their affinity to one or more of five adjective-keywords: systemic, critical, global, financial or structural.	A1 - Its nature is systemic A2 - Its nature is critical A3 - Its nature is global A4 - Its nature is financial A5 - Its nature is structural

Q2. Meaning?	16, 21	Insights for this question in the core literature can be clustered by their affinity to one or more of three noun-keyword combinations: causes, consequences, causes and consequences; or similar terms.	A1 - It is defined by its causes A2 - It is defined by its consequences A3 - It is defined by its causes and consequences A4 - Similar terms and meanings
Q3. Materialization?	50, 544	Insights for this question in the core literature can be clustered by their affinity to one or more of four attributive verb-phrases addressing: participants, financial services, the system's infrastructure and the system's economic environment.	A1 - Through the behaviour of systemically important participants A2 - Through participation in systemically important financial services A3 - Through interactions with the system's infrastructure A4 - Through interactions with the system's economic environment
Q4. Mitigation?	43, 291	Insights for this question in the core literature can be clustered by their affinity to one or more of four advisory verb-phrases addressing: participation, financial services, the system's infrastructure and the system's economic environment.	A1 - Modify the behaviour of systemically important participants A2 - Modify participation in systemically important financial services A3 - Modify interactions with the system's infrastructure A4 - Modify interactions with the system's economic environment

Table 31: Interpretive Analysis of Answer Themes

D.4.2.5 Detailed Thematic Analysis

Once answer themes were interpreted for each question from contribution insights it became possible to expand the combined descriptive analysis and insight mapping of Table 30 into a detailed thematic analysis of contribution insights with weighted scores for explanatory values, as presented in Appendix D.5.

This shows how all 62 contributions to the core literature have been mapped to relevant answer themes, within literature questions, within LoTs, within conversations, together with their insight relevance and scores for each mapping.

D.4.2.6 Explanatory Gap

Table 3 presents a summary analysis of an extract from Appendix D.5 of LoT, where gaps are expected to be most evident.

The key features of this analysis are:

i. Rows containing ***a subset of LoTs*** with low weighted explanatory scores of ≤ 3 for answers to one or more literature questions (extracted from Appendix D.5). Keywords in the titles of these LoT are highlighted in bold for reference by gap assertions.

ii. Columns containing ***literature questions and answer themes*** representing answers interpreted from relevant literature as suitable for assigning explanatory value of contribution insights from LoT (see Table 31). Keywords in the titles of these literature questions and answers are highlighted in bold for reference by gap assertions.

iii. ***Weighted explanatory scores*** for LoT answers, presented as cell entries in this table, associating LoTs with literature questions through their answer themes.

iv. Outlined groupings of cells representing ***explanatory gaps***, identified by roman numerals I to X that are referenced by explanatory gap assertions,

v. ***Explanatory gap assertions***, labelled (a) to (j), summarizing inadequacies of the literature from the detail thematic analysis of Appendix D.5, for nominated explanatory gaps. The text for these gap assertions is derived from highlighted keywords in the titles of questions, answers and LoT associated with those cells. The assertions are derived from either row or column perspectives on cell groupings.

It summarizes 1062 insights from 62 core contributions of literature, generated by 59 lines of thinking (LoT) within 14 research conversations, in providing explanations mapped to 17 answers associated with 4 literature questions.

Finally, it combines a qualitative analysis of explanatory gaps in this core literature; with a set of gap assertions derived from keywords, phrases and claims found in this literature at various stages in the thematic synthesis process (see Figure 36); to express the weaknesses and omissions among contribution insights; from the perspective of literature questions derived from the research problem of this review.

D.4.3 Synthesis

D.4.3.1 Conjecture Synthesis

The thematic analysis of explanatory gaps in this core literature from Appendix D.5 and Table 3 suggested new conjectures, as shown in Table 4 which exposed a gap in theory for addressing the research problem of interest. Before explaining how those conjectures were derived, it may be useful to summarize the reasoning that brought the synthesis to this point.

From the preliminary outline of a gap in knowledge and theory exposed by the scoping study, fourteen conversations in the literature were revealed as requiring more contributions (see Table 16). In this systematic review, those conversations were first used as significance approval criteria (with abbreviated text in Table 24) for filtering contributions from a much larger multi-disciplinary evidence-base of literature. After subsequent evaluation of that evidence-base, they also formed the basis for a descriptive analysis of selected contributions (see Table 30), and distinct lines of thinking were added around which a consensus was found to have formed in the literature within each conversation. Then 'exemplar' contributions from those lines of thinking, that offer potential insights for answering the literature search questions, were mapped to the literature search questions (see Table 30).

By referring to that literature's metadata (see Appendix D.6), it became possible to assign this core subset of mapped exemplar contributions, through analysis of their shared claims and keywords, to interpretive themes representing answers to the literature questions (see Table 31). After scoring, it then became possible to create a model of gaps in the explanatory value of this core literature (see Table 3). In that model, each cell represents the highest weighted score of exemplar contribution insights from lines of thinking (LoT) providing answers for those literature questions. Bordered regions of cells in the model show where there is weak or missing explanatory value, exposing a gap in this evidence-base for answering the literature questions when addressing the research problem of interest.

Table 4 then synthesises conjectures out of this explanatory model, by re-stating the gap assertions from Table 3 as conjectures derived from the implications and terminology of those assertions. Therefore, if the gaps identified in this core literature of exemplars are representative of the entire evidence-base, then the conjectures must be new, and their potential for new theory development is highly plausible.

D.4.3.2 Addressing the Explanatory Gap

Table 5 rearranges the new conjectures synthesised in Table 4, to form a logical progression of reasoning, with references to the assertions they combine and re-state. Then each conjecture is presented alongside a mapping to the explanatory gap references and literature questions it addresses.

This table shows there are explanatory gaps associated with all 4 literature questions, and confirms that an opportunity exists for new theory development that is outlined by these 8 conjectures. The scope of these conjectures suggests this opportunity may either be another contribution to the fragmented theorising currently prevalent in this literature, based on a few of these conjectures, or a high-level unifying theory based on them all.

Conjectures (from Table 25)	**Gap**	**Q1**	**Q2**	**Q3**	**Q4**
C1. If the essential nature of the GFS is represented as a complex system by a model describing the dynamics of all discrete potential operational states the GFS is able to assume, and that model is based on an operational behaviour paradigm, then it could be used for research into an operational perspective on the GFS and its systemic risk of failure. *From assertions a, f and g.*	**I** and **VIII**	✓			
C2. In that model, systemic failure of the GFS could be understood to materialize as: an operational state that defines the system-wide consequence of aggregate distress among system operations exceeding distress tolerance and resilience criteria; producing a sustained inability of the entire system to operate as required. *From assertions c and d*	**III and VI**			✓	
C3. From which, distress in the GFS could be interpreted by the model as: an operational process whereby undesirable effects for system participants arise from participation behaviour in a part of the system; that become unsupportive of overall system operations; generating perceived disincentives or actual barriers to supportive participation in other parts of the system, or perceived incentives for unsupportive participation. *From assertion i*	**VIII**	✓			

C4. This operational interpretation implies that distress propagates from where it arises to other parts of the GFS by: some collective behaviour transmission mechanism that spreads concentrations in unsupportive participation behaviour; increasing the intensity of collective focus on that behaviour; and generating further distress in more parts; to potentially emerge as a shift in the system's actual operational state. *From assertion i*	**IV**			✓	
C5. A succession of such shifts in actual operational states over a period of elapsed time could therefore be used in a theory to represent GFS operational behaviour, such as: catastrophic instability, or total collapse, when those shifts end in an actual operational state of systemic failure. *From assertions a, f and g.*	**I** and **VIII**	✓			
C6. Which suggests that systemic risk of failure could be defined for the GFS as: the probability at a current time that a series of potential operational states of the GFS will manifest an operational behaviour capable of leading to the materialization of that risk as an actual operational state of systemic failure; by a specified time in the future; in the absence of new efforts to mitigate that risk; through some process of distress generation and propagation; to emerge in the economic environment as a financial crisis. *From assertion h.*	**IX**		✓		
C7. A model based on this definition could be used to select appropriate techniques for the assessment and mitigation of the effects of collective operational distress, in a pre-emptive or reactive response that diverts catastrophic operational behaviour before an actual operational state of systemic failure becomes unavoidable. *From assertions b, d and e.*	**II V and VII**				✓
C8. The GFS could therefore be shown to interact with its economic environment by a two-way process of transformation between its endogenous operational behaviour and exogenous macro-economic circumstances. *From assertion j.*	**X**	✓			

Table 32: Addressing Gaps in Explanatory Value

D.5 Thematic Analysis (explanatory gap details) – Scored

Table 33: Thematic Analysis

Thematic Analysis of Core Literature (with Explanatory Value Scores by Context)					
	EXPLANATORY VALUE				
CONTEXT **Conversations or Lines of Thinking (LoT) /** ↳ **Questions /** ↳ **Answer (Themes) /** ↳ **Core Contributions** (only categories with data are shown)	**a. Coverage Weighting** (1=partial, 2=broad) ↓	**b. Score** (1=implies, 2=supports, 3=introduces) ↓	**Weighted Score a** x **(highest b)** ↓	**Distinct Insights Count** ↓	**Insight Relevance to Thematic Analysis Context** (from title or claim/s of contribution, Appendix G)
S01 Discussions: about theory development Not mapped to questions (contributions cited in section 6 of this systematic review)					
S02 Assessments: of a potential gap in theory informing the research problem Not mapped to questions (contributions cited in section 6 of this systematic review)					
S03 Theories: about systemic risk				**49**	
S03.1 – Candidate theories of systemic risk				**8**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		3	4	
A Theory of Systemic Fragility *(Minsky, 1977)*		1			Theory, systemic fragility
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Model, systemic events and risk
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Conceptual framework,

					systemic risk of linkages
A theory of systemic risk and design of prudential bank regulation (*Acharya, 2009)*		3			Theory, systemic risk
A2 - Its nature is Critical	1		3	1	
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Framework, critical losses and systemic risk
A3 - Its nature is Global	1		2	1	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Government measures, systemic risk
A4 - Its nature is Financial	1		3	1	
Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		3			Theory, risks of financial intermediation
A5 - Its nature is Structural	1		2	1	
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Theory, structural fragility and systemic risk
Q2 - What is meant by the risk of such an occurrence?					
A1 - It is defined by its Causes	1		3	2	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Propagation of economic distress
A theory of systemic risk and design of prudential bank regulation (*Acharya, 2009)*		3			Endogenously chosen correlation of returns on assets held by banks
A3 - It is defined by its Causes and Consequences	1		2	2	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Various shocks severely disrupting financial markets
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Structural weaknesses that create vulnerabilities in financial markets
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	4	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Non-rational responses
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Constructive ambiguity
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Market behaviour
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
A2 - Through participation in systemically important financial services	1		3	1	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank lending stress
A3 - Through interactions with the system's infrastructure	2		6	6	

Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Financial markets
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank linkages
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Global economic architecture
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Regulatory mechanisms
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Major financial institutions
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Financial system structure
A4 - Through interactions with the system's economic environment	1		3	3	
A Theory of Systemic Fragility *(Minsky, 1977)*		2			Depression
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Economic architecture
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Macro-financial conditions
Q4 - What could be done to mitigate that risk?					
A2 - Modify participation in systemically important financial services	1		3	1	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Introduce discounted lending
A3 - Modify interactions with the system's infrastructure	2		6	6	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Introduce shock prevention and response policies
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Enable 'autarky' in bank monitoring
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Modify bankruptcy procedures in a crisis
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Mitigate aggregate risk-shifting incentives
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Charge an insurance premium
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Quantify structural issues in early warning systems
A4 – Modify interactions with the system's economic environment	1		2	2	
A Theory of Systemic Fragility *(Minsky, 1977)*		1			Increase deficit
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Introduce new governmental measures
S03.2 - Other insights				**48**	
S03.21 - Catastrophe				**3**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					

A1 - Its nature is Systemic	2		4	1	
Systemic risks in society and economics (*Helbing, 2009*)		2			Large scale, complex
A2 – Its nature is Critical	2		6	2	
A catastrophe model of bank failure (*Ho and Saunders, 1980*)		3			Cusp model
Analysis of Financial Crisis~ A Perspective Based on Catastrophe Theory (*Yang, Mu and Yao, 2009*)		2			Cusp model
Q2 - What is meant by the risk of such an occurrence?					
Q3 - How does that risk materialize?					
Q4 - What could be done to mitigate that risk?					
S03.22 - Evaluation				**19**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	5	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Benchmarking peers
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Behavioural risk framework
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		3			Ratings maps
Redefining and containing systemic risk *(Kane, 2010)*		3			Measuring regulatory safety-net exposures
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Stress tests
A2 - Through participation in systemically important financial services	1		3	5	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Benchmarking lending
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Provisioning
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Large investment portfolio exposures
The background to the 2007 financial crisis *(Goodhart, 2007)*		1			Under-pricing of risk
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Correlation of returns on assets
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		1			Credit growth
A3 - Through interactions with the system's infrastructure	1		3	3	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		3			Bank failure
Regulating Systemic Institutions *(Rochet, 2009)*		3			Measures of systemic risk exposures
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Too big / connected to fail

A4 - Through interactions with the system's economic environment	1		3	1	
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		3			Risk premia of economic shocks
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		3	2	
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			compensation framework for re-alignment
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Effects of downgrading risks
A2 - Modify participation in systemically important financial services	1		2	6	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Credit portfolio changes
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Portfolio sizes
The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Product-level leverage
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Capital reserves analysis
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		1			Stress- testing results
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		1			Interbank lending activity
A3 - Modify interactions with the system's infrastructure	1		2	6	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Track bankruptcies
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Track correlation of returns on assets
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		1			Track insurance premium
Redefining and containing systemic risk *(Kane, 2010)*		1			Monitor incentives
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Analyse stress-tests and loan guarantees
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Monitor early warning systems
A4 – Modify interactions with the system's economic environment	1		1	3	
A Theory of Systemic Fragility *(Minsky, 1977)*		1			Monitor deficit
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		1			Measure rate of inflation
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		1			Measure credit growth
S03.23 - Propagation				**9**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					

A1 - Its nature is Systemic	1		3	6	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Economic distress propagation system-wide through financial transactions
Systemic risk - A survey (*Bandt and Hartmann, 2000*)		1			Contagion paradigm missing
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Propagation of shocks
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Spreading of bank failures throughout the banking system
Systemic risks in society and economics (*Helbing, 2009*)		2			Cascading effects
A model of a systemic bank run *(Uhlig, 2010)*		2			Occurrence of systemic bank runs
A4 – Its nature is Financial	1		3	1	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Aggregate risk shifting
A5 – Its nature is Structural	1		2	3	
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Occurrence of individual bank runs
Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		2			Propagation of negative effects
Systemic risk in the financial sphere – Theoretical study and approaches to its estimation (*Govtvan and Mansurov, 2011*)		2			Accumulation of risk potential
Q2 - What is meant by the risk of such an occurrence?				3	
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	3	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank lending
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Propagation of shocks
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Spreading of bank failures throughout the banking system
A2 - Through participation in systemically important financial services	2		6	2	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Aggregate risk shifting
Systemic risk in the financial sphere – Theoretical study and approaches to its estimation (*Govtvan and Mansurov, 2011*)		3			Accumulation of risk potential
A3 - Through interactions with the system's infrastructure	2		4	3	
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Occurrence of individual bank runs

Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		2			Propagation of negative effects
A model of a systemic bank run *(Uhlig, 2010)*		2			Occurrence of systemic bank runs
A4 - Through interactions with the system's economic environment	2		4	1	
Systemic risks in society and economics (*Helbing, 2009*)		2			Cascading effects
Q4 - What could be done to mitigate that risk?					
S03.24 - Network				**1**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A4 - Its nature is Financial	2		4	1	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Interbank monitoring
Q2 - What is meant by the risk of such an occurrence?					
Q3 - How does that risk materialize?					
A2 - Through participation in systemically important financial services	1		4	1	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Interbank lending stress
A3 - Through interactions with the system's infrastructure	1		4	1	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Interbank linkages
Q4 - What could be done to mitigate that risk?					
S03.25 - Criticality				**5**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		1	1	
Systemic risks in society and economics (*Helbing, 2009*)		1			Tipping points and peturbations
A2 - Its nature is Critical	1		2	4	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Sudden crashes
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Critical point
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Critical points
Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Complexity and crises
Q2 - What is meant by the risk of such an occurrence?					
Q3 - How does that risk materialize?					
A3 - Through interactions with the system's infrastructure	1		2	2	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money markets
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Dynamic linkages

Q4 - What could be done to mitigate that risk?					
S03.26 - Operations				**8**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A4 - Its nature is Financial	1		2	2	
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Derivative operations
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Bailout operations
A5 - Its nature is Structural	1		3	1	
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Concentrations in operations
Q2 - What is meant by the risk of such an occurrence?					
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	2	
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Dealer bank operations
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Short selling operations
A2 - Through participation in systemically important financial services	1		2	4	
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Trading derivatives
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Intermediation in securities and derivatives
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		1			Securities operations
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		1			Interbank operations
A3 - Through interactions with the system's infrastructure	1		2	2	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money market operations
Economic models of systemic risk in financial systems *(Loretan, 1996)*		1			Financial market operations
Q4 - What could be done to mitigate that risk?					
A3 - Modify interactions with the system's infrastructure	1		2	1	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Shock prevention and response
S03.27 - Behaviour				**38**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	2		6	6	
A Theory of Systemic Fragility *(Minsky, 1977)*		2			Money market reversals, systemic fragility, depression / inflation

Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Various shocks severely disrupt financial systems
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Economic distress propagated system-wide through financial transactions
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			When many banks fail together throughout the banking system
Systemic risks in society and economics (*Helbing, 2009*)		2			Theories, systemic risk
A model of a systemic bank run *(Uhlig, 2010)*		2			Model, systemic bank run
A4 - Its nature is Financial	1		3	3	
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Framework, financial
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Framework, financial
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Systemic collapse of financial institutions' net worth, beyond the protection of bailouts
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	28	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Adverse selection, moral hazard
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Government intervention
Economic models of systemic risk in financial systems *(Loretan, 1996)*		3			Non-rational responses
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Constructive ambiguity
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Market behaviour
Financial crises and the challenge of moral hazard *(Wolf, 1999)*		2			Moral hazard
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Moral hazard, leverage
Bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005)		3			Bank provisioning
Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		3			Manias, panics, bubbles
The background to the 2007 financial crisis (Goodhart, 2007)		2			Under-pricing of risk
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Weak capitalization
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Behavioural biases
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		2			Adverse selection, moral hazard

	Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Procyclical policies
	Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Capital buffer reduction
	Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			'Switching' expectations
	The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Ratings downgrading
	The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Bank runs
	Redefining and containing systemic risk *(Kane, 2010)*		2			Misaligned incentives
	Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Short selling
	Intellectual Hazard: how Conceptual Biases in Complex Organizations Contributed to the Crisis of 2008 *(Miller and Rosenfield, 2010)*		3			Conceptual bias
	The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Euphorias
	Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Exploiting protection
	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Bounded rationality
	A model of a systemic bank run *(Uhlig, 2010)*		2			Bank run
	Diversification at financial institutions and systemic crises *(Wagner, 2010)*		1			Diversification
	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Intervention
	A2 - Through participation in systemically important financial services	2		6	13	
	Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Credit effects on GDP
	An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		3			Portfolio sizes
	Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Misaligned compensation on structured finance
	Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		3			Risky loan portfolios
	The great financial crisis *(Foster and Magdoff, 2009)*		3			Investment in failing hedge funds
	The corporate treasurer - Playing the leading role (Hart, 2009)		2			Trading complex financial instruments
	Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Behavioural effects of credit derivatives
	Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Regulation laxity in sub-prime mortgages
	The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		1			Ratings downgrades
	The financial crisis and its issues *(Bexley et al, 2010)*		2			Holding toxic assets
	The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Failed intermediation in securities and derivatives

Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Holding securities that are being sold short
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Providing capital for counterparty risk cover
A4 - Through interactions with the system's economic environment	2		6	8	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Depression
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Global debt-deflation
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		3			Monetary policy
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			GDP cycles
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Expanding economy
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Credit cycles
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	2		6	9	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Expand the lender of last resort role
Financial crises and the challenge of moral hazard *(Wolf, 1999)*		2			Reduce 'Riskier' behaviour
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		3			Limit firm-level leverage
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Allow for cyclicality
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Increase intervention
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Align compensation with intended behaviour
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		1			Resist over-regulation
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Include downgrade risks in stress testing
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Improve risk management
A2 - Modify participation in systemically important financial services	2		6	13	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Introduce discounted lending
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Address asymmetric information
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Review credit portfolio
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Limit Portfolio sizes

The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Limit product-level leverage
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Increase transparency
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Optimize capital reserves
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			More frequent stress- testing and mitigation
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Improve enforcement of existing rules
Intellectual Hazard: how Conceptual Biases in Complex Organizations Contributed to the Crisis of 2008 *(Miller and Rosenfield, 2010)*		2			Reform and simplify complexities
A model of a systemic bank run *(Uhlig, 2010)*		1			Purchase troubled assets
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Provide stress-test info and loan guarantees
S03.3 - Related concepts Not mapped to questions (contributions cited in overall recommendations)					
S03.4 - Foundational contributions Not mapped to questions (contributions cited in overall recommendations)					
S04 Perspectives: on the system				**53**	
S04.1 - Banking				**18**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	2		6	4	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank system
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Banking system
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Central bank and banking system
A model of a systemic bank run *(Uhlig, 2010)*		2			Model, banking system
A2 - Its nature is Critical	1		3	1	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		3			Model, banking system
A4 - Its nature is Financial	2		6	4	
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Banking system
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Model, banking system
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Model, banking
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Banking system bailouts
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	9	

Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Banking behaviour
Bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005)		3			Bank provisioning
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Banking behaviour
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		2			Banking competition
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		1			Banking behaviour
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Banking sub-system
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Banking behaviour
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Banking rationality
A model of a systemic bank run *(Uhlig, 2010)*		3			Banking panics
A2 - Through participation in systemically important financial services	2		6	6	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank services
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		2			Banking portfolios
The corporate treasurer - Playing the leading role (Hart, 2009)		3			Banking proprietary trading
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Banking derivatives trading
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Banking capital adequacy
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Banking intermediation in securities and derivatives
A3 - Through interactions with the system's infrastructure	2		6	6	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Banking collapse
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Banking regulations
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Banking, state support framework
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Banking, plus
Regulating Systemic Institutions *(Rochet, 2009)*		3			Banking supervision
A4 - Through interactions with the system's economic environment	1		3	3	
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Banking system types
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Banking induced cycles
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Banking shocks
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	2	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Change banking cyclicality
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Improve banking risk management

A2 - Modify participation in systemically important financial services	1		3	3	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank discounted lending
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Improve banking capital reserves
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Interbank loan guarantees
A3 - Modify interactions with the system's infrastructure	2		6	6	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Banks' mutual monitoring
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Improve banking regulation
Regulating Systemic Institutions *(Rochet, 2009)*		2			Reform interbank markets
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Introduce 'too big to fail' policies
A model of a systemic bank run *(Uhlig, 2010)*		2			Purchase banking assets
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide stress-test info and loan guarantees
A4 – Modify interactions with the system's economic environment	1		2	2	
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Calibrate better policy responses
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*	2				Improve monetary policy
S04.2 - Complex				**7**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		2	2	
Economic models of systemic risk in financial systems *(Loretan, 1996)*					Complex dynamics
Systemic risks in society and economics (*Helbing, 2009*)		2			Dynamic complexity
Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		2			Complexity, systemic risk
A2 - Its nature is Critical	1		3	4	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		3			Model, catastrophe
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Losses of major financial institutions reach a critical point, and they fail
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Theory, catastrophe
Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Theory, critical states
Q2 - What is meant by the risk of such an occurrence?					n/a

Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		1	1	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		1			Complex dynamics
A3 - Through interactions with the system's infrastructure	1		2	2	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Complex system
Economic models of systemic risk in financial systems *(Loretan, 1996)*		1			Complexity of financial markets
Q4 - What could be done to mitigate that risk?					
A3 - Modify interactions with the system's infrastructure	1		1	1	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		1			Introduce shock prevention and response policies
S04.3 - Economic				**29**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		2	3	
A Theory of Systemic Fragility *(Minsky, 1977)*		2			Money market reversals, systemic fragility, depression / inflation
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Various shocks severely disrupt financial systems
Systemic risks in society and economics (*Helbing, 2009*)		2			Theories, systemic risk
A3 - Its nature is Global	1		3	1	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
A4 - Its nature is Financial	1		2	7	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		2			Perspective, financial
The Financial Instability Hypothesis *(Minsky, 1993)*		2			Hypothesis, financial
Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		1			Framework, financial
Equilibrium analysis, banking and financial instability (Tsomocos, 2003)		2			Model, financial
Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		2			Emergence of various financial crisis scenarios
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		1			Model, bank capital
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		1			Model, banking
Q2 - What is meant by the risk of such an occurrence?					n/a

Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	5	
The Financial Instability Hypothesis *(Minsky, 1993)*		2			Government intervention
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Non-rational responses
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		1			Market behaviour
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Euphorias
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Intervention
A2 - Through participation in systemically important financial services	1		2	6	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		2			Inefficient financial markets
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		1			Bad credit risks
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Credit effects on GDP
The great financial crisis *(Foster and Magdoff, 2009)*		1			Investment in failing hedge funds
The financial crisis and its issues *(Bexley et al, 2010)*		1			Holding toxic assets
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		2			Credit growth
A3 - Through interactions with the system's infrastructure	1		2	1	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Global economic architecture
A4 - Through interactions with the system's economic environment	2		6	17	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Depression
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Economic architecture
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		3			Global debt-deflation
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Monetary policy
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			GDP cycles
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Boom and bust phases
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Monetary policies
The great financial crisis *(Foster and Magdoff, 2009)*		3			Growth and stagnation
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Expanding economy
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Macro-financial conditions
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Global trade contraction
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Policy mistakes

The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Business cycles / shocks
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		1			Credit cycles
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		2			Recessions, slumps and turnarounds
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	1	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Allow for cyclicality
A2 - Modify participation in systemically important financial services	1		2	1	
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Provide interbank loan guarantees
A3 - Modify interactions with the system's infrastructure	1		3	3	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		3			Introduce shock prevention and response policies
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Provide stress-test info and loan guarantees
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Quantify structural issues in early warning systems
A4 – Modify interactions with the system's economic environment	2		6	13	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Increase deficit
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Stabilize financing regime
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Introduce new governmental measures
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		3			Revise expectations
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Limit rate of inflation
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Manage scope and direction of money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Restructure for boom and bust phases
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Acquire real-time investment information
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Manage shocks and risk premia expectations
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Balance stimulus versus consolidation trade-off
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		1			Calibrate better policy responses

	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Improve monetary policy
	Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Manage credit growth
S04.4 - Financial					**49**	
Q1 -	What is the nature of catastrophic instability or total collapse of this system?					
	A1 - Its nature is Systemic	1		2	5	
	A Theory of Systemic Fragility *(Minsky, 1977)*		2			Money market reversals, systemic fragility, depression / inflation
	Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Various shocks severely disrupt financial systems
	Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Model, systematic effects
	Systemic risks in society and economics (*Helbing, 2009*)		1			Theories, systemic risk
	Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		2			Theoretical, systemic risk
	A2 - Its nature is Critical	1		3	3	
	A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Losses of major financial institutions reach a critical point, and they fail
	Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		3			Theory, catastrophe
	Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Theory, critical states
	A3 - Its nature is Global	1		2	4	
	Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Financial framework
	Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		1			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
	Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Theory review, global
	Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Theory, global
	A4 - Its nature is Financial	2		6	10	
	Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Perspective, financial
	The Financial Instability Hypothesis *(Minsky, 1993)*		3			Hypothesis, financial
	Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		3			Framework, financial

Equilibrium analysis, banking and financial instability (Tsomocos, 2003)		2			Model, financial
Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		3			Emergence of various financial crisis scenarios
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		2			Framework, financial
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Framework, financial
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Model, bank capital
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Model, banking
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Systemic collapse of financial institutions' net worth, beyond the protection of bailouts
A5 - Its nature is Structural	1		2	2	
New thinking on the financial crisis (*Allen and Snyder, 2009*)		1			Constructs, meso-structures
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			When levels of concentration and inter-dependency become untenable for the structures of financial systems
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	16	
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Government intervention
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Non-rational responses
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Constructive ambiguity
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Market behaviour
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Moral hazard, leverage
Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		3			Manias, panics, bubbles
The background to the 2007 financial crisis (Goodhart, 2007)		2			Under-pricing of risk
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Weak capitalization
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Procyclical policies
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Capital buffer reduction
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		1			'Switching' expectations
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		1			Ratings downgrading
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Short selling

A model of a systemic bank run *(Uhlig, 2010)*		1			Bank run
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Intervention
A2 - Through participation in systemically important financial services	2		6	20	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		2			Inefficient financial markets
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank lending stress
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		3			Bad credit risks
The nature of systemic risk - trying to achieve a definition *(Mundy, 2004)*		1			Uninsurable risks
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Credit effects on GDP
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Portfolio sizes
The background to the 2007 financial crisis *(Goodhart, 2007)*		1			Risky assets
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		1			Misaligned compensation on structured finance
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		2			Risky loan portfolios
The great financial crisis *(Foster and Magdoff, 2009)*		2			Investment in failing hedge funds
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Trading complex financial instruments
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Behavioural effects of credit derivatives
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		1			Regulation laxity in sub-prime mortgages
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Ratings downgrades
The financial crisis and its issues *(Bexley et al, 2010)*		1			Holding toxic assets
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Failed intermediation in securities and derivatives
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Holding securities that are being sold short
Insurance Companies and the Financial Crisis *(Schich, 2010)*		2			Insurance of mortgage-backed securities
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Providing capital for counterparty risk cover
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Credit growth
A3 - Through interactions with the system's infrastructure	1		3	5	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money market

Economic models of systemic risk in financial systems *(Loretan, 1996)*		3			Financial markets
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		1			Interbank linkages
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Major financial institutions
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Financial system structure
A4 - Through interactions with the system's economic environment	2		6	7	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Depression
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Global debt-deflation
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			GDP cycles
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Macro-financial conditions
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Recessions, slumps and turnarounds
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	2		4	8	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		2			Expand the lender of last resort role
Financial crises and the challenge of moral hazard *(Wolf, 1999)*		2			Reduce 'Riskier' behaviour
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		1			Limit firm-level leverage
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Allow for cyclicality
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Increase intervention
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		1			Resist over-regulation
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Include downgrade risks in stress testing
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Improve risk management
A2 - Modify participation in systemically important financial services	1		3	6	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Introduce discounted lending
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Review credit portfolio
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Limit Portfolio sizes
The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Limit product-level leverage
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Optimize capital reserves
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti,*		3			Provide interbank loan

Di Filippo and Harris, 2011)					guarantees
A3 - Modify interactions with the system's infrastructure	1		3	9	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Introduce shock prevention and response policies
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Mitigate aggregate risk-shifting incentives
New thinking on the financial crisis (*Allen and Snyder, 2009*)		1			Use infrastructure simulation for predictions
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Enforce regulations internationally
The financial crisis and its issues *(Bexley et al, 2010)*		3			Re-introduce something like Glass-Steagall Act
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Improve enforcement of existing rules
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Provide stress-test info and loan guarantees
The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		1			Strengthen the meta-regulation framework
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		1			Quantify structural issues in early warning systems
A4 – Modify interactions with the system's economic environment	1		3	5	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Increase deficit
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Stabilize financing regime
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		2			Manage scope and direction of money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Restructure for boom and bust phases
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Manage shocks and risk premia expectations
S04.5 - Insurance					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A2 - Through participation in systemically important financial services	1		2	2	
The nature of systemic risk - trying to achieve a definition *(Mundy, 2004)*		1			Uninsurable risks
Insurance Companies and the Financial Crisis *(Schich, 2010)*		2			Insurance of mortgage-

					backed securities
Q4 - What could be done to mitigate that risk?					
A3 - Modify interactions with the system's infrastructure	1		1	1	
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*			1		Charge an insurance premium
S04.6 - Market					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		2	1	
A Theory of Systemic Fragility *(Minsky, 1977)*		2			Money market reversals, systemic fragility, depression / inflation
A5 - Its nature is Structural	1		4	3	
New thinking on the financial crisis (*Allen and Snyder, 2009*)		1			Constructs, meso-structures
Regulating Systemic Institutions *(Rochet, 2009)*		2			Extreme stress in interbank and money markets
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			When levels of concentration and inter-dependency become untenable for the structures of financial systems
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	3	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		1			Market behaviour
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Short selling
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Intervention
A2 - Through participation in systemically important financial services	1		3	2	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Inefficient financial markets
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Holding securities that are being sold short
A3 - Through interactions with the system's infrastructure	1		2	3	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		1			Money market
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Financial markets
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Financial system structure

Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	1	
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Include downgrade risks in stress testing
A2 - Modify participation in systemically important financial services	1		3	3	
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Optimize capital reserves
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		3			More frequent stress- testing and mitigation
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide interbank loan guarantees
A3 - Modify interactions with the system's infrastructure	1		3	3	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Enable 'autarky' in bank monitoring
Regulating Systemic Institutions *(Rochet, 2009)*		3			Reform interbank markets
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide stress-test info and loan guarantees
S04.7 - Operational					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A2 - Its nature is Critical	1		2	2	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Interaction between regulators and depositors
Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Econophysics and volatility clustering in banking systems
A3 - Its nature is Global	1		2	2	
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Adverse selection and 'lemons problem'
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	4	
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Bank runs
A model of a systemic bank run *(Uhlig, 2010)*		2			Bank run

Diversification at financial institutions and systemic crises *(Wagner, 2010)*		1			Diversification
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		1			Intervention
A2 - Through participation in systemically important financial services	1		2	7	
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Portfolio sizes
The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Risky assets
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		2			Misaligned compensation on structured finance
The corporate treasurer - Playing the leading role (Hart, 2009)		2			Trading complex financial instruments
The financial crisis and its issues *(Bexley et al, 2010)*		2			Holding toxic assets
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		1			Failed intermediation in securities and derivatives
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Holding securities that are being sold short
A4 - Through interactions with the system's economic environment	1		1	1	
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		1			Cross-border money flows
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	2		6	7	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		1			Expand the lender of last resort role
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Limit firm-level leverage
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		1			Allow for cyclicality
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Increase intervention
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Align compensation with intended behaviour
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Include downgrade risks in stress testing
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Improve risk management
A2 - Modify participation in systemically important financial services	2		6	8	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Introduce discounted lending
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		1			Address asymmetric information
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Limit Portfolio sizes

	The background to the 2007 financial crisis *(Goodhart, 2007)*		3			Limit product-level leverage
	The corporate treasurer - Playing the leading role (Hart, 2009)		1			Increase transparency
	Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Optimize capital reserves
	The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			More frequent stress- testing and mitigation
	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide interbank loan guarantees
	A3 - Modify interactions with the system's infrastructure	2		6	10	
	Economic models of systemic risk in financial systems *(Loretan, 1996)*		1			Introduce shock prevention and response policies
	Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		1			Enable 'autarky' in bank monitoring
	Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Modify bankruptcy procedures in a crisis
	Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		3			Enforce regulations internationally
	A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Charge an insurance premium
	The financial crisis and its issues *(Bexley et al, 2010)*		3			Re-introduce something like Glass-Steagall Act
	The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Introduce 'too big to fail' policies
	Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Improve enforcement of existing rules
	A model of a systemic bank run *(Uhlig, 2010)*		3			Purchase troubled assets
	The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		1			Strengthen the meta-regulation framework
S04.8 - Regulatory					**15**	
Q1 -	What is the nature of catastrophic instability or total collapse of this system?					
	A4 - Its nature is Financial	1		3	2	
	Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		3			Framework, financial
	Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Model, bank capital
Q2 - What is meant by the risk of such an occurrence?						n/a
Q3 - How does that risk materialize?						
	A1 - Through the behaviour of systemically important participants	1		3	4	

A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Procyclical regulations
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Capital buffer reduction
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Ratings downgrading
A2 - Through participation in systemically important financial services	1		2	4	
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Weak credit derivatives regulation
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Sub-prime mortgages regulation
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Unregulated agencies
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Securities short-selling
A3 - Through interactions with the system's infrastructure	1		2	2	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Endogenous factors
Regulating Systemic Institutions *(Rochet, 2009)*		2			Supervisory frameworks
A4 - Through interactions with the system's economic environment	1		3	2	
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		3			Monetary policies
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		1			Policy mistakes
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	2		2	3	
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Increase intervention
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		1			Resist over-regulation
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Include downgrade risks in stress testing
A2 - Modify participation in systemically important financial services	1		3	3	
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Optimize capital reserves
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			More frequent stress- testing and mitigation
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide interbank loan guarantees
A3 - Modify interactions with the system's infrastructure	2		3	8	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Mitigate aggregate risk-shifting incentives
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		3			Enforce regulations internationally
Regulating Systemic Institutions *(Rochet, 2009)*		3			Reform interbank markets

	The financial crisis and its issues *(Bexley et al, 2010)*		3			Re-introduce something like Glass-Steagall Act
	The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Introduce 'too big to fail' policies
	Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Improve enforcement of existing rules
	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Provide stress-test info and loan guarantees
	The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		2			Strengthen the meta-regulation framework
S05 Definitions: for systemic risk					**16**	
Q1 -	What is the nature of catastrophic instability or total collapse of this system?					
Q2 -	What is meant by the risk of such an occurrence?					
	A1 – It is defined by its Causes	2		4	6	
	Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Propagation of economic distress
	What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (*Dow, 2000*)		2			
	Equilibrium analysis, banking and financial instability (*Tsomocos, 2003*)		2			
	The nature of systemic risk - trying to achieve a definition (*Mundy, 2004*)		1			
	A theory of systemic risk and design of prudential bank regulation (*Acharya, 2009)*		3			Endogenously chosen correlation of returns on assets held by banks
	Redefining and containing systemic risk (*Kane, 2010*)		2			
	A2 – It is defined by its Consequences	1		2	1	
	A framework for assessing the systemic risk of major financial institutions (*Huang, Zhou and Zhu, 2009*)		2			
	A3 – It is defined by its Causes and Consequences	1		2	5	
	Anatomy of a Financial Crisis (*Mishkin, 1992*)		2			
	Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Various shocks severely disrupting financial markets
	Systemic risk (*Schwarcz, 2008*)		2			
	Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		2			
	The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Structural weaknesses that create vulnerabilities in financial markets

A4 – Similar terms and meanings	2		4	5	
Global financial instability - Framework, events, issues (*Mishkin, 1999*)		2			
Systemic risk in the financial sphere - Theoretical study and approaches to its estimation (*Govtvan and Mansurov, 2011*)		2			
Systemic risk - A survey (*Bandt and Hartmann, 2000*)		2			
Systemic risks in society and economics (*Helbing, 2009*)		2			
What is systemic risk, and do bank regulators retard or contribute to it (*Kaufman and Scott, 2003*)		2			
Q3 - How does that risk materialize?					
Q4 - What could be done to mitigate that risk?					
S06 Forms: of distress in the system					
S06.1 – Banking					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	2		6	4	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Economic distress propagated system-wide through financial transactions
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			When many banks fail together throughout the banking system
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Model, systematic effects
A model of a systemic bank run *(Uhlig, 2010)*		2			Model, systemic bank run
A2 - Its nature is Critical	1		3	2	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		3			Catastrophic bank failures
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Losses of major financial institutions reach a critical point, and they fail
A4 - Its nature is Financial	2		4	5	
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		2			Framework, financial
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		2			Framework, financial
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Model, bank capital
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Model, banking
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Systemic collapse of financial institutions' net

					worth, beyond the protection of bailouts
A5 - Its nature is Structural	1		3	1	
Regulating Systemic Institutions *(Rochet, 2009)*		3			Extreme stress in interbank and money markets
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	14	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Constructive ambiguity
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Moral hazard, leverage
Bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005)		3			Bank provisioning
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		2			Adverse selection, moral hazard
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Capital buffer reduction
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Bank runs
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Short selling
Intellectual Hazard: how Conceptual Biases in Complex Organizations Contributed to the Crisis of 2008 *(Miller and Rosenfield, 2010)*		2			Conceptual bias
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Euphorias
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Exploiting protection
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Bounded rationality
A model of a systemic bank run *(Uhlig, 2010)*		3			Bank run
Diversification at financial institutions and systemic crises *(Wagner, 2010)*		2			Diversification
A2 - Through participation in systemically important financial services	2		6	11	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank lending stress
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Credit effects on GDP
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		2			Misaligned compensation on structured finance
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		3			Risky loan portfolios
The great financial crisis *(Foster and Magdoff, 2009)*		3			Investment in failing hedge funds
The corporate treasurer - Playing the leading role (Hart, 2009)		3			Trading complex financial instruments

Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Behavioural effects of credit derivatives
The financial crisis and its issues *(Bexley et al, 2010)*		2			Holding toxic assets
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Failed intermediation in securities and derivatives
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Holding securities that are being sold short
Insurance Companies and the Financial Crisis *(Schich, 2010)*		2			Insurance of mortgage-backed securities
A3 - Through interactions with the system's infrastructure	1		3	5	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money market
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank linkages
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Common response framework
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		1			Major financial institutions
The financial crisis and its issues *(Bexley et al, 2010)*		2			Legal frameworks
A4 - Through interactions with the system's economic environment	2		4	5	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			GDP cycles
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Expanding economy
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Macro-financial conditions
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Business cycles / shocks
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Credit cycles
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		3	2	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Allow for cyclicality
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Improve risk management
A2 - Modify participation in systemically important financial services	1		3	4	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Introduce discounted lending
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Review credit portfolio
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Increase transparency
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide interbank loan guarantees

	A3 - Modify interactions with the system's infrastructure	1		3	4	
	Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Enable 'autarky' in bank monitoring
	The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Introduce 'too big to fail' policies
	A model of a systemic bank run *(Uhlig, 2010)*		3			Purchase troubled assets
	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide stress-test info and loan guarantees
	A4 – Modify interactions with the system's economic environment	1		2	3	
	Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Limit rate of inflation
	The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Calibrate better policy responses
	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Improve monetary policy
S06.2 - Economic						
Q1 -	What is the nature of catastrophic instability or total collapse of this system?					
	A1 - Its nature is Systemic	1		3	4	
	A Theory of Systemic Fragility *(Minsky, 1977)*		2			Systemic fragility and economic depression / inflation
	Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Non-rational responses
	Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Economic distress propagated system-wide through financial transactions
	Systemic risks in society and economics (*Helbing, 2009*)		3			Theories, systemic risk
	A3 - Its nature is Global	1		2	1	
	Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
	A4 - Its nature is Financial	1		3	3	
	The Financial Instability Hypothesis *(Minsky, 1993)*		3			Government intervention
	Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		2			Credit growth
	Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		3			Emergence of various

					financial crisis scenarios
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	5	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Adverse selection, moral hazard
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Government intervention
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Non-rational responses
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Market behaviour
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		1			Euphorias
A2 - Through participation in systemically important financial services	2		6	3	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		2			Inefficient financial markets
The background to the 2007 financial crisis *(Goodhart, 2007)*		1			Risky assets
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Credit growth
A3 - Through interactions with the system's infrastructure	1		3	2	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		1			Financial markets
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Global economic architecture
A4 - Through interactions with the system's economic environment	2		6	17	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Depression
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Economic architecture
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		3			Global debt-deflation
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Monetary policy
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			GDP cycles
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Boom and bust phases
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Monetary policies
The great financial crisis *(Foster and Magdoff, 2009)*		2			Growth and stagnation
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Expanding economy
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Macro-financial conditions
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Global trade contraction
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Policy mistakes
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Business cycles / shocks

Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Credit cycles
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Recessions, slumps and turnarounds
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	1	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Allow for cyclicality
A3 - Modify interactions with the system's infrastructure	1		3	1	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		3			Introduce shock prevention and response policies
A4 – Modify interactions with the system's economic environment	2		6	12	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Increase deficit
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Stabilize financing regime
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Introduce new governmental measures
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Revise expectations
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Limit rate of inflation
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Manage scope and direction of money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Restructure for boom and bust phases
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		3			Manage shocks and risk premia expectations
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Balance stimulus versus consolidation trade-off
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		1			Calibrate better policy responses
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		1			Improve monetary policy
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Manage credit growth
S06.3 - Financial					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	2		6	3	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Various shocks severely

					disrupt financial systems
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		3			Model, systematic effects
Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		1			Theoretical, systemic risk
A2 - Its nature is Critical	1		3	3	
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Losses of major financial institutions reach a critical point, and they fail
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Theory, catastrophe
Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Theory, critical states
A3 - Its nature is Global	2		4	4	
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Framework, global
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		1			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Theory review, global
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Theory, global
A4 - Its nature is Financial	2		6	10	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Perspective, financial
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Hypothesis, financial
Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		3			Framework, financial
Equilibrium analysis, banking and financial instability (Tsomocos, 2003)		2			Model, financial
Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		3			Emergence of various financial crisis scenarios
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		2			Framework, financial
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Framework, financial
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Model, bank capital
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Model, banking
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Systemic collapse of financial institutions' net worth, beyond the protection of bailouts
A5 - Its nature is Structural	2		4	2	
Regulating Systemic Institutions *(Rochet, 2009)*		2			Extreme stress in interbank

					and money markets
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			When levels of financial concentrations and inter-dependencies become untenable for the structures of financial systems
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2			21	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Adverse selection, moral hazard
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Government intervention
Economic models of systemic risk in financial systems *(Loretan, 1996)*		3			Non-rational responses
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Constructive ambiguity
Bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005)		3			Bank provisioning
Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		2			Manias, panics, bubbles
The background to the 2007 financial crisis (Goodhart, 2007)		2			Under-pricing of risk
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Weak capitalization
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Capital buffer reduction
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Ratings downgrading
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		1			Bank runs
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Short selling
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*					Euphorias
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*					Exploiting protection
A model of a systemic bank run *(Uhlig, 2010)*					Bank run
Diversification at financial institutions and systemic crises *(Wagner, 2010)*					Diversification
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*					Intervention
A2 - Through participation in systemically important financial services	2		6	20	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Inefficient financial markets
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank lending stress
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		3			Bad credit risks
The nature of systemic risk - trying to achieve a definition *(Mundy, 2004)*		1			Uninsurable risks
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			Credit effects on GDP

An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		3			Portfolio sizes
The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Risky assets
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		1			Misaligned compensation on structured finance
Bank competition and financial stability *(Berger, Klapper and Turk-Ariss, 2009)*		3			Risky loan portfolios
The great financial crisis *(Foster and Magdoff, 2009)*		3			Investment in failing hedge funds
The corporate treasurer - Playing the leading role (Hart, 2009)		2			Trading complex financial instruments
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Behavioural effects of credit derivatives
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Regulation laxity in sub-prime mortgages
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Ratings downgrades
The financial crisis and its issues *(Bexley et al, 2010)*		3			Holding toxic assets
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		2			Failed intermediation in securities and derivatives
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Holding securities that are being sold short
Insurance Companies and the Financial Crisis *(Schich, 2010)*		1			Insurance of mortgage-backed securities
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Providing capital for counterparty risk cover
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Credit growth
A3 - Through interactions with the system's infrastructure	2		4	12	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money market
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Financial markets
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Interbank linkages
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		1			Global economic architecture
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Regulatory mechanisms
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Meso structures
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Common response framework
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and*		1			Major financial institutions

	Zhu, 2009)					
	Regulating Systemic Institutions *(Rochet, 2009)*		1			Supervisory frameworks
	The financial crisis and its issues *(Bexley et al, 2010)*		2			Legal frameworks
	The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		2			Oversight system
	The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Financial system structure
	A4 - Through interactions with the system's economic environment	2		6	13	
	A Theory of Systemic Fragility *(Minsky, 1977)*		3			Depression
	The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt
	Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Global debt-deflation
	Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Monetary policy
	Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			GDP cycles
	Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
	Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		3			Monetary policies
	The great financial crisis *(Foster and Magdoff, 2009)*		3			Growth and stagnation
	The corporate treasurer - Playing the leading role (Hart, 2009)		2			Expanding economy
	A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Macro-financial conditions
	Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Global trade contraction
	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Credit cycles
	Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Recessions, slumps and turnarounds
Q4 - What could be done to mitigate that risk?						
	A1 - Modify the behaviour of systemically important participants	1		3	3	
	Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Expand the lender of last resort role
	What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		3			Limit firm-level leverage
	Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		3			Align compensation with intended behaviour
	A2 - Modify participation in systemically important financial services	2		6	6	
	Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Introduce discounted lending
	Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Review credit portfolio
	An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Limit Portfolio sizes
	The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Limit product-level leverage
	Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Optimize capital reserves

	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide interbank loan guarantees
	A3 - Modify interactions with the system's infrastructure	1		3	3	
	A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Charge an insurance premium
	Redefining and containing systemic risk *(Kane, 2010)*		3			Re-align incentives
	A model of a systemic bank run *(Uhlig, 2010)*		3			Purchase troubled assets
	A4 – Modify interactions with the system's economic environment	2		6	7	
	A Theory of Systemic Fragility *(Minsky, 1977)*		3			Increase deficit
	The Financial Instability Hypothesis *(Minsky, 1993)*		3			Stabilize financing regime
	Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Revise expectations
	Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Limit rate of inflation
	Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Manage scope and direction of money flows
	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Improve monetary policy
	Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Manage credit growth
S06.4 - Market					**38**	
Q1 -	What is the nature of catastrophic instability or total collapse of this system?					
	A1 - Its nature is Systemic	1		2	2	
	A Theory of Systemic Fragility *(Minsky, 1977)*		2			Money market reversals, systemic fragility, depression / inflation
	Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			When funding markets dry up
	A2 - Its nature is Critical	2		6	4	
	A catastrophe model of bank failure *(Ho and Saunders, 1980)*		3			Model, catastrophe
	A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Losses of major financial institutions reach a critical point, and they fail
	Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Theory, catastrophe
	Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Theory, critical states
	A3 - Its nature is Global	2		4	5	
	Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Framework, global

Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		1			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Theory review, global
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Theory, global
The Global Financial Crisis and the Efficient Market Hypothesis~ What Have We Learned (*Ball, 2009*)		2			Global financial markets are efficient under certain conditions
A4 - Its nature is Financial	2		6	10	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			In financial markets
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Of financial markets
Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		3			Monitoring financial markets
Equilibrium analysis, banking and financial instability (Tsomocos, 2003)		2			Financial markets equilibrium
Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		3			Emergence of financial crisis scenarios in markets
Behavioral Basis of the Financial Crisis *(Rizzi, 2008)*		2			Financial markets behaviour
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Derivatives markets
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Mortgage markets
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Market equilibrium
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Market collapse of financial institutions' net worth, beyond the protection of bailouts
A5 - Its nature is Structural	2		4	3	
New thinking on the financial crisis (*Allen and Snyder, 2009*)		1			Constructs, meso-structures
Regulating Systemic Institutions *(Rochet, 2009)*		2			Extreme stress in interbank and money markets
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			When levels of concentration and inter-dependency become untenable for the structures of financial systems
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					

	A1 - Through the behaviour of systemically important participants	2		6	10	
	Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Market behaviour
	Bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005)		3			Market cycles
	Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		3			Market bubbles
	The background to the 2007 financial crisis (Goodhart, 2007)		3			Risk pricing by markets
	Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Capital markets
	Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Market expectations
	The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		3			Rated markets
	Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Shorting markets
	The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		1			Market euphorias
	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Interbank market collapse
	A2 - Through participation in systemically important financial services	2		6	11	
	Anatomy of a Financial Crisis *(Mishkin, 1992)*		2			Using inefficient financial markets
	Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Offering credit in cyclical markets
	The great financial crisis *(Foster and Magdoff, 2009)*		2			Hedging in investment markets
	The corporate treasurer - Playing the leading role (Hart, 2009)		2			Trading in markets for complex financial instruments
	Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Managing risk through credit derivatives markets
	Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Regulation sub-prime mortgage markets
	The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		3			In rated markets
	Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Holding securities that are being sold short
	Insurance Companies and the Financial Crisis *(Schich, 2010)*		2			Insurance of mortgage-backed securities markets
	Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Providing capital for counterparty risk cover
	Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		2			Credit market excess
	A3 - Through interactions with the system's infrastructure	2		4	4	

A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money market
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Financial markets
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		2			Interbank market
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Meso structures (markets)
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	2	
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Increasing markets intervention
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Resisting over-regulating markets
A2 - Modify participation in systemically important financial services	1		3	3	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Discount lending in interbank market
The corporate treasurer - Playing the leading role (Hart, 2009)		2			Increase market transparency
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Provide loan guarantees for interbank market
A3 - Modify interactions with the system's infrastructure	1		2	2	
Regulating Systemic Institutions *(Rochet, 2009)*		2			Reform interbank markets
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Improve enforcement of existing rules
S06.5 - Monetary				**23**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		2	1	
A Theory of Systemic Fragility *(Minsky, 1977)*		2			Money market reversals, systemic fragility, depression / inflation
A3 - Its nature is Global	1		3	1	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
A4 - Its nature is Financial	2		6	3	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Inability to channel funds to productive investments
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt on system

					behaviour
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Fluctations in bank capital
A5 - Its nature is Structural	1		2	1	
Regulating Systemic Institutions *(Rochet, 2009)*		2			Extreme stress in interbank and money markets
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	6	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Inefficient financial markets
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Economic limitations on capital development
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		3			Excessive financial leverage
The background to the 2007 financial crisis (Goodhart, 2007)		2			Under-pricing of risk
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		3			Weak capitalization
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Capital buffer reduction
A2 - Through participation in systemically important financial services	1		3	3	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Interbank lending stress
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Debt effects on GDP
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Credit growth
A4 - Through interactions with the system's economic environment	2		6	8	
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Impact of debt
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Global debt-deflation
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		1			Monetary policy
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		3			Monetary policies
The great financial crisis *(Foster and Magdoff, 2009)*		3			Growth and stagnation
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Macro-financial conditions
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Credit cycles
Q4 - What could be done to mitigate that risk?					
A4 – Modify interactions with the system's economic environment	2		6	11	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Increase deficit
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Stabilize financing regime
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Introduce new governmental

					measures
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Revise expectations
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		3			Limit rate of inflation
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Manage scope and direction of money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Restructurefor boom and bust phases
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Balance stimulus versus consolidation trade-off
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Calibrate better (monetary) policy responses
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Improve monetary policy
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Manage credit growth
S06.6 - Operational				**8**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		2	1	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Risk correlation operating at a collective level
A2 - Its nature is Critical	1		3	2	
Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		3			Random shocks making its operation impossible
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Non-stationary productivity shocks
A3 - Its nature is Global	1		2	1	
The corporate treasurer - Playing the leading role (Hart, 2009)		2			Challenges of operating in an expanding global economy
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	4	
Diversification at financial institutions and systemic crises (*Wagner, 2010*)		3			Diversified operations make systemic crises more likely
Financial crises and the challenge of moral hazard (*Wolf, 1999*)		2			Disposition to engage in riskier (operational)

					behaviour
Intellectual Hazard – how Conceptual Biases in Complex Organizations Contributed to the Crisis of 2008 (*Miller and Rosenfeld, 2010*)		2			Introduces a tendency to conceptual bias in organizations (that affects operations).
The Failure Mechanics of Dealer Banks (*Duffie, 2010*)		2			Loss of cash settlement privileges
A2 - Through systemically important financial services	1		2	1	
The corporate treasurer - Playing the leading role (Hart, 2009)		2			By using complex financial instruments
S06.7 - Regulatory				**28**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		2	1	
What is systemic risk, and do bank regulators retard or contribute to it (*Kaufman and Scott, 2003*)		2			Reviews historical evidence for systemic risk in banking
A2 - Its nature is Critical	1		3	1	
A catastrophe model of bank failure (*Ho and Saunders, 1980*)		3			Describes the criticality of the relationship between regulatory intervention and depositors' confidence
A3 - Its nature is Global	1		2	1	
Regulatory factors that contributed to the global financial crisis (*Espenilla, 2009*)		2			Identifies weaknesses in the global credit transfer market
A4 - Its nature is Financial	1		3	1	
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Describes regulation of credit cycles and its contribution to financial crises
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	7	
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Government intervention is frequently inept
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Government policies of 'constructive ambiguity'
What is systemic risk, and do bank regulators retard or contribute to it (*Kaufman and Scott,*		2			Concludes that regulators

2003)					'may well have contributed to systemic risk'
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Finds there is a tendency for only 'sporadic and case-by-case intervention' by governments.
The corporate treasurer - Playing the leading role (Hart, 2009)		3			The challenges of operating under acceptable levels of risk, and their systemic impact
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Describes potential regulations to address the bounded rationality of banks
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Argues for central bank intervention by releasing stress-test results for individual banks, issuing interbank loan guarantees, and direct purchase of troubled assets
A2 - Through systemically important financial services	1		3	2	
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Argues against the temporary banning of short selling, by showing that the benefits of allowing shorting far outweigh its potential harm.
A model of a systemic bank run *(Uhlig, 2010)*		3			Argues for the outright purchase of troubled assets by governments
A3 - Through interactions with the system's infrastructure	2		6	4	
The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		3			Concludes the recent crisis was caused by inadequacies of the regulatory oversight system – the meta-regulation framework
Did bank capital regulation exacerbate the subprime mortgage crisis (*Petersen et al, 2009*)		3			Concludes capital regulation

					did exacerbate the crisis, and BASEL II should not be implemented until significant changes are considered
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Regulatory mechanisms are failing to mitigate against risk-shifting incentives
Fair value accounting and the financial crisis- Messenger or contributor *(Magnan, 2009)*		3			Presents evidence for disconnection from a firm's business reality created by fair value accounting
A4 - Through interactions with the system's economic environment	1		3	1	
Regulatory factors that contributed to the global financial crisis (*Espenilla, 2009*)		3			Describes 'economic laxity' and the procyclical nature of monetary policies
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	2		6	5	
Economic models of systemic risk in financial systems *(Loretan, 1996)*		2			Role of policy institutions in mitigation
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		3			Government control over short term capital flows, and bankruptcy procedures in a crisis
The nature of systemic risk - trying to achieve a definition *(Mundy, 2004)*		2			Concludes that governments are required to insure against systemic risks at all costs
The financial crisis and its issues *(Bexley et al, 2010)*		2			Claims government intervention helped to mitigate the recent crisis, after repeal of the Glass-Steagal Act.
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Calls for different policies to address the systemic risk of dealer bank failures
A2 - Modify participation in systemically important financial services	1		3	3	
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Calls for central bank

					intervention as lender of last resort
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks (*Eisenbeis, Frame and Wall, 2007*)		3			Concludes that 'limits on portfolio size …are most desirable approach'
Credit derivatives: Banks' behaviour, financial stability and banking regulation *(Karras, 2009)*		3			Need to regulate the negative behavioural effects of credit derivatives on capital buffer 'stocks'
A3 - Modify interactions with the system's infrastructure	2		6	5	
Financial crisis resolution - The state as a lender of last resort? *(Blankart and Fasten, 2009)*		2			Calls for a common response framework to enforce regulations internationally
Regulating Systemic Institutions *(Rochet, 2009)*		3			Argues the alternative to simply downsizing systemic institutions, by imposing stricter regulations using new measures of systemic risk exposures
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		3			Suggests the use of 'ratings maps' to assess the systemic risk of revised ratings
Redefining and containing systemic risk *(Kane, 2010)*		3			Proposes a new method for measuring regulatory performance, by estimating explicit and implicit safety-net benefits
Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		3			Calls for diagnosis techniques for market tone analysis, and an improved understanding of systemic risk propagation conditions
A4 – Modify interactions with the system's economic environment	1		3	2	
Regulatory factors that contributed to the global financial crisis (*Espenilla, 2009*)		3			Describes 'economic laxity' and the procyclical nature of

					monetary policies
Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Describes monetary responses to credit cycles
S06.8 - Sudden Shock				**6**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		3	1	
Systemic risks in society and economics (*Helbing, 2009*)		3			A sudden large-scale disaster in the collective social dynamics of a socio-economic system
A3 - Its nature is Global	1		2	1	
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Describes an inter-temporal global model of the effects of 'switching' expectations about risk premia
A4 - Its nature is Financial	1		3	1	
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		3			Represented by an open economy real business cycle model, in which there are non-stationary productivity shocks
Q2 - What is meant by the risk of such an occurrence?			n/a		
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	4	
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		3			Shows how moral hazard and leverage of individual firms can create small shocks that are amplified by the financial system
Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		3			Bank failures, fluctuating exchange rates and bubbles in markets are 'systematically' related.
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Increases in risk premia of firms
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Shows how banks

					participate in economic shocks and contribute to euphorias and crises.
A4 - Through interactions with the system's economic environment	1		3	3	
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Cross-border money flows
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		3			Global trade contraction
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Business cycles / shocks
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	1	
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Limit firm-level leverage
A3 - Modify interactions with the system's infrastructure	1		2	1	
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Quantify structural issues in early warning systems
A4 – Modify interactions with the system's economic environment	1		3	3	
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Manage scope and direction of money flows
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		3			Manage shocks and risk premia expectations
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Calibrate better policy responses
S07 Failure: how distress propagates and failure materializes					
S07.1 - Contagion					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		3	3	
Systemic risk - A survey (*Bandt and Hartmann, 2000*)		2			Instability materializes as contagious effects in the system, together with various forms of external effects
Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		3			A financial crisis is considered to be comprised of separate systemic and contagious elements, for predicting contagious difficulties during a time

					period
A model of a systemic bank run *(Uhlig, 2010)*		2			Fear aspects of uncertainty aversion in bank runs
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	1	
Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		3			An event that threatens effective operation of the system of interest
Q4 - What could be done to mitigate that risk?					
S07.2 - Emergence				**9**	
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	2		4	3	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			When many banks fail together through concentrations in risk emergent at collective levels of system operation
Systemic risks in society and economics (*Helbing, 2009*)		3			Emergence in socio-economic systems
Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		2			Emergence as changes in 'market tone' in the system
A2 - Its nature is Critical	1		2	1	
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Emergence as an outbreak of brittleness at critical points
A5 - Its nature is Structural	2		4	2	
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Emergence as complex systems phenomena associated with structural changes
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Emerges as concentrations and inter-dependency that become untenable for the structures of financial systems

Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	2	
Bank provisioning behaviour and procyclicality (Bikker and Metzemakers, 2005)		3			Provisioning for emergent business cycles
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
A2 - Through participation in systemically important financial services	2		6	3	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			Credit effects on GDP
The great financial crisis *(Foster and Magdoff, 2009)*		3			Stagnation interrupted by periods of growth
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Credit growth is single best predictor of emergent financial instability
A3 - Through interactions with the system's infrastructure	1		2	3	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Regulatory mechanisms
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Meso structures
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Structural effects of concentrations and dependencies
A4 - Through interactions with the system's economic environment	2		6	4	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			GDP cycles
New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Boom and bust phases
The great financial crisis *(Foster and Magdoff, 2009)*		3			Growth and stagnation
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Recessions, slumps and turnarounds
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		3	1	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		3			By counter-cyclical credit provisioning for emergent business cycles
A2 - Modify participation in systemically important financial services	1		2	1	
Bank provisioning behaviour and procyclicality *(Bikker and Metzemakers, 2005)*		2			React more closely to changes in credit portfolio
A3 - Modify interactions with the system's infrastructure	1		3	3	
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		2			Mitigate aggregate risk-shifting incentives
New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Use infrastructure simulation

					for predictions
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Quantify structural issues in early warning systems
A4 – Modify interactions with the system's economic environment	1		2	2	
New thinking on the financial crisis (*Allen and Snyder, 2009*)		2			Restructure for boom and bust phases
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		2			Manage credit growth
S07.3 - Collapse					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A1 - Its nature is Systemic	1		3	2	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Money market reversals, systemic fragility, depression / inflation
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			When many banks fail together throughout the banking system
A2 - Its nature is Critical	1		3	4	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		3			Model, catastrophe
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Losses of major financial institutions reach a critical point, and they fail
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Theory, catastrophe
Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		3			Theory, critical states
A3 - Its nature is Global	1		2	1	
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Disasterous short-term capital flows across the GFS, and high levels of bankruptcy
A4 - Its nature is Financial	1		3	1	
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		3			Systemic collapse of financial institutions' net worth, beyond the protection of bailouts
A5 - Its nature is Structural	1		3	2	

Regulating Systemic Institutions *(Rochet, 2009)*		3			Extreme stress in interbank and money markets
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			When levels of concentration and inter-dependency become untenable for the structures of financial systems
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	1	
Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		3			Burst bubbles
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*					'Switching' expectations
A2 - Through participation in systemically important financial services	1		3	2	
The nature of systemic risk - trying to achieve a definition *(Mundy, 2004)*		2			Uninsurable risks
The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Failed intermediation in securities and derivatives
A3 - Through interactions with the system's infrastructure	1		3	3	
A catastrophe model of bank failure *(Ho and Saunders, 1980)*		2			Money market falure
The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		2			Failed oversight system
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Structural failure of the financial system
A4 - Through interactions with the system's economic environment	2		6	9	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Sudden onset of depression
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Extreme impact of debt
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Bottom of global debt-deflation cycle
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Extreme cross-border money flows
New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Bust phase
The great financial crisis *(Foster and Magdoff, 2009)*		3			Stagnation
Modelling the global financial crisis *(McKibbin and Stoeckel, 2009)*		2			Global trade contraction
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Abrupt end of business cycles
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Recessions, slumps
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	1	

	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		2			Improve risk perception and management
	A2 - Modify participation in systemically important financial services	1		2	1	
	The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			More frequent stress- testing and mitigation
	A3 - Modify interactions with the system's infrastructure	1		3	3	
	The financial crisis and its issues *(Bexley et al, 2010)*		3			Re-introduce something like Glass-Steagall Act
	The Failure Mechanics of Dealer Banks *(Duffie, 2010)*		3			Introduce 'too big to fail' policies
	The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Quantify structural issues in early warning systems
	A4 – Modify interactions with the system's economic environment	2		6	6	
	Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		2			Limit rate of inflation
	Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			Manage scope and direction of money flows
	New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Restructure for boom and bust phases
	Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Balance stimulus versus consolidation trade-off
	Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality *(Rotheli, 2010)*		3			Improve monetary policy
	Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Improve credit growth management
S08 Recognition: of the potential for systemic failure						
S08.1 - Early warning systems						
	Q1 - What is the nature of catastrophic instability or total collapse of this system?					
	Q2 - What is meant by the risk of such an occurrence?					n/a
	Q3 - How does that risk materialize?					
	A3 - Through interactions with the system's infrastructure	2		6	5	
	Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		3			Leading indicators
	Comparing early warning systems for banking crises *(Davis and Karim, 2008)*		3			Comparison of techniques
	Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		2			Identifying the propagation of negative effects

Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		2			Warning of changes in 'market tone'
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Warning of structural fragility
Q4 - What could be done to mitigate that risk?					
S08.2 - Criteria					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A3 - Through interactions with the system's infrastructure	2		4	7	
Towards a macro-prudential leading indicators framework for monitoring financial vulnerability *(Bhattacharyay, 2003)*		2			Macro-prudential benchmarks
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		1			Critical points for the emergence of brittleness
Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		2			Standard risk measures for the entire system
Systemic risk in the financial sphere: Theoretical study and approaches to its estimation *(Govtvan and Mansurov, 2011)*		2			Acceptable macro-levels of risk
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		1			Benchmarking against policy expectations
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		2			Theoretical insurance premium
The background to the 2007 financial crisis *(Goodhart, 2007)*		2			Acceptable levels of leverage
Q4 - What could be done to mitigate that risk?					
S08.3 - Stress testing					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	1	
The Systemic Regulation of Credit Rating Agencies and Rated Markets *(Sy, 2009)*		2			Ratings maps
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Central bank intervention effects identified by stress tests
Q4 - What could be done to mitigate that risk?					
S08.4 - Measuring implications					

Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	1	
Regulating Systemic Institutions (*Rochet, 2009*)		2			Loopholes revealed in the supervisory / regulatory framework, with a proposal for using new measures of systemic risk exposure to address the problem
Q4 - What could be done to mitigate that risk?					
S08.5 - Concentrations					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	9	
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Adverse selection, and moral hazard
Financial crises and the challenge of moral hazard (*Wolf, 1999*)		3			Moral hazard
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		3			Moral hazard
Manias, panics, and crashes - A History of Financial Crises (*Kindleberger and Aliber, 2005*)		3			Bubbles
A theory of systemic risk and design of prudential bank regulation *(Acharya, 2009)*		3			Risk correlation
Bank competition and financial stability (*Berger, Klapper and Turk-Ariss, 2009*)		3			Adverse selection, and moral hazard
Regulating Systemic Institutions (*Rochet, 2009*)		3			Too big to fail
The Failure Mechanics of Dealer Banks (*Duffie, 2010*)		3			Too big to fail
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		3			Too big to fail, too connected to fail
A3 - Through interactions with the system's infrastructure	1		2	1	
Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory *(Yang, Mu and Yao, 2009)*		2			Critical points
Q4 - What could be done to mitigate that risk?					
S09 Responses: to the potential for systemic failure					
S09.1 - Governance				**0**	

S09.2 - Intervention					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	1	
Bailouts, the incentive to manage risk, and financial crises (*Panageas, 2010*)		2			Bailouts
A2 - Modify participation in systemically important financial services	1		2	1	
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Inhibit banking innovation
A3 - Modify interactions with the system's infrastructure	2		6	8	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Lender of last resort, and discount window for liquidity
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Discounted lending, and centralized liquidity management
Minsky's Theory of Financial Crises in a Global Context *(Wolfson, 2002)*		2			Lender of last resort
Financial crisis resolution - The state as a lender of last resort (*Blankart and Fasten, 2009*)		3			Lender of last resort
The financial crisis and its issues (*Bexley, James and Haberman, 2010*)		3			Provide funds to institutions in difficulties
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Temporarilly banning short positions in certain securities
A model of a systemic bank run *(Uhlig, 2010)*		2			Outright purchase of troubled assets
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		3			Liquidity support
A4 – Modify interactions with the system's economic environment	1		2	2	
Containment and Resolution in the Financial Crisis~ Too Little, Too Late (Honohan, 2008)		2			Interventions too sporadic
Reforming the global economic architecture~ Lessons from recent crises (*Stiglitz, 1999*)		2			Government intervention frequently inept
S09.3 - Regulation					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		3	2	

A theory of systemic risk and design of prudential bank regulation (*Acharya, 2009*)		3			Regulatory incentives for mitigating aggregate risk-shifting incentives
Regulating Systemic Institutions (*Rochet, 2009*)		3			Close loopholes for the 'too big to fail' problem
A2 - Modify participation in systemically important financial services	1		2	3	
Credit derivatives~ Banks' behaviour, financial stability and banking regulation (*Karras, 2009*)		2			Do not inhibit banking innovation by regulation
Did bank capital regulation exacerbate the subprime mortgage crisis (*Petersen et al, 2009*)		2			Avoid regulatory practices that exacerbated the recent crisis
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		2			Do not introduce a regulatory ban on short-selling
A3 - Modify interactions with the system's infrastructure	2		4	6	
Financial crisis resolution - The state as a lender of last resort (*Blankart and Fasten, 2009*)		2			Systemic risk generated by banking regulation
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Deal with counter-productive regulatory factors
The Systemic Regulation of Credit Rating Agencies and Rated Markets (*Sy, 2009*)		2			Regulate rating agencies
The financial crisis and its issues (*Bexley, James and Haberman, 2010*)		2			Re-introduce something like Glass-Steagall Act
The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		1			Strengthen the meta-regulation framework
Systemic risk in the financial sphere – Theoretical study and approaches to its estimation (*Govtvan and Mansurov, 2011*)		2			Introduce systemic risk estimation techniques in regulation
S09.4 - Risk management					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
Q4 - What could be done to mitigate that risk?					
A1 - Modify the behaviour of systemically important participants	1		2	4	
Equilibrium analysis, banking and financial instability (Tsomocos, 2003)		2			Risk management requirements discussed
Redefining and containing systemic risk *(Kane, 2010)*		2			Redefine the incentives of

					risk managers
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Bailout operations should consider the influence of bankruptcy cost incentives on the risk management attitude of a firm's shareholders
Causes of the financial crisis~ Risk misperception, policy mistakes, and banks' bounded rationality (*Rotheli, 2010*)		2			Address the bounded rationality of risk management
S10 Effects: of systemic failure				**0**	
S11 Recovery: from systemic failure					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
Q4 - What could be done to mitigate that risk?					
A4 – Modify interactions with the system's economic environment	1		3	2	
Policies to rebalance the global economy after the financial crisis (*Freedman et al, 2010*)		2			Consider the systemic risk trade-offs between short-run effects and the long-run effect of economic policies
Financial crisis resolution - The state as a lender of last resort (*Blankart and Fasten, 2009*)		3			Enforce a common resolution policy internationally
S12 Involvement: in the system					
S12.1 - Collective					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	4	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Decentralized bank linkages for mutual lending.

A theory of systemic risk and design of prudential bank regulation (*Acharya, 2009*)		3			Aggregate risk-shifting incentives at a collective level of operations
Manias, panics, and crashes - A History of Financial Crises (*Kindleberger and Aliber, 2005*)		3			The collective failures of banks
Bank competition and financial stability (*Berger, Klapper and Turk-Ariss, 2009*)		3			Tensions between ‘competition fragility’ and ‘competition stability’ issues
Q4 - What could be done to mitigate that risk?					
S12.2 - Deliberate (strategic or tactical)					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	2	
Diversification at financial institutions and systemic crises (*Wagner, 2010*)		3			Diversification makes systemic crises more desirable
Fair value accounting and the financial crisis- Messenger or contributor *(Magnan, 2009)*		3			A disconnection from a firm’s business reality is created by fair value accounting
A2 – Through participation in systemically important financial services	1		3	3	
Credit derivatives~ Banks’ behaviour, financial stability and banking regulation (*Karras, 2009*)		3			CDs used to reduce capital reserves below tenable levels
Insurance Companies and the Financial Crisis (*Schich, 2010*)		2			Insuring mortgage related securities
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Short selling operations
A3 - Through interactions with the system’s infrastructure	1		2	4	
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		1			Differences in banking systems
An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks *(Eisenbeis et al, 2007)*		2			Reducing large investment portfolio exposures
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Providing bailout facilities
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti,*		2			To improve liquidity

Di Filippo and Harris, 2011)					
Q4 - What could be done to mitigate that risk?					
S12.3 - Dysfunctional					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	2		6	12	
A Theory of Systemic Fragility *(Minsky, 1977)*		1			'Ponzi' financing of debt
Behavioral Basis of the Financial Crisis (*Rizzi, 2008*)		3			Misaligned compensation
Bank competition and financial stability (*Berger, Klapper and Turk-Ariss, 2009*)		3			Moral hazard, adverse selection
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Moral hazard, adverse selection
What is systemic risk, and do bank regulators retard or contribute to it (*Kaufman and Scott, 2003*)		2			Counterproductive regulation
Manias, panics, and crashes - A History of Financial Crises (Kindleberger and Aliber, 2005)		3			Manias, panics, bubbles
Financial crises and the challenge of moral hazard *(Wolf, 1999)*		2			Moral hazard
What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation (Dow, 2000)		2			Moral hazard
Global financial instability: Framework, events, issues *(Mishkin, 1999)*		2			Adverse selection
Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States *(McGavin, 2010)*		3			Short selling operations
Bailouts, the incentive to manage risk, and financial crises *(Panageas, 2010)*		2			Exploitation of implicit protection
Redefining and containing systemic risk *(Kane, 2010)*		3			Misaligned incentives
Q4 - What could be done to mitigate that risk?					
S12.4 – Ignorant					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 – Through the behaviour of systemically important participants	1		3	2	
Causes of the financial crisis~ Risk misperception, policy mistakes, and banks' bounded rationality (*Rotheli, 2010*)		3			Bounded rationality
Intellectual Hazard~ how Conceptual Biases in Complex Organizations Contributed to the Crisis of 2008 (*Miller and Rosenfeld, 2010*)		2			Intellectual hazard (i.e. lack of understanding through inadequate education,

					experience or insight)
Q4 - What could be done to mitigate that risk?					
S12.5 - Procedural					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	3	
Behavioral Basis of the Financial Crisis (*Rizzi, 2008*)		2			
Bank competition and financial stability (*Berger, Klapper and Turk-Ariss, 2009*)		2			Competitive banking system
The Failure Mechanics of Dealer Banks (*Duffie, 2010*)		2			Failure resolution policies
A3 - Through interactions with the system's infrastructure	1		3	5	
Containment and Resolution in the Financial Crisis: Too Little, Too Late *(Honohan, 2008)*		2			Regulation
Did bank capital regulation exacerbate the subprime mortgage crisis? *(Petersen et al, 2009)*		2			Regulation
Regulating Systemic Institutions *(Rochet, 2009)*		3			Regulation
Crises in competitive versus monopolistic banking systems *(Boyd, De Nicola and Smith, 2004)*		1			Monopoly versus competition policies
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Failure resolution policies
Q4 - What could be done to mitigate that risk?					
S13 Operations: of the system					
S13.1 – Cycles					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A4 - Through interactions with the system's economic environment	2		6	6	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Economic cycles
The Financial Instability Hypothesis *(Minsky, 1993)*		3			Cycles of instability
Bank provisioning behaviour and procyclicality (*Bikker and Metzemakers, 2005*)		3			Credit provisioning pro-cyclicality
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Procyclical monetary policies
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		3			Open economy real business cycle model
Financial crises, credit booms, and external imbalances: 140 years of lessons *(Jorda, Schularick and Taylor, 2011)*		3			Boom and bust cycles

Q4 - What could be done to mitigate that risk?					
S13.2 – Innovation					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	1	
The corporate treasurer - Playing the leading role (Hart, 2009)		3			Innovative uses of complex financial instruments
A3 - Through interactions with the system's infrastructure	1		3	2	
Regulatory factors that contributed to the global financial crisis *(Espenilla, 2009)*		2			Allowing uninhibited banking innovation
Fair value accounting and the financial crisis- Messenger or contributor *(Magnan, 2009)*		3			Unintended effects of accounting innovations
Q4 - What could be done to mitigate that risk?					
S13.3 – Interconnectedness					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
Q2 - What is meant by the risk of such an occurrence?					n/a
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		3	1	
Interbank lending and systemic risk *(Rochet and Tirole, 1996)*		3			Decentralized bank linkages for mutual lending.
A3 - Through interactions with the system's infrastructure	2		6	6	
New thinking on the financial crisis (*Allen and Snyder, 2009*)		3			Complex systems and meso-structures
Systemic risks in society and economics (*Helbing, 2009*)		2			Non-linear and/or network interactions, collective social dynamics
A framework for assessing the systemic risk of major financial institutions *(Huang, Zhou and Zhu, 2009)*		3			Dynamic linkages between major US banks and macro-financial conditions
Systemic risk, financial contagion and financial fragility (*Martinez-Jaramillo et al, 2010*)		2			Contagion mechanism for propagating negative effects through connections in a financial system
Complexity Theory and the Financial Crisis: a Critical Review *(Zeidan and Richardson, 2010)*		1			Complex systems, network topologies and neural

					networks
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		1			Interbank loan guarantees and counterparty risk
Q4 - What could be done to mitigate that risk?					
S13.4 – Resilience					
Q3 - How does that risk materialize?					
A1 - Through the behaviour of systemically important participants	1		2	2	
Bank provisioning behaviour and procyclicality (*Bikker and Metzemakers, 2005*)		2			Aligning bank credit provisioning to business cycles for improved resilience
The corporate treasurer - Playing the leading role (Hart, 2009)		1			Enterprise-wide risk framework
A3 - Through interactions with the system's infrastructure	1		3	5	
A Theory of Systemic Fragility *(Minsky, 1977)*		3			Systemic fragility
The structural fragility of financial systems *(Gramlich and Oet, 2011)*		2			Financial system structure, vulnerabilities and concentrations
Systemic risks in society and economics (*Helbing, 2009*)		3			Self-organizing, adaptive nature of complex systems, and robustness to external peturbations
Policies to rebalance the global economy after the financial crisis *(Freedman et al, 2010)*		2			Rebalancing policies to be more resilient to short and long-run economic effects
The banking crisis as dynamic stochastic general equilibrium *(Minford, 2010)*		2			Calibrating policy responses to address non-stationary productivity shocks
S13.5 – Visibility					
Q3 - How does that risk materialize?					
A3 - Through interactions with the system's infrastructure	1		3	2	
Fair value accounting and the financial crisis- Messenger or contributor *(Magnan, 2009)*		3			Visibility of fair value accounting in financial institutions' reporting can severely undermine their financial condition
The 2008 financial collapse: Lessons for engineering failure *(Fisk, 2011)*		2			Systemic failure is normally

					due to inadequacies of the oversight system, its meta-regulation framework
Q4 - What could be done to mitigate that risk?					
A3 - Modify interactions with the system's infrastructure	1		3	4	
Anatomy of a Financial Crisis *(Mishkin, 1992)*		3			Address asymmetric information
The Systemic Regulation of Credit Rating Agencies and Rated Markets (*Sy, 2009*)		3			Apply 'ratings maps' in stress tests
The corporate treasurer - Playing the leading role (Hart, 2009)		2			Greater transparency from trading partners
Effects of central bank intervention on the interbank market during the subprime crisis *(Brunetti, Di Filippo and Harris, 2011)*		2			Release stress-test results
S14 Reviews: of systemic crises and failures					
S14.1 - Current crisis					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A4 - Its nature is Financial	2		6	3	
The background to the 2007 financial crisis (*Goodhart, 2007*)		3			
The financial crisis and its issues (*Bexley, James and Haberman, 2010*)		3			
The great financial crisis (*Foster and Magdoff, 2009)*		3			
S14.2 - Other specific crises					
S14.3 - General crises					
Q1 - What is the nature of catastrophic instability or total collapse of this system?					
A4 - Its nature is Financial	2		6	3	
Manias, panics, and crashes - A History of Financial Crises *(Kindleberger and Aliber, 2005)*		3			
Financial crises, credit booms, and external imbalances~ 140 years of lessons (*Jorda, Schularick and Taylor, 2011*)		3			
Understanding financial crises - Clarendon Lectures (*Allen and Gale, 2007*)		3			

D.6 Core Literature Metadata

Authors	Year	Pub Type	Literature Domain Theme	Discipline	Title and Claim/s (summarised using Keywords and phrases from each contribution)	Keywords and Phrases
Minsky	1977	Book	Systemic Risk	Economics	*A Theory of Systemic Fragility* Argues that an incipient **financial crisis** will be triggered when **money market** changes lead to present value reversals or appreciable decreases in their margins of safety. Once 'ponzi' financing of debt reaches significant levels, it is followed either by serious **depression** or the 'floating off' of debt made possible by **inflation** through large increases in **government deficits**.	• **Systemic fragility** • **Financial crisis** • **Money market** • **'Ponzi' financing of debt** • **Depression** • **Inflation** • **Government deficits**
Ho and Saunders	1980	Journal article	Op Behaviour	Complex Sys	*A catastrophe model of bank failure* Offers a **model** showing how interaction of bank management, regulators and depositors can induce **catastrophic failure**. Shows the crucial relationship between the power of **regulatory intervention** and depositors' confidence levels which are both necessary and sufficient for catastrophe to occur. Also argues that catastrophe appears to be more likely for **large money market banks** rather than small banks.	• **Catastrophe model** • **Bank failure** • **Catastrophic failure** • **Regulatory intervention** • **Large money- market banks**
Mishkin	1992	Journal article	Systemic Risk	Economics	*Anatomy of a Financial Crisis* Provides an **asymmetric information framework** and a definition for explaining financial crises. These are used to argue that a **financial crisis** is a disruption to **financial markets** in which **adverse selection** and **moral hazard** problems become much worse,	• **Financial crisis definition** • **Asymmetric information framework** • **Financial markets** • **Adverse selection** • **Moral hazard** • **Lender-of-last-resort role**

					restricting the efficient channelling of funds to those who have the most productive investment opportunities. The framework explains effects beyond those generated by bank panics, and provides a rationale for an expanded **lender-of-last-resort** role for the central bank in which it uses the **discount window** to provide **liquidity** to sectors outside of the **banking system**.	• **Discount window for liquidity** • **Banking system**
Minsky	1993	Book	Systemic Risk	Economics	*The Financial Instability Hypothesis* Argues that, from time to time, **capitalist economies exhibit inflations and debt deflations** which seem to have the potential to spin out of control. In such circumstances the **economic system**'s reactions to a movement of the economy are observed to amplify that movement, while **government intervention**s aimed at containing deterioration in financial stability are frequently inept. An explanation of this systemic behaviour argues a view that is contrary to the accepted views of Smith and Walras, who implied that the economy can best be understood by assuming that it is an equilibrium seeking and sustaining system. By interpreting the substance of Keynes' "General Theory" as describing a particular time in history, and drawing on the credit view of money and finance by Joseph Schumpeter, an alternative view is proposed for the modern world which holds that an understanding of financial relations and their implications cannot be restricted to the liability structure of businesses and the cash flows they entail. This view constitutes a new theory of the **impact of debt (instruments) on systemic behaviour**, incorporating the way	• **Financial instability** • **Capitalist economies exhibit inflations and debt deflations** • **Economic system** • **Government intervention** • **Impact of debt (instruments) on systemic behaviour** • **Cycles of stability.**

					debt is validated. Its first hypothesis holds that the economy has financing regimes in which it is stable and those in which it is unstable. The second hypothesis holds that, over a prolonged period of prosperity, the economy transits from financial relations that make for a stable system to those that make for an unstable system (**cycles of stability**).	
Loretan	1996	Journal article	Systemic Risk	Economics	*Economic models of systemic risk in financial systems* A number of **definitions of systemic risk** are examined. While **various shocks** are often cited as having the potential to severely disrupt the functioning of **financial markets**, an argument is developed that holds it is also necessary to consider the **'nonrational' behavioral responses** of agents involved in these shocks, to fully understand the **dynamics of systemic events**. The **role of policy institutions** in preventing or **mitigating** such events is also considered.	• **Definitions of systemic risk** • **Shocks** • **Financial markets** • **'nonrational' behavioral responses** • **Dynamics of systemic events** • **Role of policy institutions** • **Mitigation**
Rochet and Tirole	1996	Journal article	Systemic Risk	Economics	*Interbank lending and systemic risk* **Systemic risk** is defined as the '**propagation** of an agent's **economic distress** to other agents linked to that agent through financial transactions.' This concept is examined in manufacturing, re**insurance** and banking. Then '**too big to fail**' policies for protecting uninsured depositors of large insolvent banks are considered. Government **authorities** are described as sometimes applying a policy of **'constructive ambiguity'** in their willingness to **intervene** in such circumstances. The	• **Interbank lending** • **Systemic risk definition** • **Propagation** • **Economic distress** • **Insurance** • **Too big to fail** • **Authority intervention** • **'Constructive ambiguity'** • **Mitigation** • **Discounted lending to distressed banks** • **Centralized liquidity**

					mitigation techniques considered include: **discounted lending** by governments **to distressed banks**; **centralizing** the **liquidity management** of banks (by a central bank providing guarantees, or acting as a central **counterparty); or bank transactions** on derivatives market **having collateral conditions applied**. However, **no clear conceptual framework exists** for applying these techniques, and the hybrid nature of the current system of **interbank linkages** (largely decentralized interbank mutual lending, with central government intervention) makes clarity difficult to achieve. A discussion of policy issues leads to a proposed model for **benchmarking** different forms of peer monitoring for failure avoidance and systemic risk mitigation, and comparison with **'autarky'** - where banks do not monitor each other.	**management** • **Collateral conditions on derivatives transactions** • **No clear conceptual framework exists** • **Interbank linkages** • **Benchmarking** • **'Autarky'**
Mishkin	1999	Journal article	Op Behaviour	Economics	<u>*Global financial instability: Framework, events, issues*</u> Defines **financial instability** and shows how it harms economic activity through **asymmetric information** and two basic problems in the **financial system**: **adverse selection** and **moral hazard**. Adverse selection is described as behaviour that occurs before the financial transaction takes place, when potential bad credit risks are the ones who most actively seek out a loan. Moral hazard is described as behaviour that occurs after the transaction takes place, when a borrower has insufficient incentives to pay back the loan because the lender bears most of the loss on that loan if the	• **Global** • **Financial instability definition** • **Asymmetric information** • **Financial system** • **Adverse selection** • **Moral hazard** • **Financial intermediaries**

					borrower defaults. The underlying rationale for involving **financial intermediaries** in such transactions is that they have both the ability and the economic incentive to address problems of asymmetric information.	
Stiglitz	1999	Journal article	Systemic Risk	Risk	*Reforming the global economic architecture: Lessons from recent crises* Focuses on **global financial crises**, and proposes **government measures** to dampen (**mitigate**) **financial instability** and **systemic risk**, including governmental controls over **short-term capital flows** and the modifications of **bankruptcy procedures in a crisis**. Which is followed by a general discussion on the need to: (1) better integrate financial and real economics, (2) be wary of anthromorphizing market behaviour, and (3) reach beyond anecdotes to construct **coherent theoretical models** and undertake empirical testing.	• **Economic architecture** • **Global Financial crises** • **Government measures** • **Mitigation** • **Financial instability** • **Systemic risk** • **Short-term capital flows** • **Bankruptcy procedures in a crisis** • **Need for coherent theoretical models**
Wolf	1999	Journal article	Systemic Risk	Economics	*Financial crises and the challenge of moral hazard* '**Moral hazard**' is defined as a disposition on the part of individuals or organizations to engage in **riskier behavior** because of a tacit assumption that someone else will bear all or part of the costs. Moral hazard decision-making is then considered in the context of financial crises.	• **Financial crises** • **Moral hazard** • **Riskier behavior**
Bandt and Hartmann	2000	Working Paper	Systemic Risk	Economics	*Systemic risk: A survey* Surveys the literature on the broad concept of **systemic risk**, and finds there is a consensus on defining it as comprised of **contagion** effects and various forms of **external** effects. However, the conclusion drawn is that a general	• **Systemic risk definition** • **Contagion and external effects** • **'Theoretical paradigm is still missing'**

					theoretical paradigm is still missing.	
Dow	2000	Journal article	Systemic Risk	Risk	*What is Systemic Risk - Moral Hazard, Initial Shocks and Propagation* Surveys the research on various topics related to **systemic risk**, and examines case studies of **financial crises and failures.** Then discusses the significance of references to **moral hazard** in that literature, and recommends it as a potentially fruitful area for future research. Existing research is described as emphasizing the powerful **propagation mechanisms** whereby a small initial **shock** can be amplified by the **financial system**. However, the combination of moral hazard and **leverage at the level of the individual firm** is argued to be an important cause of initial shocks to the financial system worthy of more research attention.	• **Systemic risk** • **Financial crises and failures** • **Moral hazard** • **Propagation mechanisms** • **Shocks** • **Financial system** • **Firm-level leverage**
Wolfson	2002	Journal article	Op Behaviour	Economics	*Minsky's Theory of Financial Crises in a Global Context* Describes how Minsky's debt-deflation process has so far been averted, and how a **major revision** of the optimistic **expectations** of a boom period has not occurred since the **Great Depression** due to the **intervention** of the Federal Reserve as **lender of last resort**.	• **Global financial crises** • **Major revision of expectations** • **Great Depression** • **Intervention** • **Lender of last resort**
Bhattacharyay	2003	Journal article	Op Behaviour	Economics	*Towards a macro-prudential leading indicators framework for monitoring financial vulnerability* Proposes a **macroprudential indicators** (MPI) framework for **monitoring** the **vulnerability** of **financial markets**. A literature survey on studies of **leading indicators** is presented.	• **Macropruden-tial leading indicators framework** • **Monitoring** • **Vulnerability** • **Financial markets** • **Benchmarks**

					Then an illustrative and simple framework for analysis and interpretation of a core set of 22 leading indicators (that were identified from 67 commonly agreed Asian Development Bank Indicators for selected AsiaPacific countries) is presented using annual time-series data for those countries, with a simple methodology for constructing **benchmarks** for **early warning signals** and for developing a **set of composite indicators**.	• **Early warning signals** • **Set of composite indicators**
Kaufman and Scott	2003	Journal article	Systemic Risk	Risk	*<u>What is systemic risk, and do bank regulators retard or contribute to it?</u>* Discusses the alternative **definitions** and sources of **systemic risk**, briefly reviews the historical evidence of systemic risk in **banking**, and describes how participants in financial markets traditionally have protected themselves from systemic risk. Then **banking regulations** that were adopted to reduce the probability of systemic risk and the damage it causes (its **effects**) are evaluated, and recommendations are made for **mitigating** that risk.	• **Systemic risk definitions** • **Bank regulators** • **Banking system** • **Banking regulations** • **Effects** • **Mitigation**
Tsomocos	2003	Journal article	Systemic Risk	Economics	*<u>Equilibrium analysis, banking and financial instability</u>* Extends the canonical 'General Equilibrium with Incomplete Markets' (GEI) model with money and default to allow for competitive banking and **financial instability**. A non-trivial quantity theory of money is derived and the **model** provides a useful analytical device **for policy analysis** of situations in which crisis prevention (**mitigation**) and (**risk**) **management** become necessary to reduce the risks and costs of	• **Financial instability** • **Quantity theory of money** • **Model for policy analysis** • **Mitigation** • **Risk management**

					financial instability.	
Boyd, De Nicola and Smith	2004	Journal article	Op Behaviour	Economics	<u>*Crises in competitive versus monopolistic banking systems*</u> A **banking crisis** is **defined** as a case in which banks exhaust their reserve assets. Then a model is presented which shows, under different specifications, the banking industry in a country or region is either a single **monopoly** bank or a **competitive banking** industry. Relative **crisis probabilities** under the two banking systems are determined to be independent of the conduct of **monetary policy** (i.e. they depend on the **rate of inflation**).	• **Banking crisis definition** • **Monopoly/ competitive banking** • **Crisis probabilities** • **Monetary policy** • **Rate of inflation**
Mundy	2004	Journal article	Systemic Risk	Risk	<u>*The nature of systemic risk - trying to achieve a definition*</u> Argues that **systemic risk** is an elusive concept, and the search for a 'proper' **definition** can be fruitless, but an understanding of its nature is essential. Some risks are described as **uninsurable**, which mostly fall into two categories: either they are inevitable or they are illegal. However, systemic risk is defined as a risk that is both so extreme and so critical in its impact on society that **governments are required to insure them**, even at the cost of their own economic principles.	• **Systemic risk definition** • **Search for 'proper' definition can be fruitless** • **Uninsurable risks** • **Governments are required to insure against systemic risk at all costs**
Bikker and Metzemakers	2005	Journal article	Op Behaviour	Economics	<u>*Bank provisioning behaviour and procyclicality*</u> Investigates how **bank provisioning behaviour** is related to business **cycles**. Provisioning is shown to be substantially higher when **GDP growth** is lower, reflecting increased riskiness of the **credit portfolio** when the business cycle turns downwards, which is argued to also	• **Bank provisioning behaviour** • **Procyclicality** • **Based on level of GDP growth** • **Credit risk** • **Credit portfolio**

					increase the risk of a **credit crunch**.	• **Credit crunch**
Kindleberger and Aliber	2005	Book	Systemic Risk	Economics	*Manias, panics, and crashes - A History of Financial Crises* Provides a history of **financial crises**, and analyses the stages of financial crises over the past two and a half centuries, with further references to a **monetary history** covering four centuries. The conclusion reached is that a combination of **bank failures**, the overshooting and undershooting of **exchange rates** around their long-run equilibrium values, and **bubbles** in real estate and stock markets, were **systematically related** and resulted from various shocks that led to large changes in the scope and direction of **cross-border money flows**.	• **Financial crises** • **Stages** • **Monetary history** • **Bank failures** • **Bubbles** • **Shocks** • **Bank failures, exchange rates and bubbles 'are systematically related'** • **Cross-border money flows**
Allen and Gale	2007	Book	Systemic Risk	Economics	*Understanding financial crises - Clarendon Lectures in Finance* Gives a brief introduction to prominent **theories of financial crises**, but confirms that **theory is at a relatively early stage**, even though there is a significant empirical literature on financial crises. Then, out of the observation that **crises are complex phenomena** in practice, an argument is developed for concluding **'there is no one theory of crises** that can explain all aspects of the phenomena of interest.'	• **Theories of financial crises** • **Theory is at a relatively early stage** • **Crises are complex phenomena** • **'There is no one theory of crises'**
Eisenbeis et al	2007	Journal article	Systemic Risk	Risk	*An analysis of the systemic risks posed by Fannie Mae and Freddie Mac and an evaluation of the policy options for reducing those risks* Describes the nature of large mortgage- and non-mortgage oriented **investment portfolios**	• **Systemic risks** • **Investment portfolios** • **Policy options** • **Limits on portfolio size** • **Mitigation**

					held by these institutions, and related systemic concerns. Then several **policy options** are evaluated for reducing their systemic risk exposure, and concludes that **limits on portfolio size** (assets or liabilities) would be the most desirable approach to **mitigating** the **systemic risk** posed by **Fannie Mae and Freddie Mac**.	• **Fannie Mae and Freddie Mac**
Goodhart	2007	Journal article	Op Behaviour	Risk	*The background to the 2007 financial crisis* Discusses the background to the **financial crisis** in 2007, and asserts that many aspects this crisis were already **predicted**. Archival research is shown to confirm that almost all **central banks** and **international financial institutions** that published some form of **Financial Stability Review** were predicting a serious **under-pricing of risk** in that publication well before the middle of 2007. This risk manifested as quite low risk spreads between risky assets and safe assets, while overall **volatility** declined. At the same time **leverage** was high, as financial institutions were clearly prepared to move into **increasingly risky assets** in pursuit of their goals.	• **Financial crisis** • **Predicted** • **Central banks** • **International financial institutions** • **Financial Stability Review** • **Under-pricing of risk** • **Volatility** • **Leverage** • **Increasingly risky assets**
Davis and Karim	2008	Journal article	Systemic Risk	Risk	*Comparing early warning systems for banking crises* Assesses the logit and signal extraction **early warning systems (EWS)** for **banking crises** using a comprehensive common dataset, and suggests that logit is the most appropriate approach for **global EWS** and signal extraction for country-specific analysis.	• **Global early warning systems** • **Banking crises** • **Logit approach** • **Country-specific analysis**
Honohan	2008	Journal	Op Behaviour	Risk	*Containment and Resolution in the Financial*	• **Containment and**

		article			<u>*Crisis: Too Little, Too Late*</u> Finds that **regulatory authorities** allowed strained credit conditions reflecting **weak capitalization** of major banks to persist for over a year with only sporadic and case-by-case **interventions**.	**resolution** • **Regulatory authorities** • **Weak capitalization** • **Sporadic interventions**
Rizzi	2008	Journal article	Op Behaviour	Economics	<u>*Behavioral Basis of the Financial Crisis*</u> **Major risks** are conjectured as being frequently ignored due to **behavioral biases**, which are reinforced by organizational obstacles, resulting in mistakes such as **misaligned compensation** systems. A **supplemental behavioral risk framework** is outlined, and applied to the structured finance market.	• **Financial crisis** • **Major risks** • **Behavioral biases** • **Misaligned compensation** • **Supplemental behavioral risk framework**
Schwarcz	2008	Journal article	Systemic Risk	Risk	<u>*Systemic risk*</u> Provides a summary of testimony presented before the U.S. House of Representatives Committee on Financial Services on October 2, 2007. A legal perspective on the **definition of systemic risk** was outlined, along with a conceptual framework for examining what risks are truly 'systemic,' what **causes** those risks, and how, if at all, those risks should be **regulated**.	• **Legal definition of systemic risk** • **Conceptual framework** • **Causes** • **Potential for regulation**
Acharya	2009	Journal article	Systemic Risk	Economics	<u>*A theory of systemic risk and design of prudential bank regulation*</u> **Systemic risk is modelled** as the endogenously chosen correlation of returns on assets held by banks. **Regulatory mechanisms** are described as failing to **mitigate aggregate risk-shifting incentives**, thereby increasing systemic risk. More prudential regulation is shown to **operate at a collective** level,	• **Systemic risk model** • **Regulatory mechanisms** • **Mitigation** • **Aggregate risk-shifting incentives** • **Collective level of operation** • **Risk correlation** • **Individual risk**

					regulating each bank as a function of both its joint (**correlated**) **risk** with other banks as well as its **individual** (bank-specific) **risk**.	
Allen and Snyder	2009	Journal article	Systems	Complex Sys	<u>*New thinking on the financial crisis*</u> Argues that many features of **financial crises** occur naturally in **evolutionary and complex systems**. In particular, the **boom phase** leading to this current crisis (early 1980s through 2006) and **bust phase** (2007-) are described as being associated with **structural changes** in institutions, technologies, and monetary processes, i.e. changing '**meso structures**'. **Dominant** examples of such **infrastructures** within the **global economy** are observed to increasingly be purely **financial** constructs and processes. Rigorous analytical **predictions of financial crisis** variables are further argued to be, at present, **'not possible using evolutionary and complex systems'** approaches; although, such systems are described as being potentially fruitful subjects for study through **simulation methods and certain types of econometric modeling**. Scholars, policymakers, and practitioners are thought to appreciate the more comprehensive evolutionary and complex systems framework and see that it suggests a new political economy of financial crisis. Despite a huge scholarly literature (organized recently as **first-, second- and third-generation models of financial crises**) and a flurry of topical essays in recent months, **systemic understanding has been lacking**.	• **Financial crisis** • **Evolutionary systems** • **Complex systems** • **Boom and bust phases** • **Structural changes** • **'Meso structures'** • **Dominant financial infrastructures** • **Global economy** • **predictions of financial crisis 'not currently possible using evolutionary and complex systems'** • **'simulation methods and certain types of econometric modeling useful'** • **First-, second- and third-generation models of financial crises** • **Systemic understanding has been lacking**
Ball	2009	Journal	Op Behaviour	Risk	<u>*The Global Financial Crisis and the Efficient*</u>	• **Efficient markets**

		article			*Market Hypothesis: What Have We Learned?* Challenges the view that the **efficient markets hypothesis**, by Eugene Fama, is in some way responsible for the **current worldwide crisis**.	**hypothesis** • **Cause** • **Current worldwide crisis**
Berger, Klapper and Turk-Ariss	2009	Journal article	Op Behaviour	Risk	*Bank competition and financial stability* Argues how, under the **'competition-fragility' view**, more bank competition erodes **market power**, decreases profit margins, and results in reduced franchise value that encourages bank risk taking. Under the alternative **'competition-stability'** view, more market power in the loan market is described as potentially resulting in higher bank risk as the higher interest rates charged to loan customers make it harder to repay loans, thereby exacerbating **moral hazard** and **adverse selection** problems. Observed results are described as supporting the former view: banks with a higher degree of market power also have less **overall risk exposure**. However, the "competition-stability" view does show that market power increases **loan portfolio risk**.	• **'Competition-fragility' view** • **'Competition-stability' view** • **Market power** • **Moral hazard** • **Adverse selection** • **Overall risk exposure** • **Loan portfolio risk**
Blankart and Fasten	2009	Journal article	Systemic Risk	Economics	*Financial crisis resolution - The state as a lender of last resort?* A **model** is proposed for the **contractual state** resulting from an **'exchange of protection'** against the **systemic risks** of **regulation** for the banking sector. Governments are described as having neglected to install institutions to reduce '**systematic' risks** during the years of **globalisation**, and are An evaluation is offered for what can be undertaken in both the short and long run, and how far a common response	• **Financial crisis resolution** • **Lender of last resort** • **Model of a contractual state** • **'Exchange of protection'** • **Systemic risks of regulation** • **Globalisation** • **'Systematic' risks** • **Enforced internationally**

					framework can be **enforced internationally**.	
Espenilla	2009	Journal article	Op Behaviour	Economics	<u>*Regulatory factors that contributed to the global financial crisis*</u> Exposes **regulatory factors** that contributed to the 2008 **global financial crisis**, during which weaknesses in the CRT (credit risk transfer) market are believed by many to have catalyzed the present economic slowdown. However, that slowdown is argued to be more attributable to **economic laxity** at the time, through the **procyclical nature of monetary policies** that reinforced the **market downturn**. Therefore regulators are urged to resist the temptation of addressing previous failures in financial stability management by simply **inhibiting banking innovation**. Instead, they are advised to review their procyclical policies.	• **Regulatory factors/ failure** • **Global financial crisis** • **Economic laxity** • **Procyclical nature of monetary policies** • **Market downturn** • **Inhibiting banking innovation**
Foster and Magdoff	2009	Book	Systemic Risk	Economics	<u>*The great financial crisis*</u> Offers a combined **review** of the causes and consequences of the **'Great Financial Crisis'**, starting in late summer 2007 with the failure of two Bear Stearns **hedge funds**. It is argued that, from a long-term historical perspective, this crisis will be seen as symptomatic of a more general **crisis of financialization**, beyond which lurks the specter of stagnation. Then a **radically different economic view** is proposed, that suggests the normal path of mature capitalist economies is one of **stagnation interrupted by periods of growth** until favourable conditions wane and stagnation resurfaces.	• **Review** • **'Great Financial Crisis'** • **Hedge funds** • **Crisis of financialization** • **Radically different economic view** • **Stagnation interrupted by periods of growth**
Hart	2009	Journal	Op Behaviour	Risk	<u>*The corporate treasurer - Playing the leading*</u>	• **Corporate treasurers**

		article			<u>*role*</u> Describes how **corporate treasurers** are faced with a growing list of challenges, including a series of new concerns around counterparty risk, liquidity and **systemic risk** inherent in owning increasingly complex instrument types. **Operating in an expanding global economy** and **innovative** uses of increasingly **complex financial instruments** to finance and **run daily operations** is described as a challenge. It is suggested that treasurers can improve their capabilities significantly by demanding **greater transparency** from their trading counterparties, and by leveraging near real-time information on the financial health of the firms in which they invest. They could also develop clear, objective methods to evaluate the strength of their investments, as well as insist that their firms employ **enterprise-wide risk management** solutions to **ensure they operate under acceptable levels of risk** throughout the corporation.	• **Systemic risk** • **Operating in an expanding global economy** • **Innovative, complex financial instrument types** • **Run daily operations** • **Greater transparency** • **Enterprise-wide risk management** • **Ensure they operate under acceptable levels of risk**
Helbing	2009	Proceedings	Systemic Risk	Complex Sys	<u>*Systemic risks in society and economics*</u> Discusses the observation that many **large-scale disasters** have a strong human component that cannot be solved by technical approaches alone, but requires an understanding of **collective social dynamics**. A summary is presented of how **complexity** contributes to the **emergence of systemic risks** in **socio-economic systems**. Then such disasters are described as being mostly based	• **Review of theories of systemic risk** • **Large-scale disasters** • **Collective social dynamics** • **Complexity** • **Emergence** • **Social and economic systems** • **Cascading effects**

					on **cascading effects**, which are due to **non-linear and/or network interactions**. It is therefore argued that linear, experience-based, or intuitive approaches to these disasters often fail to provide a suitable picture of the functioning of such systems. Instead, they lead to the **illusion of control**, a dangerous **logic of failure**, **paradoxical system behaviours**, unwanted side effects, and **sudden regime shifts**. Whereas, the application of **complex systems methods** is thought to enable the anticipation, avoidance, or mitigation of systemic risks and their effects. Furthermore, by using the **self-organising, adaptive nature** of complex systems to interpret the behaviour of socio-economic systems, opportunities arise for inducing favourable system behaviours which are robust to **external perturbations** and adaptive to changing conditions.	• **Non-linear and/or network interactions** • **Illusion of control** • **Logic of failure** • **Paradoxical system behaviours** • **Sudden regime shifts** • **Complex systems methods** • **Self-organising, adaptive nature** • **External perturbations**
Huang, Zhou and Zhu	2009	Journal article	Systemic Risk	Economics	<u>*A framework for assessing the systemic risk of major financial institutions*</u> An **integrated micro-macro model** is presented, that takes into account **dynamic linkages** between the health of **major US banks and macro-financial conditions**. Results suggest that the **theoretical insurance premium** that would be charged to protect against losses (**mitigation**) that equal or exceed 15% of total liabilities of 12 major US financial firms stood at $110 billion in March 2008 and had a projected upper bound of $250 billion in July 2008.	• **Systemic risk** • **Integrated micro-macro model** • **Dynamic linkages** • **Major US banks and macro-financial conditions** • **Theoretical insurance premium** • **Mitigation**

Karras	2009	Journal article	Op Behaviour	Risk	<u>*Credit derivatives: Banks' behaviour, financial stability and banking regulation*</u> In studying the **behavioural effects** of **credit derivatives** on banks, this theoretical analysis models how banks can achieve optimal capital reserves with credit derivatives, in the context of a capital inventory management **framework**. It is shown that credit derivatives can have the negative behavioural effect of encouraging banks to reduce their **capital buffer stocks**, if they are unregulated.	• **Credit derivatives** • **Behavioural effects** • **Banking regulation** • **Capital buffer stock reduction** • **Framework** • **Behaviour of banks**
Magnan	2009	Journal article	Op Behaviour	Economics	<u>*Fair value accounting and the financial crisis: Messenger or contributor?*</u> An explanation is proposed for how **fair value accounting** (FVA) affects the nature of **financial reporting**, and the impacts it had on **financial institutions** during the **2007-9 financial crisis**. Evidence presented suggests that FVA applied by banks and their regulators may have severely undermined the financial condition of some institutions. In particular, this effect is shown to be amplified for institutions holding assets in markets that saw their liquidity dry up during the crisis. It is argued that, in such circumstances, the use of FVA in financial reporting may accelerate a firm's **disconnection from its business reality**.	• **Fair value accounting** • **Financial reporting** • **Financial institutions** • **2007-9 financial crisis** • **Disconnection from a firm's business reality**
McKibbin and Stoeckel	2009	Journal article	Op Behaviour	Economics	<u>*Modelling the global financial crisis*</u> The **global financial crisis** is represented by a combination of **shocks to global housing markets**, and sharp **increases in the risk premia** of firms, households, and international investors, in an **intertemporal** (dynamic	• **Global financial crisis** • **Shocks to global housing markets** • **Intertemporal global model** • **'switching' of**

					stochastic general equilibrium or DSGE) **global model**. This shows that a **'switching' of expectations about risk premia** in financial markets can easily generate a **severe economic contraction in global trade and production**, as is currently being experienced in 2009. Results suggest that the future direction of the global economy depends critically on whether the effects of recent shocks are expected to be **permanent or temporary**.	**expectations about risk premia** • **Severe economic contraction in global trade** • **Permanent or temporary**
Petersen et al	2009	Journal article	Op Behaviour	Economics	*Did bank capital regulation exacerbate the subprime mortgage crisis?* A model is presented for the dependence of bank credit and capital on the level of **macroeconomic activity** under Basel I and Basel II (**regulation**), and their connection with **banking behavior** for the period before and during the **subprime mortgage crisis** (SMC).	• **Model** • **Bank capital regulation** • **Macro-economic activity** • **Banking behavior** • **Subprime mortgage crisis**
Rochet	2009	Journal article	Systemic Risk	Risk	*Regulating Systemic Institutions* Considers loopholes revealed in the **supervisory/regulatory framework for banks**, particularly regarding the **'too big to fail'** problem. Then a solution is proposed based on an **industrial organization approach**. As an alternative to simply downsizing large financial institutions, or imposing stricter regulations based on newly developed **measures of systemic risk exposures**, in-depth **reform** is proposed for the organization (**structure**) of **interbank and money markets**.	• **Systemic institutions** • **Supervisory/ regulatory framework for banks** • **Too big to fail** • **Industrial organization approach** • **Measures of systemic risk exposures** • **Structural reform of interbank and money markets**
Sy	2009	Journal article	Systemic Risk	Risk	*The Systemic Regulation of Credit Rating Agencies and Rated Markets* A model is proposed for illustrating how	• **Systemic regulation** • **Credit rating agencies** • **Financial markets**

					financial markets have relied too heavily on **ratings**. It shows how **downgrades** have led to **systemic market losses** and **deteriorating liquidity**. The paper suggests the use of **'ratings maps' and stress-tests** to assess the **systemic risk of ratings**, and increased capital or liquidity buffers to manage such risk (**mitigation**).	• **Ratings downgrades** • **Systemic market losses** • **Deteriorating liquidity** • **'Ratings maps' and Stress-tests** • **Systemic risk of ratings** • **Mitigation**
Yang, Mu and Yao	2009	Proceedings	Systemic Risk	Complex Sys	<u>*Analysis of Financial Crisis: A Perspective Based on Catastrophe Theory*</u> Argues that an outbreak of **brittleness** is the **root cause of financial crises**. Results are presented from a study of the brittleness **critical points** that are conjectured to have triggered **catastrophic instability** of the **financial system**. A **cusp** catastrophe **model** is applied to analyze a sub-loan crisis, using the catastrophe progression method to evaluate brittleness of the **financial system**.	• **Financial crisis** • **Brittleness** • **Root cause of financial crises** • **Critical points** • **Catastrophe** • **Cusp model** • **Catastrophe progression method** • **Financial system**
Bexley et al	2010	Journal article	Op Behaviour	Risk	<u>*The financial crisis and its issues*</u> Discusses the **timeline, causes and severe impact** on the **U. S. economy** of the recent **financial crisis**, when 305 of its banks failed in 2009, compared to 1,600 banks that failed during the entire period spanning the 1980s and early 1990s. **Government intervention** is claimed to have helped **mitigate** the crisis by providing funds to a number of financial institutions in difficulties, after repeal of the **Glass-Steagall Act** from the US **legal framework** allowed them to develop **risky financial products** that generated extreme financial instability. **Toxic assets, mortgages,**	• **U. S. economy** • **Financial crisis** • **Banking industry** • **Government intervention** • **Mitigation** • **Glass-Steagall Act** • **Legal framework** • **Risky financial products** • **Toxic assets, mortgages, and subprime lending** • **Credit crunch**

					and subprime lending are argued to have been the main drivers of this financial crisis, compounded by the subsequent limited availability of credit referred to as the **credit crunch**.	
Duffie	2010	Journal article	Op Behaviour	Risk	*The Failure Mechanics of Dealer Banks* Describes how, during the recent **financial crisis**, **major dealer banks** (banks that intermediate in markets for **securities and derivatives**) suffered from **new forms of bank runs**. The **failure mechanics** of these banks are illustrated by the 2008 failures of Bear Stearns and Lehman Brothers, who were previously considered by regulatory authorities as "**too big to fail**." The mechanics by which dealer banks can fail, and the **policies** available to treat the **systemic risk** resulting from their failures, are shown to differ markedly from those of conventional **commercial bank runs**.	• **Financial crisis** • **Major dealer banks** • **Securities and derivatives** • **New forms of bank runs** • **Failure mechanics** • **Too big to fail** • **Policies** • **Systemic risk** • **Commercial bank runs**
Freedman et al	2010	Journal article	Op Behaviour	Risk	*Policies to rebalance the global economy after the financial crisis* Considers some of the **main risks** and opportunities currently facing the **global economy**, and discusses a number of potential **policy mistakes** that could lead to even **worse outcomes than currently envisaged**. Then the **trade-offs between short-run and long term economic effects** are examined. This is illustrated by a case study of the United States, that provides estimates of the long-term damage from protracted excessive **fiscal deficits**, and of the benefits from significant **fiscal consolidation**.	• **Main risks** • **Global economy** • **Policy mistakes** • **Worse outcomes than currently envisaged** • **trade-offs between short-run effects and long-run crowding-out effect** • **Fiscal deficits and consolidation**

Kane	2010	Journal article	Systemic Risk	Risk	<u>*Redefining and containing systemic risk*</u> After **redefining systemic risk**, the need to manage it better is addressed by re-examining **misaligned incentives** in government and financial sectors of the economy. Then reforms are suggested for restoring faith in the diligence, competence, and integrity of officials who manage the financial system's safety net. The **incentives** of private **risk managers**, **accountants**, **credit-rating firms**, and **government supervisors** are aligned with the interests of ordinary taxpayers, by a proposed new method for **measuring regulatory performance** in terms of its effect on safety-net risk exposures, and for **estimating the explicit and implicit safety-net benefits** individual institutions receive, so that performance awards can be attributed to appropriate officials.	• **Systemic risk definition** • **Mitigation (containment)** • **Misaligned incentives** • **Risk managers** • **Accountants** • **Credit-rating firms** • **Government supervisors** • **Measuring regulatory performance** • **Estimating the explicit and implicit safety-net benefits**
Martinez-Jaramillo et al	2010	Journal article	Op Behaviour	Risk	<u>*Systemic risk, financial contagion and financial fragility*</u> Suggests **systemic risk** is generally acknowledged to be the risk of the occurrence of an event that threatens the well functioning of the **system of interest** (financial, payments, banking, etc.), sometimes to the point of **making its operation impossible**. It is modelled with two main components: a **random shock** that weakens one or more financial institutions, and a mechanism which transmits (**propagates**) and possibly exacerbates such **negative effects to the rest of the system**. This model shows how it is possible to **estimate the distribution of losses for the banking system**, and derive	• **Systemic risk definition** • **System of interest** • **Making its operation impossible** • **Random shock** • **Propagation of negative effects to the rest of the system** • **Estimate the distribution of losses for the banking system** • **Standard risk measures for the entire system** • **Prediction of contagious difficulties during a**

					standard risk measures for that entire system. From which the systemic and contagious elements can be separated to predict if the system is more likely to experience **contagious difficulties during a certain period of time**.	**certain period of time**
McGavin	2010	Journal article	Op Behaviour	Risk	*Short Selling in a Financial Crisis: The Regulation of Short Sales in the United Kingdom and the United States* Discusses how **market regulators in 2008**, including the US Securities and Exchange Commission ("SEC") and the UK Financial Services Authority ("FSA"), attempted to restore investor **confidence in** public capital **markets** to protect **financial institutions** from rapid devaluation of their stock by **temporarily banning short positions in certain securities**. As an alternative to that approach, it is argued that in a well-regulated market with **minimal risk of abuse**, the liquidity and information efficiency benefits of short selling far outweigh its potential harm. Short sellers have exploited lax regulation and inattentive enforcement of anti-abuse rules to manipulate stock prices and earn substantial fees. However, these are shown to be rare episodes, suggesting that the **world's major capital markets need better enforcement of existing rules and not new rules**.	• **In 2008** • **Market regulators** • **Confidence in markets and financial institutions** • **Temporarily banning short positions in certain securities** • **Minimal risk of abuse** • **World's major capital markets need better enforcement of existing rules and not new rules**
Miller and Rosenfield	2010	Journal article	Systemic Risk	Risk	*Intellectual Hazard: how Conceptual Biases in Complex Organizations Contributed to the Crisis of 2008* Discusses **intellectual hazard** as an unrecognized **systemic risk** in **financial**	• **Intellectual hazard** • **Systemic risk** • **Financial markets** • **Crisis in 2008** • **Impairs the acquisition,**

					markets, and how it contributed to the **crisis in 2008**. Then observations are offered for how intellectual hazard **impairs the acquisition, analysis and communication of information** between a **complex organization** and its external parties, creating a **tendency to conceptual bias** that interferes with accurate thought and analysis within such organizations. From which general recommendations are derived for **organizational reforms** that might help address intellectual hazard.	**analysis and communicat-ion of information** • **Complex organizations** • **Tendency to conceptual bias** • **Organizational reforms**
Minford	2010	Journal article	Op Behaviour	Risk	*The banking crisis as dynamic stochastic general equilibrium* Argues that crises are triggered by the inherent uncertainty of the capitalist system. This uncertainty is represented in an **open economy real business cycle model** of the UK by including **non-stationary productivity shocks**. In this model a random sequence of good or bad economic shocks accumulate, producing **euphorias and crises**. **Banking crises** are then superimposed in this model, when banks get sucked in by the euphoria. From this new explanation of how crisis shocks originate, existing **macro models** can describe how the **macro effects** of a banking crisis develop, to calibrate the necessary **policy responses.** An Illustration of this is provided by DSGE models of the EU and the US.	• **Open economy real business cycle model** • **Non-stationary productivity shocks** • **Euphorias and crises** • **Banking crises** • **Macro models** • **Macro effects** • **Policy responses**
Panageas	2010	Journal article	Op Behaviour	Risk	*Bailouts, the incentive to manage risk, and financial crises* Derives **risk management** rules about **bancruptcy cost incentives** for the outside	• **Bailouts** • **Risk management** • **Bancruptcy cost incentives**

					stakeholders or debtholders of a firm to bail it out as bankruptcy looms, optimized against incentives for that firm's shareholders to deliberately increase volatility in order to **exploit** the **implicit protection** of a bailout. Then a model is introduced based on these rules, which shows how acceptable risk limits (of potential bankruptcy) tighten abruptly when the firm's net worth declines below an **endogenously determined threshold**, which can account for **phenomena** such as '**flight to quality**.'	• **Exploiting implicit protection** • **Endogenously determined threshold of risk limits** • **Model of risk phenomena such as 'flight to quality'**
Rotheli	2010	Journal article	Op Behaviour	Risk	<u>*Causes of the financial crisis: Risk misperception, policy mistakes, and banks' bounded rationality*</u> Describes important **determinants** of the **current financial crisis**, and argues that the **bounded rationality of banks** contributes to **credit cycles**. After discussing the shortcomings of **monetary policy**, **risk management**, **rating agencies**, and **banking regulations**, measures are proposed for strengthening their stabilizing effects.	• **Determinants of the current financial crisis** • **Bounded rationality of banks** • **Credit cycles** • **Monetary policy, risk management, rating agencies and banking regulations**
Schich	2010	Journal article	Op Behaviour	Risk	<u>*Insurance Companies and the Financial Crisis*</u> Describes how for many **insurers**, direct exposure to the US **mortgage** market **epicentre of the current crisis**, and to **related securities**, appears to have been limited. Where it did occur, the **insurance purposes** for using **financial instrument types** at the core of difficulties is cited as the reason why some institutions from that sector were affected.	• **Insurers** • **Epicentre of financial crisis** • **Mortgage related securities** • **Insurance purposes of financial instrument types**
Uhlig	2010	Journal article	Systemic Risk	Economics	<u>*A model of a systemic bank run*</u> Presents a **model** explaining the **2008 financial**	• **Model** • **Systemic bank run**

					crisis as being reminiscent of a **bank run**. This suggests a prudent response would be the **outright purchase of troubled assets** by **governments** (**mitigation**), at prices above current market prices, that may both alleviate the financial crisis as well as provide tax payers with returns above those for safe securities	• **2008 financial crisis** • **Outright purchase of troubled assets** • **Mitigation by governments**
Wagner	2010	Journal article	Op Behaviour	Economics	_Diversification at financial institutions and systemic crises_ Shows that **diversification of financial institutions** may be beneficial, but it also entails a cost. Even though diversification reduces each institution's individual probability of failure, it is observed to **make systemic crises more likely**. Then, when systemic crises induce additional individual costs (over and above individual failures), **full diversification becomes no longer desirable**. As a result, it is argued that the optimal degree of diversification may be arbitrarily low. A similar rationale is also suggested as applicable beyond diversification, regarding the benefits of **interbank insurance and financial integration**.	• **Diversification of financial institutions** • **Makes systemic crises more likely** • **Full diversification becomes no longer desirable** • **Interbank insurance and financial integration**
Zeidan and Richardson	2010	Journal article	Systems	Complex Sys	_Complexity Theory and the Financial Crisis: a Critical Review_ Reviews the **financial crisis** through the lens of **complexity theory**. Two prominent general approaches to complexity are identified for economics and finance: **econophysics** and **econobiology**. Both are **bottom-up, population-based approaches**, but are said to differ sharply in their methods of dealing with complexity. Regarding the former approach, it is	• **Financial crisis** • **Complexity theory** • **Econophysics** • **Econobiology** • **Bottom-up, population-based approaches** • **'no single econophysics model of the banking system'** • **Network topology**

					argued there is **'no single econophysics model of the banking syste'**, citing **network topology** as one of many ways to analyze financial markets, representing a particular type of model in that literature. However, the disadvantages of models from this literature are given as: 'narrow explanations, and theoretically empty.' The three main types of econobiology models of the banking system discussed are: **neural networks**, **support vector machines** and **genetic algorithms**. The disadvantages of models from this literature are given as: 'lack of predictions, and hard to model.' However, it is observed that 'A specific line of research could concentrate on **developing an encompassing theory** to tie all the different approaches together to arrive, at some point, at a complexity-based standard model of finance.'	• **Neural networks** • **Support vector machines** • **Genetic algorithms** • **Need for developing an encompassing theory**
Brunetti, Di Filippo and Harris	2011	Journal article	Op Behaviour	Risk	_Effects of central bank intervention on the interbank market during the subprime crisis_ Explores whether **central bank intervention** improved liquidity in the **inter-bank market** during the current **subprime crisis**. Results suggest that the central bank should **release stress tests** for individual banks, issue **interbank loan guarantees**, or engage in **direct asset purchases**, rather than simply providing more capital when **counterparty risk** poses **systemic risk** to the interbank market during the current subprime crisis.	• **Central bank intervention** • **Inter-bank market** • **Subprime crisis** • **Release stress tests** • **Inter-bank loan guarantees** • **Direct asset purchases** • **Counterparty risk** • **Systemic risk**
Fisk	2011	Journal article	Systems	Complex Sys	_The 2008 financial collapse: Lessons for engineering failure_ Argues that the problems for **systemic risk**	• **Systemic risk** • **Regulation** • **Financial systems**

					regulation in **financial systems** are very similar to real world engineering. First, the **evolution of the crisis** is described, drawing on published contributions. Then parallels at each stage of the crisis to **engineering systems failures** are identified. The conclusion reached is that the real failure was not caused by incompetent regulators, but inadequacy of their **oversight system** - the **meta-regulation framework**.	• **Evolution of the crisis** • **Engineering systems failures** • **Oversight system** • **Meta-regulation framework**
Govtvan and Mansurov	2011	Journal article	Systemic Risk	Risk	<u>*Systemic risk in the financial sphere: Theoretical study and approaches to its estimation*</u> Discusses how the international financial crisis stimulated research interest in the problem of financial risks. **Systemic and systematic risks** are described as the '**most complicated and poorly studied macrolevel risk effects.'** Approaches to their **regulation and estimation** are reviewed, and special attention is paid to methods for qualitative analysis of the **potential accumulation mechanism of crisis development**. Then **definitions for systemic risk** and its **mitigation** (or neutralization) are discussed, covering the **use of market instruments**, diagnosis of crisis potential by means of **market tone analysis**, and analysis of systemic risk spreading (**propagation**) **conditions** (in terms of the interbank credit market).	• **Systemic and systematic risk definitions** • **'Most complicated and poorly studied macrolevel risk effects'** • **Regulation and estimation of systemic risks** • **Potential accumulation mechanism** • **Use of market instruments** • **Market tone analysis** • **Propagation conditions**
Gramlich and Oet	2011	Journal article	Systemic Risk	Risk	<u>*The structural fragility of financial systems*</u> Argues that lessons from the most **recent financial crisis** show specific **vulnerabilities** of financial markets due to weaknesses in the structure of the financial system (**structural**	• **Recent financial crisis** • **Vulnerabilities** • **Structural fragility** • **Impact of systemic risk** • **Concentration ('too big**

					fragility). As the literature points out, the **impact of systemic risk** can be closely related to issues of **concentration ('too big to fail')** and **dependency ('too connected to fail'**). Elements of structural fragility and their modelling requirements are explored in the light of current transformations in financial markets. Then an extended approach for conceptualizing structural fragility is suggested, that can be used to evaluate proposals for quantifying structural issues in **early warning systems** (EWSs) for systemic crises, which introduces the **theoretical groundwork** for further empirical studies.	**to fail')** • **Dependency ('too connected to fail')** • **Early warning systems** • **Theoretical groundwork**
Jorda, Schularick and Taylor	2011	Working Paper	Systemic Risk	Economics	*Financial crises, credit booms, and external imbalances: 140 years of lessons* Studies the experience of 14 developed countries over 140 years (1870-2008), and applies new statistical tools to describe the **temporal and spatial patterns of crises** in **five episodes of global financial instability** over that time period. From the **macroeconomic dynamics before crises**, credit growth is shown to have a tendency to be elevated, and short-term interest rates are depressed. Furthermore, **recessions** associated with financial crises lead to deeper **slumps** and stronger **turnarounds** in external imbalances than during normal recessions. This leads to asking to what extent external imbalances help predict financial crises. The overall finding is that **credit growth emerges as the single best predictor of financial instability**. External imbalances have played an additional role, but more so in the pre-	• **Financial crises** • **Credit booms** • **External imbalances** • **Temporal and spatial patterns of crises** • **Five episodes of global financial instability in the past 140 years** • **Recessions, slumps and turnarounds** • **Credit growth emerges as the single best predictor of financial instability**

					WWII era of low financialization than today.		
Grand Total (62 contributions)							

Appendix E. THEORY BUILDING METHODOLOGY

E.1 Process

A 16-step process for implementing the four projects/phases of this methodology (see Figure 4) is described in the following sub-sections. The actions involved in each step are given, along with inputs, outputs and the implementation project/phase.

E.1.1 Step 1: Review the Scoped Literature

E.1.1.1 Inputs

i. Business issue.
ii. Sample evidence base of relevant multi-disciplinary literature.
iii. Complete evidence base of relevant multi-disciplinary literature.

E.1.1.2 Actions

Conduct an exploratory review of the sample literature to identify gaps in knowledge regarding the business issue, and follow up with a formal systematic review of literature.

E.1.1.3 Outputs

i. Critical review of the literature.
ii. Protocol for a systematic review of literature.
iii. Evidence base of core selected literature.
iv. Detailed thematic analysis.

E.1.1.4 Implementation

Project/phase 1.

E.1.2 Step 2: Synthesize Theoretical Conjectures

E.1.2.1 Inputs

i. Outputs from step 1.

E.1.2.2 Actions

Conduct a thematic synthesis of theoretical conjectures about the gap in theory identified in the literature, according to the systematic review protocol.

E.1.2.3 Outputs

i. Summary thematic analysis of an identified gap in theory.
ii. Theoretical conjectures.

E.1.2.4 Implementation

Project/phase 1.

E.1.3 Step 3: Determine a research problem

E.1.3.1 Inputs

i. Output from step 1.
ii. Theoretical conjectures from step 2.

E.1.3.2 Actions

Review theoretical conjectures about the identified gap in theory, and scope out a research problem from that gap..

E.1.3.3 Outputs

i. Scoped research problem statement (as a research question).

E.1.3.4 Implementation

Project/phase 1.

E.1.4 Step 4: Assess Research Focus and Revise Conjectures

E.1.4.1 Inputs

i. Output from step 3.

E.1.4.2 Actions

Consider the focus of research to be attempted, and translate the research question into a tightly worded goal assertion in line with the purpose selected for theory development. Then revise conjectures accordingly.

E.1.4.3 Outputs

i. Goal assertion.
ii. Revised conjectures.

E.1.4.4 Implementation

Project/phase 2.

E.1.5 Step 5: Search Alternative Literature for Insights

E.1.5.1 Inputs

i. Output from step 4..

E.1.5.2 Actions

Extract keywords from the goal assertion and revised conjectures, and use them in search strings applied in an exploratory search of literature from alternative academic disciplines.

E.1.5.3 Outputs

i. Insights from alternative literature.

E.1.5.4 Implementation

Project/phase 2.

E.1.6 Step 6: Propose Theoretical Model and Outline of Theory

E.1.6.1 Inputs

i. Insights from step 5.
ii. Revised conjectures from step 4.

E1.6.2 Actions

Use insights and revised conjectures to deveop a theoretical model and inform the development of initial propositions and hypotheses that present an outline of new theory for further research.

E.1.6.3 Outputs

i. Theoretical model.
ii. Propositions and hypotheses of an outline of theory.

E.1.6.4 Implementation

Project/phase 2.

E.1.7 Step 7: Collect Empirical Data for Analysis

E.1.7.1 Inputs

i. Output from step 6.
ii. Source of empirical data about real world cases for theory validation.

E.1.7.2 Actions

Collect empirical data relevant to the propositions and hypotheses for financial analysis and theory validation. Then do financial analysis of phenomena of interest.

E.1.7.3 Outputs

i. Collected empirical data.
ii. Financial analysis.

E.1.7.4 Implementation

Project/phase 3.

E.1.8 Step 8: Specify Conceptual Model and Experiments

E.1.8.1 Inputs

i. Output from step 6.
ii. Output from step 7.

E.1.8.2 Actions

Develop and specify a conceptual model and experimentation suitable for testing and validating the outline of theory using empirical data collected.

E.1.8.3 Outputs

i. Conceptual model.
ii. Experiment specifications.
iii. Simulation protocol.

E.1.8.4 Status

Completed in project 2.

E.1.9 Step 9: Create/ Modify Computational Representation

E.1.9.1 Inputs

i. Output from step 8.

E.1.9.2 Actions

Create or modify a computational representation from the conceptual model that fits the objectives of the experiment specifications. This step may be iterated multiple times due to change requirements arising from the verification and validation steps.

E.1.9.3 Outputs

i. Computational representation.

E.1.9.4 Implementation

Project/phase 3.

E.1.10 Step 10: Verify Computational Representation

E.1.10.1 Inputs

i. Computational representation from step 9.

E.1.10.2 Actions

Confirm the internal validity of the computational representation for enacting specified theoretical logic, and check for its robustness by analysing its sensitivity to variations in design choices.

E.1.10.3 Outputs

i. Verification results.

E.1.10.4 Implementation

Project/phase 3.

E.1.11 Step 11: Simulate for Calibration and Experimentation

E.1.11.1 Inputs

i. Output from step 9.

E.1.11.2 Actions

Design and run a preliminary series of simulation experiments to understand how phenomena related to the theoretical propositions arise. Make adjustments to the computational specifications, update the simulation design and re-verify as necessary for eliminating error effects. Then design and run the main series of simulation experiments, to evaluate potential changes to assumptions or logic, and to test theoretical propositions and hypotheses.

E.1.11.3 Outputs

i. Calibration results.
ii. Final computational representation.

E.1.11.4 Implementation

Project/phase 3.

E.1.12 Step 12: Validate with Empirical Data

E.1.12.1 Inputs

i. Financial analysis and data from step 7.
ii. Output from step 11.

E.1.12.2 Actions

Use financial analysis to compare the simulation results using the same collected data, for testing validating the propositions and hypotheses, to enable empirical confirmation of the external validity of the simulation. If confirmed, this strengthens the argument for the validity of the new theory.

E.1.12.3 Outputs

i. Quantitative analysis of simulation results validation.
ii. Qualitative analysis of simulation results validation.

E.1.12.4 Implementation

Project/phase 3.

E.1.13 Step 13: Corroborate Final Results by Theoretical Triangulation

E.1.13.1 Inputs

i. Output from step 11.
ii. Propositions and hypotheses from step 6.

E.1.13.2 Actions

Review phenomena visible in the computational representation interface to confirm the null-hypothesis as an outcome of the final experiment.

E.1.13.3 Outputs

i. Observed phenomena.
ii. Confirmation or refutation of the null-hypothesis.

E.1.13.4 Implementation

Project/phase 3.

E.1.14 Step 14: Summarize findings

E.1.14.1 Inputs

i. All outputs from all steps.

E.1.14.2 Actions

Gather all research findings together regarding the final version of the simulation, review them against the research goal assertion, and present them in an overall findings discussion.

E.1.14.3 Outputs

i. Overall research findings discussion.

E.1.14.4 Implementation

Project/phase 4.

E.1.15 Step 15: Refine and Complete Theory

E.1.15.1 Inputs

i. Observed phenomena from step 13.
ii. Propositions and hypotheses from step 6.

E.1.15.2 Actions

Return to the outline of theory and update it to reflect the refinements suggested by experimentation. Then examine the theory implications and its potential for informing regulatory practice regarding risk mitigation.

E.1.15.3 Outputs

i. Revised/new propositions.
ii. Revised/new conjectures.
iii. Discussion of theory and implications.
iv. Contribution to practice of systemic risk mitigation policy/technique.

E.1.15.4 Implementation

Project/phase 4.

E.1.16 Step 16: Discuss Implications and Reach Conclusions

E.1.16.1 Inputs

i. Output from step 15.

E.1.16.2 Actions

Consider the implications of the theory for the programme research problem, and present them in an overall conclusions discussion.

E.1.16.3 Outputs

i. Overall research conclusions discussion, with implications.

E.1.16.4 Implementation

Project/phase 4.

Appendix F. THEORETICAL FOUNDATIONS

This section provides reference material in support of theory discussions throughout this thesis. In particular, it identifies the domain and premises on which the proposed theory is founded that are important for its understanding (Pawar, 2009; Dubin, 1978), but not directly relevant to its explanation. This is intended to ensure that a logical progression of reasoning is maintained by separating foundational matters from discussions regarding new theory proposals, to improve clarity in the latter.

F.3 Domain

F.3.1 Nature of contributions

A general theory of systemic risk is outlined for the global financial system, with practical implications for systemic risk mitigation, based on evolutionary economics viewed from an operational behaviour perspective. It introduces a unifying thesis in the literature, to expose fundamental principles about diverse crisis phenomena, by modelling the way the global financial system operates as a system of supply and demand in SIFS. The final model is comprised of 9 conjectures and a theoretical topology in the form of a cusp catastrophe-type model for a dynamical complex system. Then 13 theoretical propositions use the concept of systemic failure from that model to offer new insights about the nature of systemic risk for recognizing, avoiding and responding to the potential of such failures wherever they may emerge in the future. Out of which five hypotheses are derived, and used for validating the final theory by computational experimentation.

F.3.2 Boundaries

The scope of this theory is limited to SIP interactions directly related to the supply and demand of SIFS, and only includes those types of interaction that materially affect the systemic risk impact of SIFS among SIPs.

F.3.3 Unit of theory

An execution-level activity-type is the fundamental unit of theory, describing the lowest granularity of participation between SIPs over SIFS.

F.4 Premises

F.4.1 Accepted principles

The following key principles established elsewhere in the literature, and supported in current debates by credible academic opinion, are accepted in this thesis.

i. It is accepted as evident that macroeconomic crises in the global financial system's external environment exhibit common patterns that interact with the internal operations of that system, and their effects can be represented by a two-dimension cusp catastrophe-type topology (Thom 1975; Zeeman 1977) for explaining its systemic risk of failure.
ii. Then, from the properties of complex systems (Rosser Jr, 2007; Helbing, 2012), the emergent behaviour of that system arising as complexity at systemic level out of changes in execution-level activity can be taken as reflecting those patterns of interaction in some deterministic way.
iii. Agent-based model simulation provides a credible alternative to nonlinear mathematical analysis, as a method of interpreting the qualitative nature of that emergent behaviour for systematic analysis (Davis, Eisenhardt and Bingham, 2007; Helbing, 2012).
iv. The evolutionary paradigm of economics offers the most appropriate basis for exploring emergent phenomena in a theory using a multi-agent computational model to explain how those phenomena emerge (Helbing, 2012; Safarzynska and van den Bergh, 2010a).
v. Insights from behavioural economics can be applied to the notion of changes in the state of a system from complex systems theory, to explain operational behaviour of the global financial system (Shiller, 2003; Helbing, Yu and Rauhut, 2011).

F.4.2 Constraints

i. Consideration in this theory of both the intended and actual supply and demand for SIFS among SIPs is constrained by the lack of empirical evidence for its complete validation. Therefore, validation is limited to the observed phenomena of actual participation, while theoretical predictions are focused on an explanation for how underlying intentions are transformed by complex system characteristics to generate such phenomena. A computational model is developed for experimentally demonstrating how this occurs.

ii. Limitations in the realism of the computational model used are necessary to achieve practical results within the time and budget constraints of a doctoral thesis. Therefore, an emphasis is placed on modelling the participations of stylized SIPs in the supply and demand of stylized SIFS within a stylized financial system. The insights gained are nonetheless shown to be realistic by observable and replicable phenomena.

F.4.3 Assumptions

i. Whatever causes or effects of distress may be argued, understanding the way it propagates operationally through the system is more crucially relevant for recognizing, avoiding and responding to potential systemic failures.

ii. Erratic changes are assumed not to occur in the size and nature of the population of SIPs, and in the composition of a list of financial services considered to be SIFS.

iii. It is assumed that the systemic importance of particular generic financial services is an intrinsic property, and not significantly dependent on circumstances in a way that that can change materially between the time periods under analysis.

F.4.4 Practicalities

The potential for practical applications of this theory depends on data becoming available for identifying ‘intended’ supply and demand activities in SIFS, alongside existing 'actual' data. This is not as improbable as it may at first seem. Most financial services that would qualify as SIFS are already traded electronically, and therefore have published bid and offer activity levels and rates. Even over-the-counter trading is required to maintain this information for best-execution pricing rules of MiFID regulations. Therefore, it will only be direct trading between counterparties that will need to comply in the future.

Appendix G. COMPUTATIONAL REPRESENTATION

G.1 Documentation

This appendix contains supporting material for section 5.4 of the thesis.

The artifacts found here are:

i. The computational model interface, with a description of the main features of interest and basic run instructions.
ii. An extract listing of the NetLogo 3D 5.0.4 simulation code, containing examples of extensive commentary including rule numbering for model verification with Table 8.
iii. A subset of the data output from the final simulation experiment, providing the output at key datapoint ticks for reconciliation with the data analysis spreadsheets and charts.

G.2 Interface

G.2.1 Simulation Dashboard

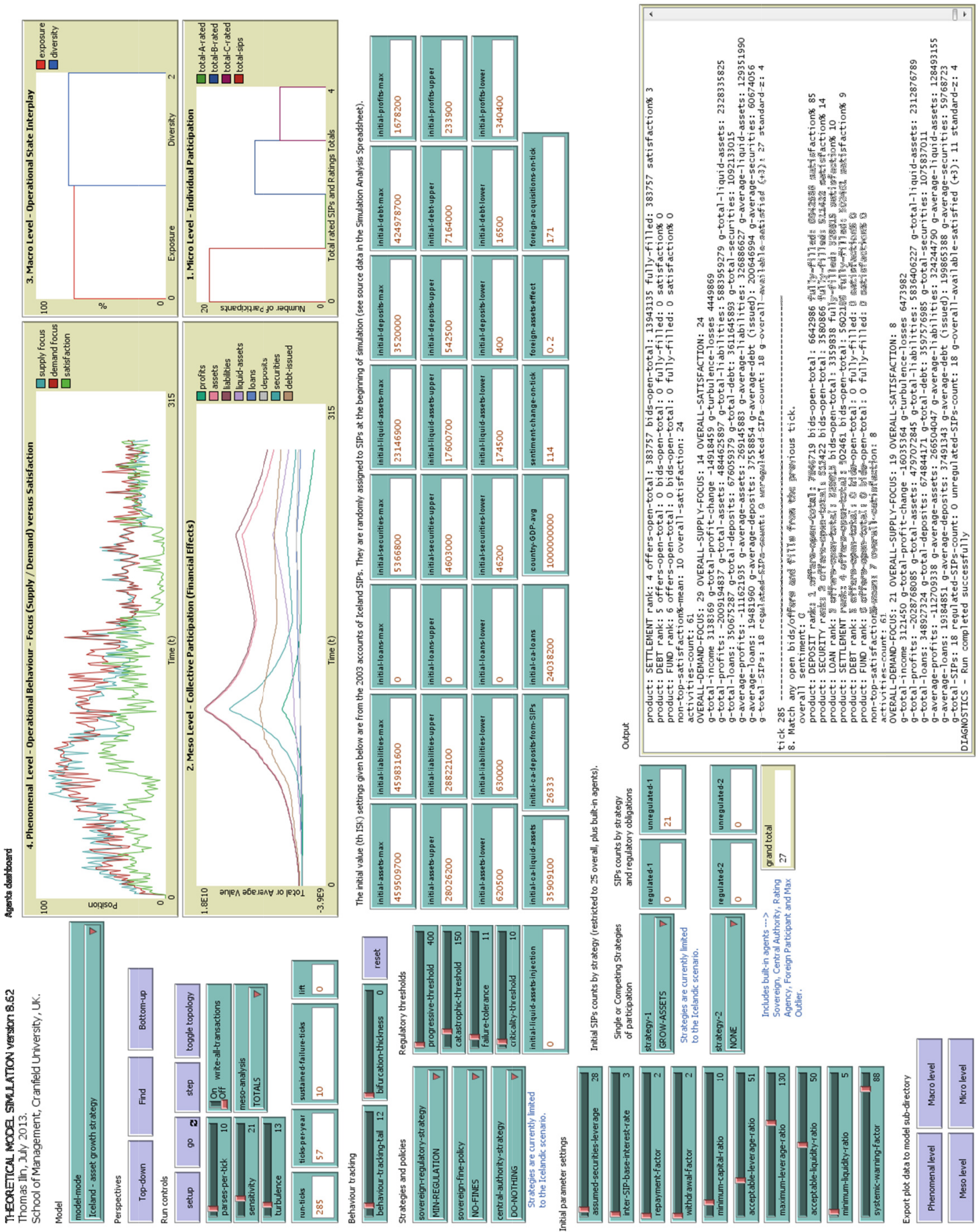

Figure 41: Simulation interface dashboard

The interface component shown in Figure 41 is the simulation dashboard used to setup, run and monitor the output of simulation experiments. It is a simplified version of the full interface used for exploratory testing over 862 simulation development runs. Among various features tested, those remaining are considered to be essential requirements for generating the financial effects of Iceland's financial system collapse over the years between 2003 and the end of 2008.

Any previously tested code behind this simulation dashboard that is not necessary for generating the financial effects of interest has been removed, to make verification easier. Therefore, only the parameter settings, initial conditions and initial values presented 'out of the box', or when the model-mode "Iceland - asset growth strategy" is selected, are assured to produce verified and validated results.

Consequently, running the simulation is simply a matter of pressing the 'setup' button and waiting until the diagnostics message "Setup completed successfully" appears, Then the 'go', 'step' and 'toggle topology' buttons are enabled.

When replicating the experiment, the 'go' button runs the entire simulation through all 285 ticks, whereas the 'step' button runs one tick at a time. The 'toggle topology' button simply hides or shows the reference standard topology in the 3D-View. The other buttons enable a 'top-down' and 'bottom-up' perspective on that topology, or the current operational state can be placed in the centre by pressing 'find'. Then visualizations of the financial effects are observed in the chart boxes for the micro, meso, macro and phenomenal levels, the 'output' text box, and the separate 3D-View.

G.2.2 3D-View

The other interface component is shown in Figure 26. It presents an interactive 3D rendering of the computational model's three-surface topology, which provides a dynamic visual representation of changes in the operational state of the system in a catastrophe theory state-manifold.

When experimental observations are being made, three self-explanatory buttons can be used to gain a better perspective: 'orbit', 'zoom' and 'move'.

G.3 Code Extract

The following code has been copied from the NetLogo simulation. It is also provided with this thesis in electronic form for replication purposes on a CD labelled '*PhD Thesis – Thomas Ilin, 2013. Supplementary material*" containing the original source code in NetLogo 3D 5.0.4 readable format, along with installation files for that version of NetLogo.

The code is pasted here for verification purposes. It enables references to rules and data fields in Table 8 to be verified by examining code labelled by comments (text prefixed by double semi-colons ';;') containing corresponding rule-numbers.

```
;; Project 3: Theory Testing and Validation, of a PhD thesis. Cranfield University School of Management.
;; Titled:'An evolutionary theory of systemic risk and its mitigation for the global financial system'.
;; Researcher: Thomas Ilin.
;; Presenting: An Agent-Based Simulation Model.
;; First Published: in March, 2013.
;; Current Version: July, 2013.
;; Version: 8.62

extensions [ matrix ]

;; ------------------------------------------------------------------------------------------------------------------------------------------------ Global variables
globals [

  g-parses-per-tick            ;; parameter - number of parses through participation rules taken each tick
  g-write-all-transactions     ;; parameter - identifies output reporting as on/off. Off shows only summary totals per tick. On shows all participation.
  g-sensitivity                ;; parameter - assumed system-wide sensitivity to losses shared by all participants
  g-meso-analysis              ;; parameter - values used in the meso analysis chart (TOTALS or AVERAGES)
  g-turbulence                 ;; parameter - assumed system-wide turbulence experienced by all participants
  g-run-ticks                  ;; parameter - total duration of the simulation experiment in number of ticks
  g-ticks-per-year             ;; parameter - number of ticks representing one year in the simulation
  g-sustained-failure-ticks    ;; parameter - number of consecutive ticks in which zero satisfaction must be maintained for systemic failure to be declared
```

>>> BEGINNING OF CODE LISTING EXTRACT

```
;; Calculate % of SATISFACTION
let rank-count 0
let running-total 0
let product-list (list )
let satisfaction-list (list )
let overall-satisfaction 0
let top-product-satisfaction% 0
let second-product-satisfaction% 0
let third-product-satisfaction% 0
let fourth-product-satisfaction% 0
let fifth-product-satisfaction% 0
let sixth-product-satisfaction% 0
let non-top-satisfaction%-mean 0

if (g-overall-fully-filled != 0)
  [
    ;; Sort and list PRODUCTS into a descending order of their satisfaction%.
    set product-list sort-on [ (- satisfaction%) ] market
    foreach product-list
      [
        ;; Sequentially process the SATISFACTION list in descending sequence, and allocate ranking.
        ask ?
          [
            set rank-count (rank-count + 1)
            if (rank-count = 1) [ set top-product-satisfaction% satisfaction% ]
            if (rank-count = 2) [ set second-product-satisfaction% satisfaction% ]
            if (rank-count = 3) [ set third-product-satisfaction% satisfaction% ]
            if (rank-count = 4) [ set fourth-product-satisfaction% satisfaction% ]
            if (rank-count = 5) [ set fifth-product-satisfaction% satisfaction% ]
            if (rank-count = 6) [ set sixth-product-satisfaction% satisfaction% ]
```

```
          output-print (word "      product: " function " rank: " rank-count " offers-open-total: " offers-open-total " bids-open-total: " bids-open-total " fully-filled: " fully-filled " satisfaction% " satisfaction%)
        ]
      ]
    ;; SATISFACTION is the satisfaction% NOT concentrated in the first PRODUCT.
    set satisfaction-list (list second-product-satisfaction% third-product-satisfaction% fourth-product-satisfaction% fifth-product-satisfaction% sixth-product-satisfaction%)
    set non-top-satisfaction%-mean round (mean satisfaction-list)
    set overall-satisfaction (round ((non-top-satisfaction%-mean / top-product-satisfaction%) * 100))
   ]
  ;; If g-overall-available-satisfied is 0 then default overall satisfaction is already 0.
  set g-overall-available-satisfied overall-satisfaction

  output-print (word "     non-top-satisfaction%-mean: " non-top-satisfaction%-mean " overall-satisfaction: " overall-satisfaction)
  output-print (word "     activities-count: " activities-count )

;; 12. Calculate/update the value effects of fills for SIPs.
  if (g-write-all-transactions = true)
   [ output-print "12. Calculate/update the value effects of fills for SIPs." ]

  if (g-write-all-transactions = true)
   [
    output-print "     PERFORMANCE"
   ]
  let deal 0
  let cash 0
  let credit 0
  let profit-running-total 0
  let profit-change-total 0
  let my-loans-to-SIPs 0
  let my-liquid-assets 0
  let my-borrowings-from-SIPs 0
  let my-liabilities 0
  let my-assets 0
```

```
  ask SIPs with [ ((SIP-type = "PARTICIPANT-REGULATED") or (SIP-type = "PARTICIPANT-UNREGULATED") or (SIP-type = "FOREIGN-PARTICIPANT") or (SIP-type =
"CENTRAL-AUTHORITY")) and (live? = true) and (ticks > 1) ]
   [
     let SIP-who who
     let SIP-activities (link-set activities with [ by-SIP = SIP-who ])
     let securities-proceeds 0
     let debt-charges 0
     let fees 0
     let my-sentiment sentiment
     If ((SIP-type = "PARTICIPANT-REGULATED") or (SIP-type = "PARTICIPANT-UNREGULATED"))
       [
         ;; Rule R04
         ask SIP-activities with [ (SIFS-code = "LL")]
           [
             set deal filled
           ]
         if (deal > 0)
           [
             ;; Set non-SIPs participation factors by datapoint for lending
             let LL-1-non-SIPs-factor 0
             let LL-2-non-SIPs-factor 2.1
             let LL-3-non-SIPs-factor 0.28
             let LL-4-non-SIPs-factor 2.00
             let LL-5-non-SIPs-factor 4.10
             set loans-to-SIPs loans-to-SIPs + deal
             ;; add % of SIPs lending as simulation of non-SIPs lending (not handled in participation rules).
             let deal-from-non-SIPs 0
             if (ticks > (g-ticks-per-year))
               [
                 ifelse (ticks <= sentiment-change-on-tick)
                   [
                     ;; datapoint 2 ...
                     set deal-from-non-SIPs (round (deal * LL-2-non-SIPs-factor))
                   ]
```

```
          [
           ifelse (ticks <= foreign-acquisitions-on-tick)
            [
             ;; datapoint 3 ...
             set deal-from-non-SIPs (round (deal * LL-3-non-SIPs-factor))
            ]
            [
             ifelse (ticks <= (g-foreign-acquisitions-on-tick + g-ticks-per-year))
              [
               ;; datapoint 4 ...
               set deal-from-non-SIPs (round (deal * LL-4-non-SIPs-factor))
              ]
              [
               ;; datapoint 5 ...
               set deal-from-non-SIPs (round (deal * LL-5-non-SIPs-factor))
              ]
            ]
          ]
        ]
      ifelse (liquid-assets < (deal + deal-from-non-SIPs))
        [ set liquid-assets 0 ]
        [ set liquid-assets (liquid-assets - (deal + deal-from-non-SIPs)) ]
      set deal 0
    ]
  ;; Rule R14
  ask SIP-activities with [ (SIFS-code = "DT") ]
    [
      set deal filled
    ]
  if (deal > 0)
    [
      ;; set non-SIPs participation factors by datapoint for deposit taking.
      let DT-1-non-SIPs-factor 3.38
      let DT-2-non-SIPs-factor 3.38
```

```
let DT-3-non-SIPs-factor 11
let DT-4-non-SIPs-factor 2
let DT-5-non-SIPs-factor 3
;; add % of SIPs deposits as simulation of non-SIPs deposits (not handled in participation rules).
let deal-from-non-SIPs 0
ifelse (ticks > (g-ticks-per-year))
  [
    ifelse (ticks <= sentiment-change-on-tick)
      [
        ;; datapoint 2 ...
        set deal-from-non-SIPs (round (deal * DT-2-non-SIPs-factor))
      ]
      [
        ifelse (ticks <= foreign-acquisitions-on-tick)
          [
            ;; datapoint 3 ...
            set deal-from-non-SIPs (round (deal * DT-3-non-SIPs-factor))
          ]
          [
            ifelse (ticks <= (g-foreign-acquisitions-on-tick + g-ticks-per-year))
              [
                ;; datapoint 4 ...
                set deal-from-non-SIPs (round (deal * DT-4-non-SIPs-factor))
              ]
              [
                ;; datapoint 5 ...
                set deal-from-non-SIPs (0 - (round (deal * DT-5-non-SIPs-factor)))
                set deal (0 - deal)
              ]
          ]
      ]
  ]
  [
    ;; datapoint 1 ...
```

```
        set deal-from-non-SIPs (round (deal * DT-1-non-SIPs-factor))
      ]
    if ((liquid-assets + deal + deal-from-non-SIPs) >= 0)
      [
        set deposits-from-SIPs deposits-from-SIPs + deal
        set liquid-assets (liquid-assets + deal + deal-from-non-SIPs)
        set assets (assets + deal + deal-from-non-SIPs)
        set liabilities (liabilities + deal + deal-from-non-SIPs)
      ]
    set deal 0
  ]
;; Rule R17
ask SIP-activities with [ (SIFS-code = "DP") ]
  [
    set deal filled
  ]
if (deal > 0)
  [
    ;; net change to assets is zero
    set deposits-with-SIPs deposits-with-SIPs + deal
    set liquid-assets liquid-assets - deal
    set deal 0
  ]
;; Rule R20
ask SIP-activities with [ (SIFS-code = "DI") ]
  [
    set cash filled
  ]
if (cash > 0)
  [
    ;; set liquidity, trading and charging tactics by datapoint for debt issuance.
    let DI-1-liquidity-tactic 0.20
    let DI-1-trading-tactic 0.80
    let DI-1-charging-tactic 0.0333
```

```
    let DI-2-liquidity-tactic 0.05
    let DI-2-trading-tactic 0.95
    let DI-2-charging-tactic 0.017
    ;; Debt issuance is simulated within a leveraged strategy applied to short-selling debt.
    set deal (round (cash * (g-assumed-securities-leverage)))
    ifelse (ticks > (g-ticks-per-year))
      [
        ;; datapoint 2 ...
        set liquid-assets (round (liquid-assets + (deal * DI-2-liquidity-tactic))) ;; put a portion of new liquidity into liquid assets.
        set trading (round (trading + (deal * DI-2-trading-tactic)))              ;; put the rest into the trading account.
        set debt-charges (round (debt-charges + (deal * DI-2-charging-tactic)))    ;; post the charges to profit calculations.
      ]
      [
        ;; datapoint 1 ...
        set liquid-assets (round (liquid-assets + (deal * DI-1-liquidity-tactic))) ;; put a portion of new liquidity into liquid assets.
        set trading (round (trading + (deal * DI-1-trading-tactic)))              ;; put the rest into the trading account.
        set debt-charges (round (debt-charges + (deal * DI-1-charging-tactic)))    ;; post the charges to profit calculations.
      ]
    set debt-issued (debt-issued + deal)
    set liabilities (liabilities + (deal + cash))
    set assets (assets + deal)
    set deal 0
    set cash 0
  ]
;; Rule R21
ask SIP-activities with [ (SIFS-code = "DR") ]
  [
    set cash filled
  ]
if (cash > 0)
  [
    ;; set liquidity, trading and charging tactics by datapoint for debt retirement.
    let DR-1-liquidity-tactic 0.082
    let DR-1-trading-tactic 0.918
```

```
let DR-1-charging-tactic 0.114
let DR-2-liquidity-tactic 0
let DR-2-trading-tactic 0
let DR-2-charging-tactic 0.114
let DR-3-liquidity-tactic 0.599
let DR-3-trading-tactic 0.401
let DR-3-charging-tactic 0.80
;; Debt retirement is simulated within a leveraged strategy applied to short-selling debt.
set deal (round (cash * (g-assumed-securities-leverage)))
ifelse (ticks <= foreign-acquisitions-on-tick)
  [
    ;; datapoint 1 ...
    ifelse (liquid-assets >= (deal * DR-1-liquidity-tactic))
      [
        set liquid-assets (round (liquid-assets - (deal * DR-1-liquidity-tactic)))
        set trading (round (trading - (deal * DR-1-trading-tactic)))
      ]
      [
        set trading (trading - deal)
      ]
    set debt-charges (round (debt-charges + (deal * DR-1-charging-tactic)))    ;; for profit calculations.
  ]
  [
    ifelse (ticks > (g-foreign-acquisitions-on-tick + g-ticks-per-year))
      [
        ;; datapoint 3 ...
        ifelse ((liquid-assets - deal) >= 0)
          [
            set liquid-assets (round (liquid-assets - (deal * DR-3-liquidity-tactic)))
            set trading (trading - (deal * DR-3-trading-tactic))
          ]
          [ set trading (trading - deal) ]
        set debt-charges (round (debt-charges + (deal * DR-3-charging-tactic)))    ;; charges and penalties for retiring deal.
      ]
```

G.4 Data

There are two types of data available from the 'output' text box control in the simulation dashboard. If the 'write-all-transactions' switch is on, then all participation transactions, sub-totals and tick summaries are written to that control. If the switch is off, then only tick summaries are written to that control. For the purpose of validating financial results produced by the simulation this switch can be left off. This allows tick summaries for specific tick numbers corresponding to the 6 validation datapoints* to be easily found, copied and pasted into a word document for analysis, or directly pasted into the 'Financial Analysis' spreadsheet for statistical comparison with actual financials already collected into that spreadsheet from the annual reports of Icelandic financial institutions provided by Bankscope. * *see row 6 in the 'Results Data' tab of the 'Financial analysis' spreadsheet for the relationship between the 6 validation datapoints and simulation year-ends.*

The following sub-sections contain simulated financial results from datapoint tick summaries pasted in that way into this document, which were also used to paste individual simulation values into the financial analysis spreadsheet for statistical comparison. Together, they offer a full audit-trail of simulation data from collection point to results analysis. Further validation can be achieved by replicating the simulation, collecting this data again, and comparing it with the results pasted here.

G.4.1 Datapoint 1

SETUP in progress: Iceland - systemic failure from asset growth strategy.
g-total-income 0 g-total-profit-change 0 g-turbulence-losses 0
g-total-profits: 2288092 g-total-assets: 565463619 g-total-liabilities: 568777007 g-total-liquid-assets: 103384474
g-total-loans: 0 g-total-deposits: 5801338 g-total-debt: 437144393 g-total-securities: 17649488
g-average-profits: 104004 g-average-assets: 25702892 g-average-liabilities: 25853500 g-average-liquid-assets: 4699294
g-average-loans: 0 g-average-deposits: 263697 g-average-debt (issued): 19870200 g-average-securities: 802249
g-total-SIPs: 22 regulated-SIPs-count: 0 unregulated-SIPs-count: 22 g-overall-available-satisfied (+3): 3 standard-z: 0
DIAGNOSTICS - Setup completed successfully.

G.4.2 Datapoint 2

tick 57 --
11. Match any open bids/offers and fills from the previous tick.
    overall sentiment: 2
    product: DEBT rank: 1 offers-open-total: 1286385 bids-open-total: 3868736 fully-filled: 1286385 satisfaction% 33
    product: LOAN rank: 2 offers-open-total: 32232982 bids-open-total: 9729786 fully-filled: 9729786 satisfaction% 30
    product: SECURITY rank: 3 offers-open-total: 7606785 bids-open-total: 1036449 fully-filled: 1036449 satisfaction% 14
    product: DEPOSIT rank: 4 offers-open-total: 5790762 bids-open-total: 47880632 fully-filled: 5790762 satisfaction% 12
    product: FUND rank: 5 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
    product: SETTLEMENT rank: 6 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
    non-top-satisfaction%-mean: 11 overall-satisfaction: 33
    activities-count: 49
    OVERALL-DEMAND-FOCUS: 56 OVERALL-SUPPLY-FOCUS: 39 OVERALL-SATISFACTION: 33
    g-total-income 3277132 g-total-profit-change 1291773 g-turbulence-losses 1946470
    g-total-profits: 6181635 g-total-assets: 3031255287 g-total-liabilities: 3088906629 g-total-liquid-assets: 690826769
    g-total-loans: 245375324 g-total-deposits: 129829178 g-total-debt: 1958031151 g-total-securities: 423267494
    g-average-profits: 294364 g-average-assets: 144345490 g-average-liabilities: 147090792 g-average-liquid-assets: 32896513
    g-average-loans: 11684539 g-average-deposits: 6182342 g-average-debt (issued): 93239579 g-average-securities: 20155595
    g-total-SIPs: 21 regulated-SIPs-count: 0 unregulated-SIPs-count: 21 g-overall-available-satisfied (+3): 36 standard-z: 28

G.4.3 Datapoint 3

tick 114 --
11. Match any open bids/offers and fills from the previous tick.
    overall sentiment: 1
    product: DEBT rank: 1 offers-open-total: 18367624 bids-open-total: 14662404 fully-filled: 14662404 satisfaction% 80
    product: DEPOSIT rank: 2 offers-open-total: 7397988 bids-open-total: 10778944 fully-filled: 7397988 satisfaction% 69
    product: SECURITY rank: 3 offers-open-total: 55137778 bids-open-total: 16581777 fully-filled: 16581777 satisfaction% 30
    product: LOAN rank: 4 offers-open-total: 1431023 bids-open-total: 9652627 fully-filled: 1431023 satisfaction% 15
    product: FUND rank: 5 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
    product: SETTLEMENT rank: 6 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
    non-top-satisfaction%-mean: 23 overall-satisfaction: 29
    activities-count: 50
    OVERALL-DEMAND-FOCUS: 74 OVERALL-SUPPLY-FOCUS: 41 OVERALL-SATISFACTION: 29

g-total-income 133065160 g-total-profit-change 129924371 g-turbulence-losses 32413466
g-total-profits: 3385689093 g-total-assets: 16436266933 g-total-liabilities: 16685274017 g-total-liquid-assets: 1446451674
g-total-loans: 359320471 g-total-deposits: 340840201 g-total-debt: 7315991927 g-total-securities: 12476793277
g-average-profits: 161223290 g-average-assets: 782679378 g-average-liabilities: 794536858 g-average-liquid-assets: 68878651
g-average-loans: 17110499 g-average-deposits: 16230486 g-average-debt (issued): 348380568 g-average-securities: 594133013
g-total-SIPs: 21 regulated-SIPs-count: 0 unregulated-SIPs-count: 21 g-overall-available-satisfied (+3): 32 standard-z: 39

G.4.4 Datapoint 4

tick 171 --
11. Match any open bids/offers and fills from the previous tick.
overall sentiment: 0
product: LOAN rank: 1 offers-open-total: 23543524 bids-open-total: 21962275 fully-filled: 21962275 satisfaction% 93
product: SECURITY rank: 2 offers-open-total: 1835796 bids-open-total: 4286857 fully-filled: 1835796 satisfaction% 43
product: DEPOSIT rank: 3 offers-open-total: 3137641 bids-open-total: 11743062 fully-filled: 3137641 satisfaction% 27
product: SETTLEMENT rank: 4 offers-open-total: 1914479 bids-open-total: 10855255 fully-filled: 1914479 satisfaction% 18
product: DEBT rank: 5 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
product: FUND rank: 6 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
non-top-satisfaction%-mean: 18 overall-satisfaction: 19
activities-count: 64
OVERALL-DEMAND-FOCUS: 30 OVERALL-SUPPLY-FOCUS: 29 OVERALL-SATISFACTION: 19
g-total-income 4409212 g-total-profit-change -22936609 g-turbulence-losses 4812007
g-total-profits: 249148320 g-total-assets: 8000871811 g-total-liabilities: 8249878895 g-total-liquid-assets: 2390728361
g-total-loans: 878666766 g-total-deposits: 509252986 g-total-debt: 4333688799 g-total-securities: 1707138211
g-average-profits: 11864206 g-average-assets: 380993896 g-average-liabilities: 392851376 g-average-liquid-assets: 113844208
g-average-loans: 41841275 g-average-deposits: 24250142 g-average-debt (issued): 206366133 g-average-securities: 81292296
g-total-SIPs: 21 regulated-SIPs-count: 0 unregulated-SIPs-count: 21 g-overall-available-satisfied (+3): 22 standard-z: 4

G.4.5 Datapoint 5

tick 228 --
11. Match any open bids/offers and fills from the previous tick.
overall sentiment: 0
product: LOAN rank: 1 offers-open-total: 3092091 bids-open-total: 7254903 fully-filled: 3092091 satisfaction% 43
product: DEPOSIT rank: 2 offers-open-total: 10347707 bids-open-total: 209809788 fully-filled: 10347707 satisfaction% 5

product: SECURITY rank: 3 offers-open-total: 91036 bids-open-total: 15781669 fully-filled: 91036 satisfaction% 1
product: SETTLEMENT rank: 4 offers-open-total: 371965 bids-open-total: 75440144 fully-filled: 371965 satisfaction% 0
product: DEBT rank: 5 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
product: FUND rank: 6 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
non-top-satisfaction%-mean: 1 overall-satisfaction: 2
activities-count: 85
OVERALL-DEMAND-FOCUS: 33 OVERALL-SUPPLY-FOCUS: 33 OVERALL-SATISFACTION: 2
g-total-income 5355604 g-total-profit-change 613957 g-turbulence-losses 5352309
g-total-profits: 197303904 g-total-assets: 10300805545 g-total-liabilities: 11420319044 g-total-liquid-assets: 4979384503
g-total-loans: 993576401 g-total-deposits: 1075600763 g-total-debt: 4733905672 g-total-securities: 2693061723
g-average-profits: 9395424 g-average-assets: 490514550 g-average-liabilities: 543824716 g-average-liquid-assets: 237113548
g-average-loans: 47313162 g-average-deposits: 51219084 g-average-debt (issued): 225424080 g-average-securities: 128241034
g-total-SIPs: 21 regulated-SIPs-count: 0 unregulated-SIPs-count: 21 g-overall-available-satisfied (+3): 5 standard-z: 8

G.4.6 Datapoint 6

tick 285 --
11. Match any open bids/offers and fills from the previous tick.
overall sentiment: 0
product: DEPOSIT rank: 1 offers-open-total: 7846719 bids-open-total: 6642986 fully-filled: 6642986 satisfaction% 85
product: SECURITY rank: 2 offers-open-total: 511422 bids-open-total: 3580866 fully-filled: 511422 satisfaction% 14
product: LOAN rank: 3 offers-open-total: 328615 bids-open-total: 3359838 fully-filled: 328615 satisfaction% 10
product: SETTLEMENT rank: 4 offers-open-total: 502461 bids-open-total: 5602166 fully-filled: 502461 satisfaction% 9
product: DEBT rank: 5 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
product: FUND rank: 6 offers-open-total: 0 bids-open-total: 0 fully-filled: 0 satisfaction% 0
non-top-satisfaction%-mean: 7 overall-satisfaction: 8
activities-count: 61
OVERALL-DEMAND-FOCUS: 21 OVERALL-SUPPLY-FOCUS: 19 OVERALL-SATISFACTION: 8
g-total-income 3121450 g-total-profit-change -16035364 g-turbulence-losses 6473982
g-total-profits: -2028768085 g-total-assets: 4797072845 g-total-liabilities: 5836406227 g-total-liquid-assets: 2312876789
g-total-loans: 348927324 g-total-deposits: 674844171 g-total-debt: 3597576985 g-total-securities: 1075837011
g-average-profits: -112709338 g-average-assets: 266504047 g-average-liabilities: 324244790 g-average-liquid-assets: 128493155
g-average-loans: 19384851 g-average-deposits: 37491343 g-average-debt (issued): 199865388 g-average-securities: 59768723
g-total-SIPs: 18 regulated-SIPs-count: 0 unregulated-SIPs-count: 18 g-overall-available-satisfied (+3): 11 standard-z: 4

DIAGNOSTICS - Run completed successfully

Appendix H. SIMULATION - PROTOCOL

This appendix is an experimental simulation protocol for project 3. As the last output of step 8 in the methodology process (see Figure 4), it combines the simulation approach, methodology and simulation environment outputs from that step in a predefined written list of research specifications to be adopted, followed and fulfilled by that project.

This helps to ensure successful replication of the results produced by project 3, as far as the stochastic nature of simulation allows, and facilitates their assessment through peer review.

Based on the recommendations of Helbing (2012: page 35, 2.2).

Table 34: Project 3 Research Protocol

Item	Description	Specification/ Objectives/ Outcomes
1	Type of research.	Theory development.
2	Research approach	A systems-theoretic approach, incorporating a simulation-interpretivist orientation towards the meaning of theory and theory building.
3	Goal of research	To describe and explain in order to diagnose and understand.
4	Simulation technique	Uses (multi) agent-based computational economics simulation as an experimental technique for theory illustration and hypothesis testing, with empirical validation.
5	Simulation Environment	NetLogo 3D 5.0.4 (see sub-section 5.6.1 for architecture).
6	Phenomena to be explained	Predictions of hypotheses 1, 2 and 5 (from sub-section 4.11).
7	Purpose of simulation	To illustrate qualitative aspects of the

		proposed new theory, and to generate quantitative data by simulation for empirical validation with data from a real financial system failure at national level, used as a proxy for the global financial system.
8	Methodology	Agent-based theory building (see section 3.5.2).
9	Experimental design	Multiple calibration and verification runs, with one final validation run.
10	Simulation rationale	Simulate the financial system collapse of Iceland over the years 2003 to 2008).
11	Model outline	See sub-sections 5.3 and 5.4.
12	World	The macro-level agent-space is a manifold within a 3-D state-space of the type described by catastrophe theory (see Figure 18). Also includes an embedded micro-level agent-space in the 2D plane at the base of the 3D state-space, and an embedded phenomenal-level agent-space in the 2D plane at the top of the 3D state-space for tracking the movements of the current state.
13	Agents	1. Phenomenal-level agents representing the operational behaviour of the system. 2. Macro-level agents representing operational states of the system. 3. Meso-level agents representing participation summaries. 4. Micro-level agents representing system participation.

14	Mechanisms	1. Collective participation behaviour. 2. Distress propagation. 3. Operational behaviour emergence. 4. Systemic failure.
15	Assumptions	See sub-section 5.3.6.
16	Verification	This will be achieved by a table reconciling artefacts between the theoretical model, conceptual model, and computational representation.
17	Initial conditions	Will be extracted from fiancial analysis of the icelandic collapse, and entered into the simulation dashboard.
18	Boundary conditions	Uses a finite 3D world with fixed boundaries, over which agents are not able to cross.
19	Time discretization	The model uses discrete, fixed time-periods which will be calibrated during design and verification.
20	Fluctuations treatment	Noise effects and issues related to such concerns as quasi-random number generation will be considered during design and verification.
21	Visualization	Phenomena of interest to the theory will be illustrated by agent behaviour in the 3D View. Also, time-plots and other real-time analyses will be incorporated in the simulation interface (dashboard) design.
22	Performance and scalability	The simulation will be run on a high-spec

		computer, and the model will be calibrated for different performance and scalability demands.
23	Reproducibility	A full functional specification of the simulation model and the experimentation design will be provided in a supplementary document, along with all source code and results.
24	Robustness checks	This will be performed in the usual manner by changing the values of simulation parameters, constants and conditions to confirm predictions can be manifested.
25	Statistical ensembles	Statistical analysis will be applied to the final simulation only, due to the 'granular' version of pragmatic validation considered.
26	Statistical Analysis	Analysis will calculate the Pearson correlation coefficient, and Kologorov-Smirnov test for a time-series of datapoints.
27	Sensitivity analysis	Sensitivities of simulation results to such influences as micro/macro parameters, ergodicity, across run variability, etc., will be checked prior to the final run.
28	Results validation	A quantitative description of the results of simulations will be empirically validated against data and academic analyses from the Icelandic financial system failure, with further qualitative validation of visual phenomena generated by theoretical triangulation.
29	Validation data sources	The Bankscope database and a review of

		empirical academic articles about the Icelandic financial system collapse, and government reports.
30	Known limitations	See sub-section 5.4.4.
31	Outcome appraisal	See sub-section 5.8.

Appendix I. SUPPORTING EVIDENCE AND MATERIALS

A .zip file containing materials useful for replication and other assessment pruposes is provided with this thesis, in a zipped directory titled:

PhD - THOMAS ILIN Thesis and Reference Materials

- NetLogo5.0.4Installer.exe
- PhD - THOMAS ILIN Final 2014 (data).xlsx
- PhD - THOMAS ILIN Final 2014 (simulation) v862.nlogo3d
- PhD - THOMAS ILIN Final 2014 (Systematic Review of Literature) v38.0.nvp
- PhD - THOMAS ILIN Final 2014 (thesis).docx
- PhD - THOMAS ILIN Final 2014 (thesis).pdf