THE PRIVATE GOVERNANCE OF ENTREPRENEURSHIP:

AN INSTITUTIONAL APPROACH TO ENTREPRENEURIAL DISCOVERY

A thesis submitted

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and any editorial work, paid or unpaid, carried out by a third party is acknowledged. I acknowledge the support I have received for my research through the provision of an Australian Government Research Training Program Scholarship.

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To my future wife, Klara—thank you for your love. This thesis is dedicated to you.

Publications

The following peer-reviewed journal articles, book chapters and conference proceedings have been published from this thesis.

Parts of Chapter 2 relating to the entrepreneurial fundamental transformation were presented as conference proceedings at:

- *86th Annual Meeting of the Southern Economic Association Conference,* Washington, DC, USA, 19-21 November 2016.
- *28th PhD Conference in Business and Economics*, University of Queensland, Queensland, Australia, 11-13 November 2015.

Parts of Chapter 3 relating to the innovation commons were jointly developed with Professor Jason Potts and published as a co-authored peer-reviewed journal article:

- Allen, DWE and Potts, J 2016, 'How the Innovation Commons Contribute to the Discovery and Development of New Technologies', *International Journal of the Commons*, vol. 10, no. 2, pp. 1035-54.

An earlier version of this theory of the innovation commons in Chapter 2 was presented as conference proceedings at:

- Allen, DWE and Potts, J 2015, 'The Innovation Commons – Why it Exists, What it Does, Who it Benefits, and How', Presented at the *International Association for the Study of the Commons Biannual Global Conference*, Edmonton, Canada, 25-29 May, 2015.

Some parts of Chapter 5 on blockchain and bitcoin technology were jointly developed with Dr Trent MacDonald and Professor Jason Potts, and published as a peer-reviewed book chapter:

- MacDonald, TJ, Allen, DWE, and Potts, J 2016, 'Blockchains and the Boundaries of Self-Organized Economies: Predictions for the Future of Banking', In P. Tasca, T.

Aste, L. Pelizzon, N. Perony (eds.), *Banking Beyond Banks and Money: A Guide to Banking Services in the Twenty-First Century*, Springer International Publishing, pp. 279-96.

Some initial results of the blockchain innovation commons in Chapter 5 were presented at:

- *Sydney Blockchain Workshops*, Sydney, 10-11 December 2015.

The theoretical development of the new subjective political economy framework in Chapter 7 was jointly developed with Dr Chris Berg and is forthcoming as a co-authored peer-reviewed journal article:

- Allen, DWE and Berg, C (forthcoming), 'Subjective Political Economy', *New Perspectives on Political Economy*.

Although not presented for examination, a peer-reviewed publication and conference paper are cited through this thesis:

- Moilanen, J, Daly, A, Lobato, R, Allen, DWE 2014, 'Cultures of Sharing in 3D Printing: What Can We Learn From the Licence Choices of Thingiverse Users?', *Journal of Peer Production*, vol. 6.
- Allen, DWE, Berg, C, Lane, AM, Potts, J 2017, 'The economics of crypto-democracy,' Presented at *Linked Democracy: AI for Democratic Innovation, 26th International Joint Conference on Artificial Intelligence,* Melbourne, Australia, 19 August 2017.

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Abstract

This thesis develops and applies an institutional governance approach to the economic problem of entrepreneurial discovery of market opportunities. In doing so it expands understanding of one of the fundamental drivers of economic growth, innovation, and contributes both to institutional economics and entrepreneurial theory. This thesis applies the analytical approaches and theories of institutional mainline economics—including transaction cost economics, entrepreneurial theory, common pool resource management and new comparative political economy—to analyse the governance choices of entrepreneurs in the earliest stages of entrepreneurial discovery. Early stage entrepreneurs face an economic problem of coordinating non-price information about future market opportunities with others, under uncertainty, with non-zero transaction costs. This new contract-theoretic approach to the innovation problem does not emphasise a market failure of a misallocation of investment to innovation activities, but rather emphasises the entrepreneurial problem of the governance of knowledge under uncertainty to discover actionable market opportunities. The main proposition is that it may be transaction cost economising for an early stage entrepreneur to privately self-govern opportunity discovery in polycentric hybrids called innovation commons. This theoretical development is applied to the cases of hackerspaces and the hybrid organisations coalescing around blockchain technology. The role of innovation commons also has implications for the political economy of the institutions of innovation policy. As such, this dissertation has three structural parts—theoretical development, application and political economy—that converge on the theme of the private collective action governance of entrepreneurial discovery.

The first part of the thesis theoretically develops a transaction cost economics approach to entrepreneurial discovery of market opportunities. My first contribution is to shift the conventional choice-theoretic market failure analysis of the innovation problem—which focuses on allocation and investment of innovation resources—to a contract-theoretic analysis, which focuses on the entrepreneur and the transaction costs they face (Chapter 2). In the earliest stages of entrepreneurial discovery the primary economic problem facing the

entrepreneur is coordinating distributed, uncertain and non-price information to reveal actionable market opportunities. This is the economic problem of the proto-entrepreneur, who must first define market opportunities prior to acting or exploiting them. Given the information proto-entrepreneurs require to solve their economic problem is distributed about the economy in the minds of others, and that coordinating this information faces non-zero transaction costs, the proto-entrepreneurial innovation problem is primarily a comparative institutional governance problem. Further, given that the structure of transaction costs shifts throughout an innovation trajectory—as the economic problem moves from one of discovering opportunities to exploiting those opportunities—so too may the economising governance structure. While proto-entrepreneurs begin with high levels of structural uncertainty and low levels of perceived asset specificity, as they begin to solve their economic problems and market opportunities become clearer, their level of structural uncertainty falls and the potential for opportunism over quasi-rents increases—that is, there is an entrepreneurial fundamental transformation.

The second contribution is to introduce and define a potential transaction cost economising governance solution to these earliest stages of the proto-entrepreneurial problem (Chapter 3). Through the logic of transaction cost economics and the common pool resource management literature, the innovation commons are introduced as polycentric collective action governance structures where proto-entrepreneurs coordinate distributed and uncertain information to whittle away uncertainty over potential market opportunities. The theoretical characteristics of these innovation commons were jointly developed with Professor Jason Potts, and are predicted to be transaction cost economising in the beginning of new industries and technologies, where structural entrepreneurial uncertainty is highest. This new type of innovation commons is compared to existing physical and knowledge commons, revealing several unique institutional behavioural characteristics. Innovation commons are predicted to only be transaction cost economising for a temporary period of time because they process uncertainty and in doing so their success may instigate their decline into other institutions of firms and markets. This also implies that innovation commons are complementary to the other institutions of innovation at later stages in an

innovation trajectory, rather than only being substitutes to them. Further, an innovation commons is not an economy-wide phenomenon, but is rather likely to emerge around new technologies and industries, where there are potential gains from trade of non-price coordination with other proto-entrepreneurs.

The second part of the thesis applies this theory to the private governance of entrepreneurial resources within hackerspaces, and in the polycentric innovation commons around blockchain technology. These analyses demonstrate that proto-entrepreneurs are privately governing early stage entrepreneurial resources under collectively developed governance structures. The first application is to a type of small social organisation where individuals tinker and experiment with new technologies, called hackerspaces (Chapter 4). An analysis of secondary data of the governance of hackerspaces reveals micro-institutional mechanisms including graduated social ostracism, costly signalling to facilitate ordering, reputation-based coordination, and nested hierarchies of rules. The analysis also reveals that hackers are at least temporarily choosing to secede from other institutions of innovation, including innovation policy, to solve their economic problem through private governance rules. The second application is to the nascent but potentially general technology, blockchain (Chapter 5). Analysis of secondary data reveals a diverse range of collaborative private governance structures being used to discover the uses for blockchain, including hack-a-thons, embassies and conferences. These diverse blockchain innovation commons are compared across multiple institutional dimensions including the autonomy to coordinate with others and how goals are set. Further, a higher order institutional explanation for the emergence of blockchain innovation commons is also proposed (Chapter 6). Entrepreneurs can apply blockchains either by integrating them within the existing territorial institutions of government, or blockchains can be used as a technology for political exit (i.e. crypto-secession). This latter process of crypto-secession creates a new decentralised society called the crypto-economy. Applying the insights from new development economics, the core problem facing blockchain proto-entrepreneurs seeking to crypto-secede is to coordinate non-price information about the institutional complementarities of blockchains to develop the 'protective-tier' institutions of the crypto-

economy. Unlike in territorial nation states, where the discovery and development process could theoretically be undertaken by planners in governments, the development process for the crypto-economy must be entirely privately governed by entrepreneurs. This understanding strengthens the link between entrepreneurship and economic development and growth, and provides a higher order explanation of blockchain innovation commons as examples of private economic development.

The third part of the thesis develops a new theoretical framework of subjective political economy, and then applies the framework to understand the political economy of the institutions of innovation. Together with Chris Berg, the first contribution is to extend the institutional possibility frontier (IPF) framework to incorporate the notion of Austrian subjective costs (Chapter 7). This new subjective political economy framework introduces subjective preferences and costs into the institutional choice over the trade-off between the dictatorship and disorder costs of institutions. Subjectively perceived institutional costs imply that each individual holds their own space of cost minimising institutions—that is, the IPF is disaggregated to the level of economic problems and individuals. This subjective political economy framework demonstrates the choice by the proto-entrepreneur to govern their economic problem within polycentric innovation commons. The institutional choice to enter the polycentric innovation commons reveals a perception of the transaction cost minimising point with the IPF space. This understanding also has implications for the scope and application of the institutions of innovation and innovation policy. First, privately governed innovation commons suggest a subjective systematic overweighting of the costs of disorder in the study of the institutions of innovation. Second, the institutions of innovation must themselves be understood as the product of a discovery process over subjective costs, framed through the ideas and rhetoric of individuals. Third, the private governance of innovation outside of the scope of innovation policy speaks to the entanglement of the innovation system, and demonstrates the need for the principle of robustness.

Chapter 1: Introduction

1.1. Towards a mainline approach to entrepreneurial discovery

At least since Smith (1776 [1976]) enquired into the wealth of nations, one of the central questions of economics has been to explain modern economic growth. Since the 1800s the world has experienced over two centuries of remarkable enduring economic growth, which is often attributed to the Industrial Revolution. Precise explanations for this take-off in global prosperity, however, have remained unclear (McCloskey 1981). There are now two widely accepted drivers of modern economic growth and development. The first driver of growth comes through innovation and technical change—that is, the process of discovering novel solutions to human needs. Modern economic growth theory has endogenously integrated this into its growth models (e.g. Griliches 1991; Lucas 2009; Romer 1990).[1] A second driver of economic growth is the institutional conditions from within which growth emerges—the recognition that growth comes not just from capital accumulation and investment, but through the formal and informal institutional structures within which individuals choose to exchange and interact. The connection between institutions and economic growth has recently been developed alongside the resurgence of new institutional economics (Acemoglu and Robinson 2012; Allen 2011; Hodgson 1993; North 1990) and the new development economics more broadly (Boettke et al. 2008; Rodrik 2008). Further, the connection between institutions, entrepreneurship and growth has recently been strengthened by a number of economic histories (Clark 2008; McCloskey 2010, 2016; Mokyr 2009).[2] For instance, McCloskey (2010, 2016) proposes that institutional

[1] Modern (endogenous) economic growth theory emphasises that the significant contributing factors to economic growth (including innovation and investments in human capital) are endogenous, and focuses on the externalities and spillover effects within an economic system. Drawing on the work of Smith (1776 [1976]) and Ricardo (1821), modern economic growth theory expanded from the work of Arrow (1962a) and more recently includes Romer (1986, 1990), Grossman and Helpman (1991) and Aghion and Howitt (1990). The integration of innovation and technical change within economic growth models demonstrates the increasing understanding of the importance of innovation and technical change within the process of economic growth.

[2] A strand of the new institutional economics has focused on the importance of institutional structures, both formal and informal, to the process of economic growth and development (e.g. see Acemoglu and Robinson 2010, 2012; Easterly 2006; North 1990; Olson 1982 [2008]; Rodrik 2000).

decentralisation following the Enlightenment enabled people to "have a go" and act entrepreneurially. Similarly, Mokyr (2009, 2016) proposes that growth was driven by a change in culture—that humans changed the way they saw their environment and sought to discover and apply useful prescriptive knowledge in industry. Together, these studies demonstrate that the process of economic growth is both constrained within, and facilitated by, institutions, and that the role of the entrepreneur in an economic system is to discover knowledge and propel that process.[3]

Combining this perspective—that innovation is a central driver of growth and therefore prosperity—with the understanding that there is some suboptimal level of innovation reveals what is known as the 'innovation problem'. The precise diagnoses of what this innovation problem is, and how it is to be remedied, however, remain contested.[4] There are two main perspectives on what constitutes this innovation problem—market failure and systems failure—both of which come through a 'lens of choice' where the analytical foreground is on the suboptimal allocation of investment that can be remedied through state intervention.[5] Such an approach to the innovation problem, however, obscures from the entrepreneurial process and the institutions within that process takes place. In this context, this thesis develops and applies a contract-theoretic institutional approach to the innovation problem. The focus of this approach is on the economics of the discovery of market opportunities through economic organisation. Therefore, this thesis further strengthens the connection between institutions, entrepreneurship and economic growth outlined above. My contract-theoretic analysis proposes that the core economic problem of the early stage entrepreneur is to coordinate information about market opportunities with others under radical uncertainty, with non-zero transaction costs. From this new

[3] The structure of institutions also incentivises the direction of entrepreneurial activity (Baumol 1990).
[4] See Section 1.2 for a description of the market failure and systems failure perspectives of the innovation problem.
[5] James Buchanan (1975, 1979); (also see Williamson 2002a) distinguished between the 'lens of choice' of economic thought—focused on the allocation and investment of scarce resources (e.g. see Robbins 1932)—and the 'lens of contract' of economic thought—with its focus on the institutional 'rules of the game' (North 1990) and how voluntary exchange occurs within these rules (e.g. see Coase 1937; Commons 1931; Ostrom 2010; Williamson 2005). One of the primary contributions of this dissertation is to shift thinking about entrepreneurship and the innovation problem towards a 'lens of contract'.

perspective, the innovation problem is a governance problem—with various institutional solutions ranging from firms, markets, states, networks and commons, all of which comparatively effectively economise on the transaction costs the entrepreneur faces as they coordinate with others. Developing and applying this new institutional approach to the economics of the innovation problem not only expands the understanding of one of the primary drivers of economic growth, innovation, but also informs the political economy of how that problem is institutionally remedied through innovation policy. The contributions of this thesis expand the understanding of the institutional conditions of entrepreneurial discovery of market opportunities, and provide a new analytical dimension to innovation economics and entrepreneurial theory. Four of the contributions of this thesis are outlined below.

First, drawing on the transaction cost economics framework of Oliver Williamson (1975; 1979; 1985a), this thesis develops an institutional mainline contract-theoretic approach to the innovation problem. The economic problem facing the entrepreneur in the earliest stages of entrepreneurial discovery comes through the application of entrepreneurial theory and transaction cost economics. The early stage entrepreneurial problem is defined as being primarily a comparative institutional problem of which institutions economise on the transaction costs of undertaking non-price coordination with others under uncertainty. Further, an intertemporal analysis of these transaction costs reveals that the transaction costs of the entrepreneur shift throughout an innovation trajectory as the economic problem facing the entrepreneur shifts. Specifically, a distinctive intertemporal regularity is revealed, with falling structural uncertainty and increasing asset specificity, suggesting a change in the transaction cost economising governance structure—what is termed an entrepreneurial fundamental transformation.

Second, drawing on the common pool resource management literature of Elinor Ostrom (1990; 2005; 2010), this thesis introduces and characterises a new type of commons as a solution to the problem of entrepreneurial discovery—an innovation commons. Together with Jason Potts, an innovation commons is defined as a rule-governed space where non-

price distributed entrepreneurial resources are coordinated under collectively governed polycentric rules.[6] Several theoretical behavioural characteristics of innovation commons are proposed—including that an innovation commons is temporarily economising, an innovation commons is complementary to the later phases and institutions of the innovation process, and an innovation commons is predicted to emerge at the beginning of new technologies and industries.

Third, this thesis reveals some of the privately governed institutional mechanisms of entrepreneurial discovery in hackerspaces and in the hybrid innovation commons coalescing around blockchain technology. Several private governance mechanisms are analysed, including graduated social ostracism, costly signalling and nested hierarchies of rules. This also includes an analysis of the diversity of innovation commons emerging around blockchain, such as Bitcoin Embassies and hack-a-thons, and provides a higher-order explanation of the economic problem of developing the institutions of the crypto-economy through new development economics.

Fourth, drawing on new comparative economics (Djankov et al. 2003; Shleifer 2005), this thesis develops and applies a new subjective political economy framework to analyse the entrepreneurial choice over the institutions of innovation. Together with Chris Berg, the institutional possibility frontier (IPF) from new comparative economics is extended to incorporate the Austrian notion of subjective costs.[7] This leads to a disaggregation of the IPF downward to the level of the entrepreneur and the institutional solutions they perceive to the economic problem they face. This subjective political economy framework is applied to understand the political economy of the private self-governance of entrepreneurial

[6] The theory of the innovation commons was published elsewhere as a peer-reviewed journal article: Allen, DWE and Potts, J 2016, 'How the Innovation Commons Contribute to the Discovery and Development of New Technologies', *International Journal of the Commons*, vol. 10, no. 2, pp. 1035-54. See publications declaration above.

[7] The subjective political economy framework is forthcoming as a peer-reviewed journal article: Allen, DWE and Berg, C (forthcoming), 'Subjective Political Economy', *New Perspectives on Political Economy*. See publications declaration above.

discovery within modern innovation policy, providing a number of implications for the political economy of the institutions of innovation.

The present introductory chapter proceeds as follows. Section 1.2 outlines the two choice-theoretic economic perspectives of the innovation problem in economics, motivating the institutional contract-theoretic approach in this thesis. Section 1.3 outlines my aims and approach of applying the methods and theories of the institutional mainline of economic thought to the economic problem of entrepreneurial discovery. Section 1.4 outlines my research questions, the structure of the dissertation, and in doing so summarises my main findings in more detail.

1.2. The background of the innovation problem

To both contextualise and motivate this dissertation, this section outlines the two main perspectives on the innovation problem in economics—market failure and systems failure—both of which are choice-theoretic approaches. In the mid-twentieth century, Richard Nelson (1959) and Kenneth Arrow (1962b) outlined the economic problem of innovation as a *market failure*. From this perspective, new ideas have special characteristics—including indivisibilities, non-convexities and uncertainties—which, when combined with the possibility new ideas may have high fixed costs in their production, and uncertainty over later recouping those costs, means that free, frictionless and competitive markets will sub-optimally allocate resources to innovation activities (Nelson 1959; Usher 1964).[8] That is, investment in the production of new knowledge that has fixed costs and is not appropriable suffers a market failure because the marginal cost will always be below the average cost, and whoever invests those fixed costs will always be able to be outcompeted by new entrants. This is the conventional market failure definition of the innovation problem—that innovation is incompatible with perfect competition. The implication of these economics of the innovation problem is that the innovation problem is a public goods investment problem. While an economy will fail to provide the optimal level of investment because

[8] Indeed, Romano (1989, p. 863) proposes there will be zero innovative activities in free, frictionless and competitive markets: "In the frictionless perfectly competitive market, with no barriers to the use of information, the market will provide no R&D investment."

weak incentives mean that the social welfare maximizing costs of innovation will not be met by profit maximizing firms, these incentives to invest can be shaped and remedied through intervention.[9] It is from this society-wide market failure perspective of the innovation problem that government-led innovation policy has been rationalised and proposed (Bleda and Del Rio 2013; Martin 2016; Martin and Scott 2000).[10] That is, in the market failure view it is the polity who corrects the deficiencies of the market in providing the public good of innovative activity, through the application of innovation policy.

How is the innovation market failure corrected through innovation policy? Innovation policies now include intellectual property rights, direct or indirect subsidies to private firms, and direct public provision (see Jones and Williams 1998; Martin and Scott 2000; Nelson 1993). Governments impose innovation policy through two broad categories: *market-based* interventions or *planning-based* interventions (Bleda and Del Rio 2013). Market-based innovation policies include monopoly private rights through intellectual property (Boldrin and Levine 2008), while planning-based interventions include the creation of direct non-market organisations, such as public science institutions, which defrays the missing costs of innovation through public funding. Between these extremes are hybrid mechanisms operating through both markets and governments, including Research & Development (R&D) tax credits.

The entire suite of innovation policies are state-based attempts to ameliorate the innovation market failure problem by re-supplying the missing innovation through the creation of monopoly rents, transfers or public supply. In this way, while innovation policies are institutions with different costs and benefits at different margins (Davidson and Potts 2015; Goolsbee 1998), all of these institutions are designed in the context of a mismatch of private and social costs of innovation, aiming to artificially raise the level of resources dedicated to innovation activities up to the socially optimum level, by taking innovation out

[9] This gap between the private and social investments of innovation activities is a central empirical focus of the literature (Hall and Lerner 2010).

[10] Bleda and Del Rio (2013, p. 1040) outline that the market failure and systems failure perspective (outlined below) are both rationales "used as theoretical justifications for government intervention in many innovation policy analyses."

of perfect competition. The underlying public policy motivation of all of these institutional interventions are that the government can resupply the production and investment costs of the innovation process, and, by approaching the optimal level of innovation investment—and thereby filling the investment gap between private and social cost—the innovation problem is solved, and the engines of economic growth are propelled (Davidson and Potts 2016).[11]

In contrast to the market failure approach, the *innovation systems* approach views the innovation process as a highly complex evolutionary process—a system of institutions and organisations with various non-linear feedback processes, through which technologies and knowledge flow throughout the economy (Dodgson et al. 2011; Freeman 1995; Lundvall 1992, 2010). Innovation systems theory stems from both evolutionary economics and old institutional economics.[12] Schumpeter was a strong influence on both the technological change literature—which was influenced by evolutionary biology and the theory of the firm—and also the neo-Schumpeterian tradition—which focuses on how novelty transforms economics in open systems through adoption and diffusion. The innovation systems approach incorporates the study of firm dynamics and dynamic capabilities and is influenced by the theory of the firm (e.g. Penrose 1959). The evolutionary approaches to innovation are often attributed to the work of Nelson and Winter (2009). How does this evolutionary innovation systems approach differ from the market failure approach outlined above? In the innovation systems approach the different parts of the innovation system are open-ended, complex and evolutionary (Lundvall 1992; Nelson 1993). This innovation system, however, is still seen to suffer from various failures of coordination between those parts. The innovation systems approach is in some ways more general than the market failure approach, because it moves from the idea of "top-down" steering in the market failure approach to "network-steering" in the systems approach (Bleda and Del Rio 2013).[13] The different mechanisms of

[11] See Chapter 7 for a deeper discussion of the comparative properties and costs of the institutions of innovation policy using the tools of new comparative economics.
[12] See Hodgson (1993) for a review of the old and new institutional economics. The old institutional economics (e.g. Common 1931) lacked robust methods of comparative institutional economics (see Coase 1998).
[13] As Bleda and Del Rio (2013, p. 1039) argue, in the innovation systems approach "the rationale for government intervention goes beyond a market failure argument: it implies to embed policies within a broader

"steering" constitute the modern systems of innovation policy (see Soete et al. 2010). The systems failure view suggests that the innovation problem is one of system allocation failures. This systems approach provides "greater potential for identifying where public support should go" and has "given way to the identification of new rationales for government intervention" (Woolthuis et al. 2005, p. 609). In this sense, as is the case in the market failure view, the innovation systems failures perspective on the innovation problem is choice-theoretic.

Both the market failure and the systems failure perspectives on the innovation problem—despite having different economic foundations—are choice-theoretic analyses.[14] Both perspectives view the innovation problem from the view that "economics is the science which studies human behaviour as a relationship between ends and scarce means which have alternative use" (Robbins 1932, p. 16). The foreground of both perspectives of the innovation problem examines the misallocation of material resources. Following this, a theoretical diagnosis of sub-optimal choices of innovative economic agents, compared to some optimum allocation of resources, motivates steering and correction through innovation policy. That is, despite the market failure roots in neoclassical welfare economics and the systems failure perspective in evolutionary economics, both ultimately aim to generate innovation and thus economic growth by ameliorating the failures of the innovation problem through state intervention (i.e. innovation policy) by shifting incentives and allocating investment.

With this choice-theoretic background in mind this thesis develops the contrasting institutional contract-theoretic analysis of the innovation problem. My new approach is not centred on network-level or society-level steering of innovation investment and allocation, or on some level of optimal investment in innovation activities. Rather, a contract-theoretic

institutional context, and a shift from top-down to network steering." Indeed, as the innovation systems literature expanded there was a greater recognition that there were systems at lower levels than the national level (see Kastelle et al. 2009). See also Freeman (2002) for an analysis of how levels of innovation systems relate to economic growth rates.

[14] As Williamson (2002b, p. 172) outlines: "Economics throughout the twentieth century has been developed predominantly as a science of choice … economists who work out of such setups emphasize how changes in relative prices and available resources influence quantities …"

analysis is built from the perspective of the entrepreneur and the economic problems they face. In particular, my focus is on the economic problem of entrepreneurial discovery of market opportunities. The economics of entrepreneurship—of the discovery and exploitation of opportunities to meet human needs—has failed to take a prominent position within the two main perspectives of the innovation problem outlined above. As we can see, developing an institutional contract-theoretic approach to the innovation problem is not just important at the theoretical level of discovering some robust characterisations of the underlying institutional mechanisms of entrepreneurial discovery and therefore economic growth. The contact-theoretic analysis of the innovation problem developed in this thesis also contributes to the political economy understanding of how innovation policies help or hinder the solution to that problem.

1.3. Aims and approach

The aim of this thesis is to develop and apply an institutional contract-theoretic approach to the innovation problem. Given my focus on entrepreneurial discovery, my aim is to examine the governance problem facing entrepreneurs as they seek to discover market opportunities, understand how a range of private ordering governance solutions emerge to solve this economic problem, and to outline the implications of this to the political economy of the institutions of innovation policy. Most generally this thesis shifts the economics of the innovation problem to what Boettke (2007, 2012) calls the "mainline" of economic thought. A mainline of economic thought can be traced from Adam Smith (1776 [1976]), through to the focus on the coordination of knowledge and human action of Friedrich Hayek (1945; 1948) and Ludwig von Mises (1949), and to the constitutional analyses of James Buchanan (1975), the transaction cost economics framework and new institutional analyses of Oliver Williamson (1979; 1985a) and the examination of collective action solutions to social dilemmas by Elinor Ostrom (1990; 2005). The mainline of economic thought focuses on the market as a dynamic process, comparative institutional analysis and the coordination of knowledge.[15] Scholars approaching economic problems from this perspective seek to

[15] See Boettke and Mitchell (2017) for a recent overview of the mainline of economic thought.

understand the complexities and uncertainties of an economic system, and examine how individuals exchange within those institutions. This approach therefore incorporates new institutional economics.[16] Therefore a mainline analysis begins from the perspective of the individual, the economic problems they face, and the institutions necessary to coordinate the information to solve that problem. What is a mainline approach to the innovation problem in economics?

In contrast to the existing mainstream choice-theoretic analysis of the innovation problem outlined in Section 1.2, this thesis shifts the analysis of the innovation problem back to the mainline of the economic thought. A mainline approach to the innovation problem places the entrepreneur within the context of a complex market economy, seeking to explain not only how existing organisations arrange their innovation activities and the incentives they have to invest in innovation activities, but how entrepreneurs first discover and then act on market opportunities under extreme uncertainty. My analysis begins from the perspective of the entrepreneur and the economic problems they face, rather than the aggregate societal perspectives of innovation as suffering a market failure between some socially optimum level of investment and the current private allocation of investment.[17] Entrepreneurs are understood as having bounded rationality, facing fundamental structural uncertainty about the future, and must therefore coordinate information to alleviate that uncertainty through comparatively effective governance structures.[18] This analysis contrasts with the focus on allocation and investment of the choice-theoretic approach, which treats entrepreneurial discovery as an institutionally-void black box. In this way a mainline approach to the innovation problem is analysed from the perspective of the entrepreneur

[16] Ménard and Shirley (2014, p. 544) describe new institutional economics as operating on the "golden triangle" of property rights, transaction costs and contracts.

[17] This is a methodologically individualist approach. This should not be confused with the political philosophy of individualism, or suggest that an individual operates in autarky. Indeed, see Buchanan (1990, p. 13): "Individual autonomy, as a defining quality, does not, however, imply that the individual chooses and acts as if he or she exists in isolation from and apart from the community or communities of other persons with whom he or she may be variously associated."

[18] Austrian entrepreneurial theory holds that the entrepreneur is a person who must make economic calculations and judgements about future market opportunities under uncertainty, and within a complex and evolving economic system (see Foss and Klein 2012; Knight 1921; Mises 1949). Also see Chapter 2.

and how comparatively effective institutions reap the mutual gains from exchange.[19] Indeed, as Buchanan (2001, p. 29) once claimed "mutuality of advantage from voluntary exchange is, of course, the most fundamental of all understandings in economics." The following section provides the research questions to be answered, an outline of how those questions are answered, and a summary of the main contributions of this thesis.

1.4. Outline and summary of the thesis

My research questions in this thesis can be summarised as follows:

- **Question 1:** From the contract-theoretic institutional mainline of economic thought, what is the economic problem the entrepreneur faces in discovering market opportunities? (Chapter 2, Chapter 3)
- **Question 2:** How are entrepreneurs choosing to overcome this problem through private collective action governance? (Chapter 4, Chapter 5, Chapter 6)
- **Question 3:** Given this new mainline understanding of the innovation problem and its private governance solutions, what are the political economy implications for innovation policy? (Chapter 7)

Part I theoretically develops a mainline institutional approach to the innovation problem through the economics of entrepreneurship and transaction cost economics (Chapter 2), as well as the common pool resource management literature (Chapter 3). The main proposition is that it may be a transaction cost economising strategy for early stage 'proto-entrepreneurs' to exchange information under polycentric commons governance structures called innovation commons. Part II applies these propositions to two examples: the institutional mechanisms of hackerspaces (Chapter 4) and the governance of entrepreneurship over blockchain technology (Chapter 5 and Chapter 6). The main contribution is to demonstrate that groups of proto-entrepreneurs can collectively develop

[19] This thesis draws on the logic of transaction cost economics, which holds that the structure of private orderings can be understood primarily on the basis of transaction cost economising (Williamson 1975, 1979, 2005). This incorporates the potential for private orderings to be developed through collective action (Ostrom 1990, 2005, 2010) and expands the potential for the organisations to solve the innovation problem beyond firms, markets and states. Also see Chapter 2.

private polycentric governance solutions to the innovation problem of entrepreneurial discovery. Part III provides political economy context of the private governance of innovation (Chapter 7). The main contribution is a new subjective political economy framework, based on the institutional possibility frontier (IPF), to understand the process of institutional choice, and the application of this framework to the institutional solutions to the innovation problem.

Part I: Theoretical development

Chapter 2: The proto-entrepreneurial problem

Chapter 2 develops a new definition of the innovation problem through entrepreneurial theory and the logic of transaction cost economics. Knowledge coordination and governance are brought to the forefront of analysis. The first section (Section 2.2) reviews the Austrian entrepreneur in economic theory and defines the focus of the entrepreneurial problem within the thesis. The Austrian theories of entrepreneurship focus on knowledge coordination, economic calculation and the discovery of market opportunities (e.g. Hayek 1945; Kirzner 1999; Lachmann 1956; Mises 1949). The proto-entrepreneur is introduced as a person who operates in the earliest stages of the entrepreneurial process—in the 'zero-th' phase of an innovation trajectory, prior to the first phase of the origination of actionable market opportunities—where the proto-entrepreneur does not yet hold an actionable market opportunity. The proto-entrepreneur must gather and interpret further non-price information about market opportunities—such as the complementarities with other technologies or the potential political resistance—before they can act. The information the proto-entrepreneur requires, however, is distributed about the economy, shrouded under uncertainty, faces non-zero transaction costs, and therefore requires economic governance.

The second section (Section 2.3) defines this proto-entrepreneurial governance problem as escaping innovation autarky to govern the exchange of proto-entrepreneurial information with others. Rather than remaining in innovation autarky with no organisational form extending from them, the proto-entrepreneur faces an institutional choice of over governance structures through which to coordinate the complementary non-price

information with others to reveal an actionable market opportunity. Assuming there are gains from coordinating with others, then the primary proto-entrepreneurial problem includes developing or choosing transaction cost economising governance structures.

The third section (Section 2.4) outlines this economic problem facing the proto-entrepreneur using transaction cost economics logic. Oliver Williamson's transaction cost economics framework is applied to the proto-entrepreneurial problem (Williamson 1979, 1985a). From an intertemporal perspective, the proto-entrepreneurial process of coordinating information and discovering complementarities—thus solving their first economic problem of revealing actionable market opportunities—suggests a shift in the microstructure of transaction costs. What begins as an economic problem with proto-entrepreneurs facing structural uncertainty (including uncertainty over potential entrepreneurial partners), and low asset specificity (because little realisable economic value is clear), ends with lower levels of structural uncertainty and higher perceived asset specificity. The implication of this is that the transaction cost economising structure in the earliest stages of the innovation problem may be different to further along an innovation trajectory. This reveals a distinctive intertemporal regularity, termed an entrepreneurial fundamental transformation. Understanding the potentially economising structures in the proto-entrepreneurial pre-transformation phase is the task of Chapter 3.

Chapter 3: The innovation commons

Chapter 3 proposes that polycentric collective action governance in an *innovation commons* may be a governance solution to the proto-entrepreneurial problem. Together with Jason Potts, the innovation commons are defined as privately governed polycentric collective action governance structures within which proto-entrepreneurs coordinate the distributed and contextual non-price information that is necessary to reveal actionable market opportunities. This chapter compares the innovation commons with previous commons, revealing unique behavioural characteristics.

The first section (Section 3.2) outlines the various characteristics of governance structures in Williamson's transaction cost economics framework, before using transaction

cost economics logic to propose that hybrid organisational structures may be economising because of their capacity for autonomous and coordinating adaption in the face of uncertainty. Furthermore, polycentricism may deal with the structural uncertainty of coordinating non-price proto-entrepreneurial information with *ex ante* unknown trading partners, and to overcome the hazards of opportunism due to asset specificity and the realisation of an economically valuable opportunity.

The second section (Section 3.3) introduces the commons literature and defines an innovation commons based on its underlying resource: non-price, contextual and distributed information about potential market opportunities. An innovation commons is defined and introduced as a privately and collectively rule-governed space in which contextual non-price entrepreneurial information about new technologies is coordinated. Given that innovation commons exist to process uncertainty about market opportunities they are likely to be a temporary and transient governance solution. An innovation commons may be an efficient institutional choice for overcoming proto-entrepreneurial structural uncertainty (that is, in the earliest stages of new technologies) and where the gains from coordination are highest (that is, in the earliest stages of general purpose technologies). From this perspective we can direct analysis of the application towards hackerspaces (Chapter 4) and a new potential general purpose technology, blockchain (Chapter 5 and Chapter 6).

Part II: Applications

Chapter 4: Entrepreneurial secession and private governance in hackerspaces

Chapter 4 examines the institutional mechanisms of hackerspaces as an example of the private collective action governance of proto-entrepreneurial discovery. Using secondary data of previous studies on hackerspaces and their operation, several institutional mechanisms are revealed and analysed in the context of Elinor Ostrom's commons design rules.

The first section (Section 4.2) motivates the selection of hackerspaces as an example of an innovation commons and the private governance of entrepreneurial resources through

Richard Wagner's theory of entangled political economy and the difficulties it raises in analysing purely private orderings (Wagner 2016a; 2016b). One solution is to examine extreme forms of private governance far from the reach of the state, which has been the approach of the positive political anarchy literature (e.g. Leeson 2014), and motivates the examination of hackerspaces.

The second section (Section 4.3) introduces hackers as proto-entrepreneurs seeking to discover valuable uses for new technologies, some of which coordinate information about new technologies with others within hackerspaces. This section reviews the existing literature on hackerspaces with a particular focus on their history and internal governance mechanisms.

The third section (Section 4.4) outlines an analytic narrative over secondary sources of hackerspace governance. This reveals private governance mechanisms, which are analysed in the context the transaction costs of proto-entrepreneurship:

- Graduated social ostracism of other hackers as a mechanism to exclude defectors.
- Costly signalling as a form of non-price coordination to both maintain the resource and to facilitate the non-price coordination process of matching complementary information.
- Collective action democratic processes and endogenous rule formation based largely on who has contributed to the hackerspace and to help maintain governance autonomy.
- Nested hierarchies of rules (meta-constitutional, constitutional, and sub-group) are clearly distinguishable sub-systems of rules which enable the spontaneous ordering of individual hackers into sub-groups or teams.

The fourth section (Section 4.5) examines hackerspace governance in terms of the comparative political economy of entangled innovation policy. It may be comparatively costly for hackers to engage within state-based institutions of innovation policy due to rent seeking and the transaction costs of those governance institutions. Further, polycentric

private governance in the innovation commons may have evolved through time through institutional learning.[20]

Chapter 5: Blockchain innovation commons

Chapter 5 examines the private governance structures coordinating entrepreneurial information about uses of blockchain technology. Blockchain is a new institutional governance technology for creating decentralised public ledgers of information. Rather than examining a class of organisation, such as hackerspaces, this chapter examines the diversity of institutions developed by entrepreneurs as they seek to develop blockchain technology. This analysis, using secondary data, reveals a diversity of hybrid innovation commons.

The first section (Section 5.2) motivates the examination of blockchain given that innovation commons are predicted to emerge where there are potential gains from coordinating with others, such as in the early stages of general purpose technologies. As such, this section briefly outlines the functional capacity of blockchain and its disruptive potential as a general purpose institutional technology.

The second section (Section 5.3) uses secondary data sources to analyse examples of blockchain innovation commons including Bitcoin Embassies, hack-a-thons and conferences. The diversity of these organisations is then discussed along multiple dimensions—including formal hierarchy or control, the degree to which agents may autonomously interact and exchange, and how goals are generated and stated through a hierarchy—and how these characteristics relate to the proto-entrepreneurial problem. One potential explanation for this institutional diversity is that the most effective transaction cost economising solutions to the proto-entrepreneurial problem are shrouded in uncertainty.[21]

Chapter 6: The private economic development of the blockchain crypto-economy

Chapter 6 expands on the analysis of blockchain technology by more deeply examining the economic problem facing blockchain entrepreneurs. Rather than assuming blockchain is

[20] The relative costs of the efficacy of governance structures are subjectively perceived and are explored further in Chapter 7.

[21] This notion of the subjective perceived costs of institutional solutions to economic problems is expanded in the 'subjective political economy' framework developed in Chapter 7.

applied within the existing institutional environment of territorial nation states, the entrepreneurial problem is expanded to include the potential for political exit (i.e. crypto-secession). Following new development economics (Boettke et al. 2008; Fine 2006; Rodrik 2008), blockchain entrepreneurs must undertake "protective-tier" entrepreneurship to discover the complementary institutions of the crypto-economy through private governance structures (see Leeson and Boettke 2009).

The first section (Section 6.2) outlines the entrepreneurial choice to integrate within existing territorial institutions, or secede from those institutions and organisations. The first option for a blockchain entrepreneur is to integrate within existing institutions (e.g. applying blockchain within banks or governments) while maintaining recourse to public territorial protective institutions (e.g. the courts). The second option is to use blockchain as a tool for political exit to secede from the existing territorial state-based institutions (i.e. to crypto-secede). The latter economic problem of crypto-secession to the crypto-economy requires entrepreneurs to develop new self-governing, self-executing and self-enforcing "protective-tier" institutions.

The second section (Section 6.3) outlines the economic problem of crypto-secession using insights from new development economics. From this perspective, the proto-entrepreneur undertakes non-price coordination to discover the complementary institutions the develop the crypto-economy. While the economics of developing the crypto-economy, similarly to territorial developing nations, include undertaking "protective-tier" entrepreneurship, the key difference is that in the crypto-economy there is no overarching territorial sovereign state. From this perspective the diversity of blockchain innovation commons outlined in Chapter 5 are a form of private economic development.

Part III: Political economy

Chapter 7: The subjective political economy of innovation

Chapter 7 analyses the private governance of entrepreneurship in its political economy context. Together with Chris Berg, the institutional possibility frontier from new comparative economics is first extended to incorporate the Austrian notion of subjective

costs. This new 'subjective political economy' framework is applied to understand the entrepreneurial choice over the institutions of the innovation problem. This analysis has implications for the scope and application of the innovation policies that are applied to ameliorate the innovation problem.

The first section (Section 7.2) introduces the institutional possibility frontier (IPF) as an analytic tool of institutional choice. The IPF holds that institutions imperfectly control the dual costs of dictatorship from state power, and disorder from private appropriation (Djankov et al. 2003; Shleifer 2005). Given that these costs trade-off against one another in a non-linear convex way, a cost minimising institutional solution theoretically exists within the IPF space. The IPF framework requires further extension, however, to understand the institutional choice over governance solutions to the innovation problem.

The second section (Section 7.3) extends the IPF framework to incorporate the Austrian notion of subjective costs. From this perspective, each coordination problem within the innovation process will face a different constellation of trade-offs between dictatorship and disorder, and thus have a different cost minimising institutional solutions within the IPF space. This implies that the IPF should be disaggregated downwards to each coordination problem within the innovation process, and also disaggregated downward to the individual person perceiving those costs. Taken together, these extensions form a new 'subjective political economy' framework.

The third section (Section 7.4) applies the subjective political economy framework to the institutions of innovation, thereby creating a subjective innovation institutional possibility frontier. This application is used to draw broad implications for the application of innovation policy. The emergence of private governance solutions to the innovation problem implies that disorder costs of private governance in the commons may have been systematically overweighted. The application of innovation policy then becomes an institutional discovery process under uncertainty, where the range of search is constrained and evolves alongside the ideas and rhetoric of the innovation problem.

Part I:
Theoretical development

Chapter 2: The proto-entrepreneurial problem

2.1. From choice-theoretic to contract-theoretic

Just as Friedrich Hayek (1945, 1989) argued that the economic problem society faces is coordinating distributed and uncertain bits of information not known to anyone in its totality, the same is true for entrepreneurs as they seek to discover market opportunities.[22] The process of discovering market opportunities is itself an economic problem of coordinating distributed knowledge and making judgements under uncertainty.[23] The standard choice-theoretic market failure analysis of the innovation problem society faces outlined in Chapter 1, however, suggests that the innovation problem is primarily a question of what level of resources, and where, agents invest in innovation activities, as well as the incentives pushed upon them in making those choices. This chapter outlines the foundations for the contrasting contract-theoretic institutional approach to the innovation problem, through application of the logic of transaction cost economics (Williamson 1975; 1979; 1985a) to the Austrian entrepreneurial theory of making judgements and calculations under uncertainty (Knight 1921; Mises 1949; Casson 1982; Foss and Klein 2012). From this institutional perspective, the innovation problem is a question of how early stage entrepreneurs ('proto-entrepreneurs') coordinate uncertain and distributed knowledge under comparatively effective governance structures to crystallise opportunities to the point of action. The proto-entrepreneurial innovation problem is constrained by existing

[22] Throughout the socialist calculation debate in the mid-twentieth century, Hayek outlined what became known as the 'knowledge problem' in economics: "… the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate people possess. The economic problem of society is thus not merely a problem of how to allocate "given" resources … it is a problem of the utilization of knowledge not given to anyone in its totality" (Hayek 1945, p. 519). A similar perspective of the economic problem of knowledge coordination is outlined in this chapter, in the context of entrepreneurial discovery of market opportunities.

[23] As outlined in Section 2.2 below, the Austrian theories of entrepreneurship focus on the coordination and the interpretation of knowledge to discover market opportunities (e.g. Kirzner 1994; Knight 1921; Mises 1949).

technologies and transaction costs, and is therefore solved through coordination in private orderings such as firms, markets, clubs, networks and commons.

My analysis of the economics of entrepreneurial discovery draws on the transaction cost economics framework developed by Oliver Williamson (1985). This transaction cost economics builds on the earlier institutional economics scholarship from John Commons (1931) and Ronald Coase (1937), where the unit of economic analysis is taken at the level of the transaction. The logic of transaction cost economics is that economic organisation is a comparative institutional question based primarily on how different institutions economise on the hazards of exchange. A contract-theoretic perspective of economic problems is that people face private ordering problems in determining which governance structures realise the mutual gains from exchange (Williamson 2002a). By first characterising the transaction costs of a given economic problem across multiple dimensions (including uncertainty and asset specificity), and characterising governance structures across multiple dimensions (including adaptability), predictive refutable implications for the ordering of economic governance can be developed. The focus of this chapter is on the first analytical step, of characterising the transaction costs, while Chapter 3 turns to the question of the potentially transaction cost economising governance structures.

In this chapter the development of a contract-theoretic approach to the innovation problem begins from the analytical perspective of the entrepreneur, and the economic problem that they perceive they face. The economics of governance and the economics of entrepreneurial discovery, however, have generally focused on separate aspects of the innovation process. While innovation economics "disregards the role of entrepreneurial imagination in setting up the firm" the entrepreneurial literature "recognizes the significance of entrepreneurial imagination without making the connection to the particular institutional conditions of the firm" (Witt 1999, p. 108).[24] The notion of exchange of

[24] There is a literature outlining theories of entrepreneurial teams as well as the entrepreneur within the context of the firm and firms (e.g. Alvarez 2007; Alvarez and Barney 2005; Bylund 2015; Foss and Klein 2012; Harper 2008; Witt 1999). However, the organisational economics literature and the literature on entrepreneurial theory have generally focused on separate problems. These literatures are discussed throughout this chapter, including in Section 2.4.

information between entrepreneurs with non-zero transaction costs has as yet not been central to innovation economics.[25] When organisational economics is employed in the context of innovation, it generally asks where innovation activities, such as research and development, should efficiently occur (Auerswald 2008; Casson 2005; Globerman 1980; Langlois 2007).[26] Organisational solutions to this question are generally constrained to either the competitive market or to vertical integration within the hierarchical firm (Nelson and Winter 2009; Pisano 1991; Teece 1986).[27] The innovation problem, however, does not necessarily begin with existing firms operating in competitive markets. Such an approach to the organisation of innovation obscures from the core entrepreneurial problem of coordinating information and making judgements about valuable market opportunities. In this chapter I begin my analysis in the earliest stages of market opportunity discovery, when a person holds a not yet fully formed entrepreneurial prospect in their mind and lacks the necessary information to act upon that opportunity. This economic problem—what we can call the proto-entrepreneurial problem—is then analysed within a transaction cost economics framework. From this perspective, my contract-theoretic definition of the earliest stages of the entrepreneurial innovation problem is that, for the entrepreneur, the earliest stages of their innovation problem is a comparative institutional governance problem of which governance structures economise on the transaction costs of coordinating the distributed non-price information necessary to reveal an actionable opportunity. This analysis precedes the conventional starting point of the economics of innovation and

[25] For an early exception on the link between transaction costs and innovation see Teece (1996, p. 193), which begins to embrace a Williamson transaction cost within the context of firm organisation, after proposing that "much of the literature in economics proceeds as if the identity of the firm in which innovation is taking place is of little moment." Further literature embracing transaction costs in the economics of innovation are outlined below.

[26] For instance, Globerman (1980) seeks to explain the existence of hierarchical organisation of innovation in the telecommunications industry.

[27] The organisational choice for innovation can also be explained in terms of dynamic transaction costs (Langlois and Robertson 2002) or dynamic capabilities (Langlois and Foss 1997; Teece et al. 1997; Winter 2003). There has also been transaction cost based analysis of horizontal and vertical research joint ventures, and of relational contracting models of R&D, which have developed into network governance models of open innovation (Chesbrough 2003; Dahlander and Gann 2010) and user innovation (von Hippel and von Krogh 2003). The property rights approaches have also sought to analyse R&D in an incomplete contracts framework (Aghion and Tirole 1994; Hart and Moore 1990).

enquires into the knowledge coordination processes that precede acting on perceived opportunities.

My contract-theoretic approach to the entrepreneurial innovation problem also incorporates an intertemporal dimension as the economic problem facing the entrepreneur changes through time. From the perspective of the innovation process, the entrepreneur faces different economic problems throughout an innovation trajectory as they move from a problem primarily characterised by transaction costs of knowledge coordination of discovering market opportunities, towards production costs associated with acting on and exploiting those perceived opportunities. This reveals a potentially distinctive intertemporal regularity as contractual relationships develop—what is termed an entrepreneurial fundamental transformation.[28] What begins with high structural uncertainty and low perceived asset specificity transforms into a different microstructure of transaction costs as a market opportunity is perceived. The implication of this entrepreneurial fundamental transformation, as we will see, is to reveal an early pre-transformation stage economic problem, with unique transaction costs. This institutional analysis of the innovation problem is not constrained to markets and hierarchies, but rather incorporates the entire suite of potential institutional solutions to the innovation problem, thereby leaving open the analysis of innovation commons in Chapter 3.[29]

The chapter is proceeds as follows. Section 2.2 traces the history of the entrepreneur in economics and outlines some of the Austrian theories of entrepreneurship. Section 2.3 defines the proto-entrepreneurial innovation problem as a comparative institutional problem facing the proto-entrepreneur who must choose and create governance structures within which to solve their economic problem. Section 2.4 outlines the transaction costs of the proto-entrepreneurial problem, including the intertemporal proposition of an

[28] This is analogous to Oliver Williamson's 'fundamental transformation' (see Section 2.4).
[29] Following Harper (2008, p. 614) on entrepreneurial teams, the analytical approach here is "'institution neutral' in that it does not presuppose a particular governance structure (such as a start-up firm)."

entrepreneurial fundamental transformation. Section 2.5 outlines implications and concludes.

2.2. The proto-entrepreneur

The centrality of the entrepreneur in the economic system differs across schools of thought based on the underlying economic assumptions that are taken.[30] Twentieth century mainstream neoclassical economics, for instance, generally assumed that individuals held perfect information and acted within a static equilibrated system in an attempt to constrain the complex and evolving economy into tractable economic models. These assumptions obscure the process of entrepreneurial discovery. Indeed, William Baumol (1993, p. 197) has referred to the entrepreneur as the "spectre who haunts our economic models" while Stanley Metcalfe (2004, p. 157) reflected that the entrepreneur and standard economic theory "have never made easy travelling companions." This section briefly reviews the history of the entrepreneur in economics before outlining the proto-entrepreneur and the economic problem they face.

2.2.1. The entrepreneur in economic theory

Early theories of entrepreneurship lacked a distinct functional theory. The term 'entrepreneur' traces back to the eighteenth century when Richard Cantillon (1772) made a direct translation from the term 'undertaker'. Cantillon's entrepreneur was a specialised risk taker who formed contracts with employees and insulated them against the risks of changing prices. Adam Smith's (1776 [1976]) focus on the division of labour and the order of the market meant that to him entrepreneurs were individuals who translated demand into supply. Jean-Baptiste Say (1832) also argued the entrepreneur brought together workers, capital and resources to actualise new knowledge into a good, using their personality of "judgement, perseverance, and a knowledge of the world, as well as business."[31] Alfred Marshall (1890) saw the entrepreneur as a natural and rare leader with the ability to foresee

[30] See Endres and Woods (2006) for differentiation between the neoclassical, Austrian and behavioural theories of entrepreneurial decision making.
[31] While Say focused more on knowledge than did Smith, there was still little theory of the process of entrepreneurial discovery itself.

demand and supply, and the willingness to undertake risky ventures. These early approaches to the entrepreneur lacked a pure theory or a critical analytical evaluation of entrepreneur and their role in the economic system (see Kirzner 1994). Entrepreneurs were largely indistinguishable from business managers, and were regularly linked to the ownership of land, labour and capital (e.g. Quesnay 1888). Entrepreneurs were not characterised by their functionality (such as having a role in the market process), but generally by their personality—such as a tendency for daringness, wit, courage or intelligence. Because of these individualist conceptions, the entrepreneur was often added as another element in the business process as a factor of production. Indeed, the modern neoclassical production function approach similarly adds the entrepreneur—specifically, the output of the entrepreneur as embodied within technical innovations—as a fourth factor of production alongside land, labour, and capital.[32] In this way entrepreneurs are acknowledged as introducing novelty to an economic system, but there is little focus on the process of entrepreneurial discovery itself. Baumol (1968, p. 66) even went as far as to say that in the neoclassical model the "theoretical firm is entrepreneurless – the Prince of Denmark has been expunged from the discussion of Hamlet." What are the economic assumptions that make the economic system entrepreneurless?

The entrepreneur lacks meaning in an economic system that is either static, with no conception of time and uncertainty, or an economic system in equilibrium. The first assumption renders the entrepreneur meaningless because assuming perfect knowledge leaves no room for meaningful choice—perfect knowledge implies that the outcomes of choice are determined by the characteristics and the structure of knowledge within the system. This assumption implies no possibility of entrepreneurial skill or judgement or alertness associated with foresight, expectation or prediction of an uncertain future. For the entrepreneur to be incorporated into an economic system, that system must be complex, evolving and contain uncertainty. There must be opportunity costs associated with making choices over different courses of action, and this process must occur through the passage of

[32] See Endres and Woods (2006) for a review of the modern theories of entrepreneurship.

time (i.e. in a dynamic system).[33] The second assumption that renders the entrepreneur meaningless is if an economic is in equilibrium, because entrepreneurship is tightly linked to the notion of disequilibrium. In equilibrium all economic resources are assumed to be optimally allocated, thereby suggesting no economic opportunities. Indeed, as John Bates Clark (1918, p. 122) explained, in an equilibrated system the entrepreneur would become "purely passive" (see Salerno 2008). Disequilibrium is critical to the conception of entrepreneurship either when the entrepreneur is assumed to move an economy towards equilibrium (such as in the Kirznerian market process approach), or when entrepreneurial discovery and disruption push the economy away from the circular flow of economic life (such as in the process of Schumpeterian creative destruction).[34] From here we can see that any theory of entrepreneurship requires an economic system that involves coordination of information and resources under radical uncertainty (Chiles et al. 2007; Venkataraman 1997). Therefore entrepreneurial theory has largely flourished within schools of economic thought that embrace uncertainty, knowledge coordination and dynamic market processes.[35] Indeed, the theories of the entrepreneur have emerged largely within the mainline of economic theory.[36] This line of thought includes the Austrian school of economics, which has generated several theories of the entrepreneur, some of which are outlined below.[37]

Who is the entrepreneur in Austrian and mainline economic theory? In the few passages Carl Menger (1871) dedicated to the entrepreneur, he proposed that the entrepreneur must first "obtain information about the economic situation" and then make "all the various

[33] For instance, see Metcalfe (2004, p. 170) on market process theory and entrepreneurship: "In the Schumpeterian and Austrian perspectives, markets do not generate equilibrium; rather, they generate order, they solve a problem that of allocating resources to meet needs, but that order necessarily generates its own internal reasons to change."

[34] The entrepreneur may move an economic system towards equilibrium, such as in Kirzner's system of alertness, or away from equilibrium, such in Schumpeter's system of entrepreneur pushing the circular flow of economic life out of equilibrium. See Kirzner (1978a) for a description of the differences between these conceptions, or Metcalfe (2004, p. 194) for the distinction between Schumpeterian 'destruction' and Kirznerian 'creation'.

[35] This choice, imagination and creativity are "lacking in standard neoclassical analyses" (Jakee and Spong 2003b, p. 126).

[36] For an outline of the "mainline" of economic thought see Boettke (2012) and Section 1.1 above.

[37] See Dekker (2016) for an analysis of the Austrian school of economics, including the centrality of the entrepreneur. See also Hébert and Link (1988) for an analysis of the historical roots of entrepreneurial theory.

computations" of economic calculation (Kirzner 1978a; Menger 1871, p. 159). This understanding of obtaining information and then making economic judgements foreshadows the broader Austrian conception of entrepreneurs as functional agents within the context of an uncertain market process, who process information to discover opportunities under uncertainty (O'Driscoll and Rizzo 1996).[38] We can separate three common elements of the entrepreneur within the Austrian school and within mainline economics more broadly (Langlois 2007; Phelan 2016):

- *Entrepreneurs choose and act under uncertainty*. They propagate novelty and newness into the economic system by identifying and acting on new means ends relationships under a state of uncertainty.
- *Entrepreneurs exhibit or possess a kind of judgement, alertness, or skill* in acquiring information and making economic calculations. Entrepreneurs interpret information to discover or create profit opportunities within a catallaxy.
- *Entrepreneurs act to coordinate or allocate scarce resources*. Entrepreneurs act to exploit opportunities, and, in a market economy, receive economic rents as they undertake voluntary economic exchange with other choosing agents.

Giving different weights to each of these considerations, however, has generated a number of different functional conceptions of the entrepreneur. We can now examine some of these differences, and outline their comparative capacity in developing a mainline institutional approach to the entrepreneurial problem.

The Schumpeterian entrepreneur has a macroeconomic functional role in the economy and is described through their personality and tendency as an economic leader (Schumpeter 1934, 1942). Schumpeter's approach to entrepreneurship, however, shifted through time.[39]

[38] Austrian economists acknowledge macroeconomic problems, such as inflation, but diagnose these as microeconomic problems. In the context of the 'innovation problem' Austrian economists acknowledge the macroeconomic effects—for instance, lower economic growth and living standards—but seek microeconomic explanations over the entrepreneur. These microeconomic explanations occur within a dynamic context of uncertainty.

[39] For analysis of the shifting of thought on the entrepreneur by Schumpeter see Andersen (2012), Fagerberg (2012), Kirzner (1999) and Langlois (2003).

On one hand, Schumpeter's earlier scholarship (e.g. Schumpeter 1934) was influenced by Wieser (1914) and focused on the psychology of the entrepreneur and their role in shaping the world around them (Dekker 2016). Here, Schumpeter (1934) argued that the entrepreneurial function was to disrupt the "circular flow of economic life", pushing novelty and newness into the economic system through a "gale of creative destruction" and exploitation of potential profit opportunities. On the other hand, Schumpeter's later scholarship (e.g. Schumpeter 1942) focused on how large firms undertake research and development and focused more broadly on the political economy implications of change. Both of these conceptions of the entrepreneur, however, are ineffective for developing an institutional approach to the economic problem facing the entrepreneur because they focus on either the personality of the entrepreneur, or the process of research and development within firms (i.e. the approach is not institution neutral). Schumpeter's analyses lack theory over knowledge coordination and discovery and the economic process that precedes the founding of a firm. Other theories of the entrepreneur, outlined below, are more conducive to developing a mainline approach to the innovation problem because they focus on the economic problem entrepreneurs face in relation to uncertainty and knowledge coordination.

The theory of entrepreneurship as alertness to opportunities was developed by Israel Kirzner (1978a, 1997, 1999) and remains one of the most influential theories of the entrepreneur. Kirzner's entrepreneur was a product of an attempt to bridge mainstream economic theory with the conception of opportunity discovery and the market process. Entrepreneurs were characterised as those who are alert to, and thus correctly identify, the value of resources and other market factors, and are subsequently rewarded with profit (Kirzner 1978a). The Kirznerian entrepreneur exists within a broader conception of the market process, and while this is complementary to the Schumpeterian entrepreneur above, it reduced the entrepreneur to their purely functional form as an arbitrageur.[40] While the Kirznerian entrepreneur has been widely applied—including for instance the

[40] As Vaughn (1998, p. 142) notes: "in Kirzner's system, the entrepreneur functions as an arbitrageur, buying cheap and selling dear."

examination of the capacity of different individuals to be alert (e.g. Shane and Eckhardt 2003)—this theory abstracts from the process of knowledge coordination and discovery, characterising an entrepreneur who is alert to a pure arbitrage opportunity. This shortcoming generated substantial criticism, in particular relating to the trade-offs in connecting the Austrian and mainstream approaches to economic thought (see Buchanan and Vanberg 1991; McCaffrey 2014; Rothbard 1985).[41]

While Kirzner's approach to entrepreneurship may be more conducive to developing an institutional approach to the entrepreneurial problem than Schumpeter's, there is a lack of focus on knowledge coordination processes from the perspective of the entrepreneur. Kirzner's alert entrepreneur acts on market opportunities without active search, despite the fact this approach is distinct from the neoclassical models of rational search such as Stigler (1961) (see Korsgaard et al. 2016, p. 4). It is important to note, however, that some of the lesser examined scholarship of Kirzner (e.g. Kirzner 1985) does emphasise more heavily the coordination processes of subjectively imagined preferences when multiple time periods are introduced—or what Korsgaard et al. (2016, p. 5) calls "Kirzner Mark II". Nevertheless, when the notion of coordination is introduced into the Kirznerian framework, it is introduced from the perspective of the market process, rather than from the perspective of the entrepreneur coordinating with others to discover those opportunities. Furthermore, a Kirznerian approach also implicitly assumes prices and markets exist, within which an alert entrepreneur acts. These characteristics of the Kirznerian theory make it ineffective for developing an institutional approach to the innovation problem from the perspective of the entrepreneur. By focusing on entrepreneurs as having a personal characteristic of alertness in perceiving economic opportunities others do not see, the Kirznerian entrepreneur obscures from the uncertainty of discovering opportunities, and therefore also obscures

[41] There have been various criticisms of Kirzner (2009, p. 1, emphasis in original), despite the fact he recently clarified his approach as having "*nothing* to say about the secrets of successful entrepreneurship." For instance, Jakee and Spong (2003a, p. 482) outline how "the determinism inherent in his approach creates inconsistencies with any attempt to integrate a greater recognition of true uncertainty." This notion of uncertainty is elaborated further below—in particular that the entrepreneur faces radical structural uncertainty. See also Korsgaard et al (2016) for an examination of the Kirznerian entrepreneur and the distinct approaches to alertness and opportunity discovery in his work.

from the knowledge coordination processes necessary to overcome uncertainty to the point of action.

From here we can see why subjectivism and uncertainty are critical in understanding the process of entrepreneurship, and are central to outlining an institutional approach to the innovation problem. Indeed, as Jakee and Spong (2003a, p. 461) propose, "the entrepreneur is shorthand for uncertainty, imperfect information, and the unknown." George Shackle (1983, 1992) made the distinction between an objective past and a subjective future due to the constantly moving, complex and evolving "kaleidoscope" of an economic system (Shackle 1992, p. 428). This understanding is often referred to as being radical because the future is effectively considered non-existent. Indeed, entrepreneurial choice and action must take place within this constantly moving economic system. Ludwig Lachmann (1976), influenced by the work of Shackle, also focused on uncertainty—including the social institutions necessary to reduce uncertainty.[42] Further, Lachmann examined the capital combinations necessary for opportunity discovery, holding that the entrepreneur "approach[es] capital structures like complex networks of artefacts that require continuous interpretation" and the entrepreneur finds meaningful gaps in capital structures (Endres and Harper 2013, p. 323). It is important to draw attention here to the fact that Lachmann stressed continuous interpretation—that entrepreneurial interpretation occurs within a complex and dynamic economic system. Furthermore, Lachmann's work on heterogeneous capital theory (e.g. see Lachmann 1956) ties in with the broader entrepreneurial literature that entrepreneurs must create or identify new ends and means relationships which have remained undetected or underutilised as ill-structured problems of search and discovery of market opportunities (e.g. see Gaglio and Katz 2001; Shane and Eckhardt 2003). These interwoven concepts of uncertainty, discovery and knowledge coordination reveal the need for interpretation of information about market opportunities. Indeed, as Don Lavoie (1991, p. 46) wrote: "Profit opportunities are not so much like road signs to which we assign an

[42] The Lachmannian conception of entrepreneurship in incorporated further into Chapter 6 on the complementary combination of blockchains to form the crypto-economy.

automatic meaning as they are like difficult texts in need of a sustained effort of interpretation."

The discovery of market opportunities under uncertainty requires some form of entrepreneurial judgement. Entrepreneurs cannot weigh all given alternatives between market opportunities, understand the multitude of payoffs in advance, or make a choice optimally as if in an environment of probabilistic risk. In this way the economic problem of entrepreneurial judgement is a problem of case rather than class probability (Mises 1949).[43] Indeed, one of the primary differences between entrepreneurial and non-entrepreneurial activity is that entrepreneurship is characterised more by uncertainty rather than risk (Alvarez and Barney 2005; Loasby 2002).[44] Even further, entrepreneurs face *structural* uncertainty—the entrepreneur is unaware of the structure of the economic problem they face (Langlois 1994).[45] That is, to the extent entrepreneurship is the process of making judgements about future states of the world before creating new means ends frameworks, the entrepreneur does not deal with probabilistic risk within a structured problem, but rather perceives solutions to unknown problems. Uncertainty doesn't just leave pure arbitrage opportunities, room for action and potential profits for those who are alert to them (Kirzner 1978b; Rumelt 2005), it also requires entrepreneurs to apply judgement under structural uncertainty before they can act (Busenitz 1996; Gaglio and Katz 2001; Kaish and Gilad 1991).[46] In this view the economic problem facing the entrepreneur is to make economic calculations or judgements over multiple courses of action. These judgements or calculations must precede acting and exploiting those opportunities. The theory of the

[43] Following Knight (1921), uncertainty is about unique events over which outcomes are not only unknown, but are fundamentally unknowable (Shackle 1992). This is in contrast to risk, where a probabilistic understanding of the problem can be developed. The type of uncertainty relating to entrepreneurship is explored further in Section 2.4 below.

[44] Indeed, as Alvarez and Barney (2005, p. 778) note: "there is growing agreement that one of the most important differences between nonentrepreneurial and entrepreneurial decision making is that the former takes place under conditions of risk, whereas the latter takes place under conditions of uncertainty."

[45] Langlois (1994, p. 118) defines 'structural uncertainty' (*c.f.* 'parametric uncertainty') as "a lack of complete knowledge on the part of the economic agent about the very structure of the economic problem they face" which is exhibited clearly in the case of entrepreneurship.

[46] Uncertainty may also prevent entrepreneurial action because of their willingness to shoulder or bear that uncertainty, which fits more closely with entrepreneur's differential levels of motivation, attitude and so on (e.g. Douglas and Shepherd 2000).

entrepreneur as a judgemental decision maker suggests that entrepreneurs must combine and interpret information over costs, benefits and complementary investments to reveal or crystallise an actionable market opportunity in their mind, prior to acting on that potential opportunity. This notion of entrepreneurial judgement stems back to the original conception of Cantillon (1772), and continues through the work of Frank Knight (1921), Ludwig von Mises (1949) and, most recently, Foss and Klein (2012).[47] This understanding of entrepreneurship as judgement emphasises knowledge coordination and interpretation given a subjective future. The following section turns to defining the characteristics of the information entrepreneurs require to make those judgements: what inputs do entrepreneurs require to make judgements? This analysis precedes developing a contract-theoretic definition of this economic problem (Section 2.3) and then operationalizing that problem in the transaction cost economics framework (Section 2.4).

2.2.2. What is proto-entrepreneurship?

Inputs into entrepreneurial judgement and calculation include all resources required to discover and exploit market opportunities (Shane and Venkataraman 2000), including the information necessary to define market opportunities to the point of action. In the Kirznerian view of entrepreneurship as alertness the entrepreneur primarily reads this information from a public information set of market determined prices (Kirzner 1978a, 1997). Kirzner's entrepreneur is alert to, and thus perceives, arbitrage opportunities between existing prices, before acting to earn profit. This pure entrepreneur relies largely on the institutions of the market to perceive and act on entrepreneurial opportunities, as well as their own inherent alertness to those opportunities. The reason prices are a complete set for the Kirznerian entrepreneur is not that prices are the full information set, but rather that the market process that determines prices is a computation of emergent information that embodies the distributed information in an economy, including local

[47] To the extent that all human action occurs under uncertainty, then judgement precedes all economic choices, not just of that of entrepreneurs. Mises (1949) therefore defined a smaller set of actors as 'promoters', who own and invest capital, is a businessperson, is particularly alert, and exhibits above average creativity and leadership. It is the 'promoter' who drives the market towards innovation and improvement, and derives their profit from a superior ability to anticipate the future demand of consumers.

knowledge of circumstances and how they have changed. That is, market prices summarise distributed information.[48] From this perspective, the alert Kirznerian entrepreneur takes into account the distributed information contained within market prices.[49] As we saw above, however, the price system is only effective at re-coordinating extant economic activity because "prices fail to provide information on how new markets could be served … [and prices do not] accurately guide the discovery and exploitation of entrepreneurial opportunities" (Shane and Eckhardt 2003, p. 166). In the Kirznerian system markets and prices are assumed to exist as pure arbitrage opportunities which are exploited by alert entrepreneurs. For new technologies that are at the stage of invention, but that the useful applications have not been fully developed, however, markets and prices do not yet exist. As such the information contained within publically available prices is an incomplete information set for the earliest stages of entrepreneurial discovery. The early stage entrepreneur who does not yet hold a market opportunity likely requires more than price information as inputs to make judgements about future potential profit opportunities. This economic problem for the early stage entrepreneur, described below, is the *proto-entrepreneurial problem*.

The proto-entrepreneurial problem precedes the first phase of the Schumpeterian innovation trajectory.[50] The proto-entrepreneur operates in the 'zero-th' phase of a potential innovation trajectory, prior to the origination of an actionable opportunity. What information do proto-entrepreneurs require to solve this proto-entrepreneurial problem of forming actionable market opportunities? The proto-entrepreneur requires more than

[48] As Hayek (1945, p. 519) explained "the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess."

[49] Entrepreneurial discovery can be viewed as operating on different levels of Williamson's institutional hierarchy (Williamson 1998, 2000). Bylund and McCaffrey (2017) outline how the Kirznerian entrepreneur acts at the level of prices in markets, whereas the Knightian judgemental entrepreneur operates at a deeper level of, for instance, shaping public affairs and institutions. Of particular note is the claim of a higher level of entrepreneurial uncertainty when operating at deeper levels of the institutional hierarchy. This theme will be continued in both Chapter 6, on the development of the blockchain crypto-economy, and Chapter 7 on the creation and discovery of the institutions of innovation.

[50] See Dopfer (2006) for an outline of the innovation trajectory in the three main phases of origination, adoption, and retention. See also Dopfer and Potts (2009). The analysis of the proto-entrepreneurial problem in this chapter precedes the first phase, origination, because it is focused on the economic problem of coordinating information to reveal market opportunities, prior to acting on them.

purely technical information (i.e. the information constituting a new technology), or pure price information (i.e. the information read from markets) to solve their economic problem. Solving the proto-entrepreneurial problem through judgement primarily requires non-price information, such as the information necessary to develop effective business models. In this way the economic problem facing the proto-entrepreneur contrasts with the economic problem facing the Kirznerian entrepreneur. The inputs into the proto-entrepreneurial problem are primarily non-price information about potential market opportunities, while the Kirznerian entrepreneur relies on publically available price information.

In the earliest stages of proto-entrepreneurial discovery a cloud of uncertainty surrounds the proto-entrepreneur regarding a future economic opportunity. Proto-entrepreneurs endeavour to engage in entrepreneurial action and exploitation for profit, but market prices are an insufficient or incomplete information set for them to solve their economic problem. Additional non-price information is required to perceive an entrepreneurial opportunity, and therefore to engage in entrepreneurial action. In this way the primary resource the proto-entrepreneur requires as an input into their judgement is non-price information. Indeed, Hayek (1937, p. 49) argued that "it has become customary among economists to stress only the need of knowledge of prices, apparently because—as a consequence of the confusions between objective and subjective data—the complete knowledge of the objective facts was taken for granted." In this chapter the focus is precisely on this non-price information.

The non-price proto-entrepreneurial information required to solve their economic problem is clearest in the early stages of new technologies.[51] While proto-entrepreneurs may hold much of the technical information of a new technology, the information that is much less clear is the non-price information relating to economic opportunities for the technology, including: potential regulatory barriers and political uncertainty; the way consumers will apply the technology in differing circumstances through time; the

[51] See Chapter 5 and Chapter 6 for a further discussion of the nature and entrepreneurial problem of one particular technology, blockchain.

trajectories of competing and complementary technologies including those not yet developed; the forward marginal costs and revenues of acting and exploiting a potential market opportunity; the sourcing of physical resources for production; the prospect of potential investment, including, for instance venture capital or seed funding; the problems that may arise when scaling up the market opportunity; and so on.

Non-price proto-entrepreneurial information has different characteristics to the price information read in markets by the Kirznerian entrepreneur—it faces *uncertainty* before it is combined with complementary information, and is *distributed* about the economy in the minds of others. Proto-entrepreneurial information about future market opportunities has *uncertain value* across multiple dimensions. The first type of uncertainty relates to the fact that future states of the world are uncertain and proto-entrepreneurs do not have perfect hindsight or foresight, and cannot anticipate all future contingencies of profit opportunities (i.e. entrepreneurs are boundedly rational). More deeply, however, proto-entrepreneurs face further uncertainty over the value of proto-entrepreneurial information. The value of this information is not necessarily clear before it is synthesised with other information, and its value is revealed by combining that information with other complementary heterogeneous information through a process of trial and error experimentation. In this way the information necessary to form a market opportunity has highly uncertain value before it is combined because the value of such knowledge only emerges once it has been assembled. The value of an opportunity is unclear before all the parts are coherently synthesised, and the value of the information is only fully realised once the entrepreneurial agent acts upon that information in markets and in firms. To be clear, even if all proto-entrepreneurial information was obtained, the value of any opportunity would remain inherently unknowable because an economy is always in constant flux and thereby the viability of market opportunities is constantly shifting.

This information is also *distributed* about the economy in the minds of others. Some non-price proto-entrepreneurial information will be held by entrepreneurs in relation to their own prior experience and education (Shane 2000). However, owing to radical

uncertainty and bounded rationality, no entrepreneur can access or process, within any reasonable time frame or cost, the complete set of information needed to perfectly assess a market opportunity in respect of how a technology works in particular circumstances. Just as different entrepreneurs will discover different opportunities because they possess different prior knowledge (Venkataraman 1997), all of the pieces of knowledge that in total describe a market opportunity are distributed over many agents in an economy. In this way, the non-price information inputs into proto-entrepreneurial judgement suffers from a division of knowledge (Hayek 1937).[52] Proto-entrepreneurs face the constraints of both bounded rationality and uncertainty described above, but they face the economic problem that the information they require is divided and distributed about the economy in the minds of various stakeholders and consumers, and within different institutional and regulatory constraints. While no person can fully comprehend or contain all of the distributed information necessary to whittle away uncertainty over a market opportunity to zero—and further that uncertainty could not approach zero given the subjective future (Shackle 1992)—it is reasonable to assume that coordinating the distributed non-price information about opportunities may hold potential gains from exchange in whittling away uncertainty so that it is actionable.

The implication of these potential economic gains of combining distributed non-price proto-entrepreneurial information is that the proto-entrepreneurial economic problem is primarily a coordination or governance problem. Proto-entrepreneurship becomes a comparative institutional question over the coordination of non-price information that potentially constitutes actionable market opportunities. Indeed, this notion of non-price coordination was recently been developed (Kuchař and Dekker 2017), focusing on how market exchanges require a broader agreement on value that comes through non-price coordination mechanisms.[53] Viewing economic problems from the perspective of

[52] Similarly, Mises (1920 [1990], p. 15) outlined an "intellectual division of labor, which would not be possible without some system of calculating production and without economy."

[53] As we will see below, it is the non-price coordination that occurs between proto-entrepreneurs in the process of solving their economic problem that acts as a complement to later economic problems within the innovation process, including coordination between prices in markets. As Kuchař and Dekker (2017, p. 24) note: "Our thesis that exchanges typically rely not just on an overlap of interest, but on a more extensive

coordination problems can be best seen in the work of Friedrich Hayek in the context of the market price system. While Hayek did not explicitly write a theoretical account of the entrepreneur, he wrote about the institutions coordinating dispersed knowledge through prices in markets (Ebner 2005). Hayek (1988 [2011], p. 104) proposed that "the entrepreneur must in his activities probe beyond known uses and ends if he is to provide means for producing yet other means which in turn serve still others…" and outlined the adaptive discovery process of market-based institutional change:

> Much of the knowledge of the individuals which can be so useful in bringing about particular adaptations is not ready knowledge which they could possibly list and file in advance for the use of a central planning authority when the occasion arose (Hayek 1973 [2012], p. 187).

Therefore, we can now turn to the question of how the uncertain and distributed information necessary to coordinate market opportunities is coordinated. What are the institutions through which proto-entrepreneurs coordinate distributed non-price information about market opportunities? This question sits on the cusp of both organisational economics and entrepreneurial theory. Several scholars have connected these fields. Mark Casson (1982, 2005), for instance, argues the entrepreneur is a specialist in judgement over the coordination of scarce resources, and that this specialisation includes entrepreneurial skills such as finding each other, communicating reciprocal wants, negotiating prices, exchanging goods, and screening quality. This implies the entrepreneur must construct sets of institutions and mechanisms to overcome these obstacles—that entrepreneurial discovery includes creating and maintaining institutions within which to discover information (Earl and Wakeley 2005). Nicolai Foss and Peter G. Klein (2012; 2014) also connect the entrepreneurial theory of judgement with heterogeneous capital theory and the theory of the firm. These authors propose that entrepreneurial judgement itself is non-tradable, but that this judgement can be delegated within a firm. In this view, the firm is the organisation in which entrepreneurs own and manage capital and assets:

agreement rests on a contention that the orders of worth that embed this agreement and thus shape markets are emergent phenomena, just like market prices. They are kinds of emergent non-price coordination, and complement the price coordination that takes place in markets and is widely regarded as the primary type of emergent coordination."

"[entrepreneurial judgement] cannot be bought and sold on the market, such that its exercise requires the entrepreneur to own and control a firm" (Foss and Klein 2012). While it is unclear whether judgement can be traded, the proto-entrepreneurial inputs into that judgement may be coordinated and combined, potentially revealing complementarities in the form of actionable market opportunities. In this context, this chapter seeks to extend these connections between governance and entrepreneurial theory through the transaction cost economics framework.

My contract-theoretic mainline institutional approach to the proto-entrepreneurial economic problem is distinct from the literatures described above in several ways. My approach begins when proto-entrepreneurs are shrouded in a cloud of uncertainty preventing them from entrepreneurial action. While scholarship such as that of Foss and Klein (2012) acknowledges that entrepreneurial coordination and exchange is not costless—and involves the choice and development of governance structures in order to make judgements—the institutional solutions to that problem are constrained to the firm. In contrast, my approach begins from the institution neutral perspective of the proto-entrepreneurial problem as a governance problem of escaping innovation autarky, to engage and coordinate non-price information about market opportunities with others, in a wide range of potential governance structures.[54] Indeed, the proto-entrepreneurial process of coordinating information to make judgements doesn't necessarily, or even efficiently, occur within the boundaries of a hierarchical firm.[55]

2.3. Escaping innovation autarky

From a contact-theoretic perspective, the default solution to the proto-entrepreneurial problem is to remain in *autarky* with no contractual or economic organisation extending

[54] This is similar to the difference in approach from Coase (1937) to Williamson (1985a). While specifically Coase sought to examine the relationship between markets and firms, Williamson developed a more general framework which does not begin in one particular organisational form or another. That is, Williamson's transaction cost economics framework is institution neutral.

[55] Broadening the suite of potential governance structures to economise on judgement has important implications for the remainder of this dissertation, which focuses on hybrid polycentric institutions at the beginning of the entrepreneurial problem (see Chapter 3).

from them in relation to their perceived opportunity. Remaining in autarky is familiar in innovation economics because it endures in one of the popular romanticisms in modern science: that the lone genius is the prime mover of history, culture, society, and the economy.[56] The lone genius forms a market opportunity in their own autarkic mind, which is then internalised within the hierarchical firm. The entrepreneur is black-boxed as a production function for new ideas, and the choice-theoretic analytical focus is then directed towards the level of effort or investment.[57] From a contract-theoretic perspective of entrepreneurial discovery, a 'competitive innovating firm' is an isomorphism of the autarkic lone genius—the innovating firm chooses a level of investment conditioned by the economic incentives pushed upon it. Both the firm and the lone genius are viewed as single entities with little consideration of how individuals interact and coordinate dispersed and contextual non-price information. The value of the innovation is either embodied as a new technology or a commodity, or is exchanged once property rights are attached to the idea. Modern endogenous growth theory, for instance, proceeds along this market line. This view of the innovation problem comes from a choice-theoretic analysis with a foreground of misallocation, market failure, and investment. This autarkic vision assumes the transaction costs of entrepreneurial coordination are zero—there is therefore no meaningful exchange or coordination occurring at the level of entrepreneurial discovery of market opportunities. As is the case with all economic problems, however, undertaking the economic problem of innovation in autarky is not necessarily, or even likely to be, the most efficient path at solving the innovation problem.

[56] Indeed, as Cooney (2005, p. 226) outlines in relation to entrepreneurial teams: "One of the great myths of entrepreneurship has been the notion of the entrepreneur as a lone hero, battling against the storms of economic, government, social, and other environmental forces before anchoring in the harbour of success."
[57] Modern innovation economics operationalises this approach by observing the micro incentives constraining or displacing this process, and indeed attempts to correct them through innovation policy.

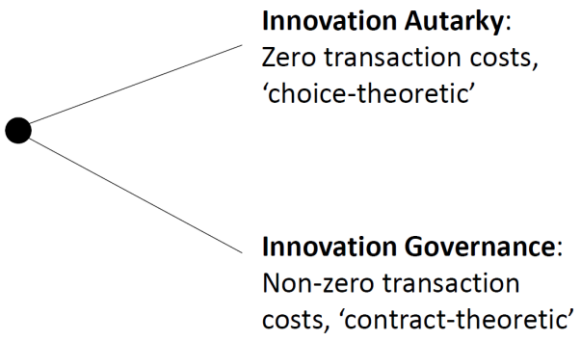

Figure 1: The analytical paths of innovation autarky or governance

Entrepreneurial judgement, at least rarely, will be best done alone. Economists have long understood that autarky tends to be a poor solution to economic problems (Smith 1776 [1976]). The process of entrepreneurial judgement and discovery of market opportunites, as with all economic activities, requires interacting, exchanging and specialising with others. Whittling away uncertainty about potential market opportunities first requires bringing other ideas together, before later applying judgement, and later acting on and exploiting those ideas. Before action, proto-entrepreneurs must first coordinate uncertain and dispersed non-price information, and, because this information is distributed about the economy and is of uncertain value (Section 2.2), entrepreneurial discovery involves coordinating and cooperating with others. From this perspective an alternative solution to the proto-entrepreneurial problem comes into view: to engage in economic governance and organisation. In this view, entrepreneurial discovery involves the organization and governance of specialized resources, capabilities and information, and over different economic problems, with different microstructures of transaction costs. This understanding implies the need for economic organisation and governance.

While the output of both the autarky and contracting views of entrepreneurship are the same—new knowledge embodied in the form of a market opportunity often attached to a technology—the former focuses on production costs and investment in a choice-theoretic analysis, while the latter focuses on how governance structures economise on transaction costs in a contract-theoretic analysis. Developing a contract-theoretic understanding of entrepreneurial judgement and discovery returns the analytic unit of analysis to the

transaction, and proceeds to examine the costs and hazards experienced by proto-entrepreneurs as they interact and exchange with others. In some respects, the innovation problem remains an investment problem, but it is not one of incentivising an optimal level of investment—the innovation problem is one of how private ordering governance structures can facilitate and incentivise exchange of entrepreneurial information that economises on the transaction costs of coordinating that information. From here it is clear why proto-entrepreneurs must 'escape' autarky—because in coordinating with others they face hazards of transaction costs. The contract-theoretic innovation problem is a question of creating privately ordered governance mechanisms to induce mutual investment and subsequent cooperation to realize gains from coordination of proto-entrepreneurial information with others.

A major conceptual implication of the contract-theoretic institutional approach to the proto-entrepreneurial phase of the innovation problem is that it redefines the innovation problem in terms of comparative governance. From a contract-theoretic perspective, the economic problem for the proto-entrepreneur is to acquire the distributed bits of contextual information about potentially exploitable opportunities by organising in groups—whether in communities, clubs, teams, departments, firms, networks, clusters, or commons—under non-zero transaction costs and hazards. This is a new foreground of the innovation problem, as compared to the choice-theoretic conception outlined in Chapter 1. This approach is built around an entrepreneurially-centred account of economic action in which transactions are the unit of analysis, and where different orders of innovation governance arise primarily in the service of transaction cost economisation. The division of knowledge, and potential gains from trade from coordinating that knowledge with others, incentivises proto-entrepreneurs to develop governance structures to economise on the transaction costs of exchange. That is, there are potential gains from trade from coordinating non-price entrepreneurial information, that coordination faces non-zero

transaction costs, and private orderings will comparatively economise on those costs.[58] The proto-entrepreneur must decide whether to proceed alone to develop their potential market opportunity to act on it, or whether to, and how to, organize with one or several others to coordinate non-price information and develop the new idea into an opportunity.

At first the contract-theoretic view of the innovation problem is oblique because it contrasts with the more familiar technology-centred or production function-centred views of innovation economics. In the technology-centred view, the only costs are resource or factors of production costs associated with exploiting an opportunity. Focusing only or primarily on production and exploitation of an opportunity is tantamount to assuming that the transaction costs of proto-entrepreneurial judgement to discover opportunities is zero. The entrepreneurial discovery is assumed to occur seamlessly and costlessly. In the contract-theoretic view, however, entrepreneurial discovery requires organization, and that organization is not free. The analytical heart of this new contract-theoretic perspective is to examine how entrepreneurs chose to enter economic organisation, and in what form, rather than assuming some form of existing organisation such as a firm, and examining the investment, or the move from one organisational form to the other, without examining the nature of the economic problem people are seeking to solve.

The way the proto-entrepreneurial problem will be solved is a function of the transaction costs facing them as they coordinate entrepreneurial information with others. Because of non-zero transaction costs, the entrepreneur faces a choice over comparatively economising governance structures, including the choice to create new governance structures. The actual form that the organizational governance of proto-entrepreneurship takes will depend upon the microstructure of transactions costs and how proto-entrepreneurs perceive comparatively effective governance structures in economising on

[58] A private ordering is what Williamson (2002b, p. 172) describes as "efforts by the immediate parties to a transaction to align incentives and to craft governance structures that are better attuned to their exchange needs."

those costs. This enables a comparative institutional analysis of the innovation problem through the logic of transaction cost economics, which is the task of the following section.

2.4. Characterising the transaction costs of proto-entrepreneurship

Understanding economic problems by taking the transaction as the analytical unit continues in a long line of institutional scholars whose work viewed economic problems in terms of coordination and governance rather than allocation and investment (e.g. Coase 1937; Commons 1931; Williamson 1985b).[59] Transaction cost economics, at its most basic level, understands that: (a) there are gains from trade from specialisation and exchanging with others; (b) that exchange relationships face non-zero production and transaction costs; and (c) that institutional governance structures can ameliorate some of these contracting hazards by structuring the order of exchange.[60] A contract-theoretic approach means that economic organisation matters and that the shape of economic ordering is primarily a result of transaction cost economising activities (Tadelis and Williamson 2012). Ronald Coase (1937) explained the existence of firms based on the costs of exchange in a market system. This analysis connected the hazards of exchange with economic organisation, and started what is now called a comparative institutional economics, where institutional structures were no longer taken as given. Alternative forms of economic organisation are themselves the result of economic choices of profit seeking people. In Coase's analysis, however, technology was the major factor determining organisational boundaries, based on the idea of marginalism of the different organisational forms of firms and markets in dealing with costs. This understanding that different governance structures deal with transaction hazards in comparatively different ways, however, still led early transaction cost economics to receive a "bad name" in economics because the concept lacked operational and predictive

[59] Propositions of governance structures to economise on the costs of entrepreneurial discovery (i.e. an application of the discriminating alignment hypothesis) are left to the following chapter. The aim of this chapter is to focus on the 'transaction' side of Williamson's private ordering equation, and therefore to outline the nature of asset specificity and uncertainty in the context of entrepreneurial judgement.

[60] See Williamson (2007) for an overview of the foundational elements of the transaction cost economics.

power (Fischer 1977).[61] Later, Oliver Williamson (1975; 1979; 1985; 2002a) operationalised transaction cost economics into a theoretical framework, thereby making the field a micro-analytic endeavour. At its most basic level, Williamson's framework aligns governance structures with transaction characteristics. This framework is based on the notion that different transaction costs are dealt with in different ways by different governance structures. Before outlining Williamson's TCE framework, we must first outline each of the behavioural assumptions sitting behind it.

The logic of transaction cost economics rests on several behavioural assumptions stemming from the inherent non-trivial uncertainty about future states of the world. That is, the behavioural assumptions outlined below are all the result of the assumption that because future changes in the world may impact on the terms of the relationship, parties must seek to determine potential changes *ex ante*. While the precise level of uncertainty varies, it is widely accepted that there is some non-trivial level of underlying uncertainty associated with each transaction. Beginning from this understanding, and then relaxing other unrealistic assumptions over the behaviour of people—including unlimited human rationality, benevolent trading partners, and mobile and homogenous investments—we can demonstrate the hazards of exchange and thus the need for economic governance and organisation. This understanding is particularly important in the context of exchanging proto-entrepreneurial non-price information, where, as we have seen, agents face structural uncertainty and radically incomplete contracts.[62]

Entrepreneurs face the constraint of bounded rationality.[63] To write any completely contingent contract requires *ex ante* determination of all potential future changes in the

[61] That is, transaction costs were seen to be invoked in a tautological way—to "explain" differences in organisation after the fact—leading the field to receive a "well-deserved bad name" (Fischer 1977, p. 322).
[62] Incomplete contacting theory holds that contracts cannot specify in advance the entire suite of contingencies, which leads to transaction hazards such as hold up problems (Grossman and Hart 1986; Hart and Moore 1990). Contracts for the coordination proto-entrepreneurial information are necessarily incomplete contracts, as we see below in relation to the inherent uncertainty over trading partners and the value of proto-entrepreneurial resources before they are combined.
[63] The literature on bounded rationality is traced back to Simon (1957), in which boundedly rational agents are compared to classical models of perfect rationality. Simon incorporated the notion of heuristics—of rules to make decisions rather than strict optimisation—which now forms a basis for behavioural economics. Proto-entrepreneurs, like all economic agents, are boundedly rational.

world—a computational capacity far exceeding the entrepreneurial mind. Because proto-entrepreneurs, like all people, are boundedly rational, they cannot devise and articulate an entire decision tree of contingencies for a particular market opportunity in advance. Even assuming uncertainty, if proto-entrepreneurs exhibited perfect rationality, then exchange hazards could be overcome by *planning* for future contingencies.[64] Relaxing the assumption of perfect rationality, however, implies that effectively planning a decision tree is impossible. Further, entrepreneurs are not necessarily benevolent in exchange and can act *opportunistically*. Even despite the unavoidable incompleteness of contracts stemming from bounded rationality, perfectly benevolent proto-entrepreneurs could simply *promise* each other to renegotiate any unforeseen contracting difficulties in good faith as they arise—for instance, whether or not an actionable opportunity is perceived. This would include writing in general clause contracts and adapting later through renegotiation.[65] When some trading partners can take economic advantage of situations of asymmetric information—that is, acting opportunistically, and particularly in the face of asset specificity outlined below—the efficacy of promise falls down because even some opportunistic agents who self-interest seek with guile make contract adaptation and renegotiation hazardous.[66] To be clear, the potential for opportunism is hazardous because it is impossible to determine whether *ex ante* a trading partner will act opportunistically.[67] Finally, the investments in entrepreneurial process may not be fully mobile—the resources the proto-entrepreneur requires to solve their economic problem can exhibit *asset specificity*, where the identities of trading partners can generate hazards and hold-ups in future time periods (Williamson 1985a). Even if we

[64] In this circumstance, writing a completely contingent contract would be possible but prohibitively costly (see Bajari and Tadelis 2001). Similarly, the incomplete contracting literature assumes that due to incompleteness the cost of writing completely contingent contracts is prohibitively expensive. This implied contracting process is closely associated with the mechanism design literature (i.e. Hurwicz 1973; Myerson 1979).

[65] One of the central problems of economic organisation, and economics more broadly, is that people are boundedly rational and cannot anticipate all potential future contingencies. This implies that all contracts are incomplete. The incomplete contacting literature is closely connected with the theory of the firm (Grossman and Hart 1986). For a review of the literature on incomplete contracting see Tirole (1999) and Aghion and Holden (2011).

[66] Maintaining opportunism while assuming perfect rationality then comprehensive contracting would still be necessary and possible.

[67] The types of entrepreneurial opportunism are explored further in Chapter 4. At present it is sufficient to note the potential for opportunistic behaviour.

take the serious contracting difficulties above—arising from bounded rationality and opportunism—the market process still theoretically enables parties who have contracted with defectors to easily turn to others to write new contracts through competition. Such a competitive process, however, requires mobile and homogenous investments so that people can employ discrete market contracts and resolve disputes in court. In the presence of asset specific investments, discrete market contracts may be hazardous because of the rise of asymmetric bargaining power and therefore potential hold-up problems and threats (this is despite the fact it is of interest to both parties to continue the exchange relationship). The implications of these various behavioural assumptions are summarised in Table 1 below, adapted from Williamson (1985a). Given that the process of entrepreneurial market opportunity discovery is highly contextual, and given the heterogeneous nature of non-price information, it is reasonable to assume some level of asset specificity in entrepreneurial coordination as well as bounded rationality and the potential for opportunism. The limited rationality of the human mind, the presence of at least some opportunistic agents, and the potential for asset specific investments which incur the loss of economic rents in finding new trading partners, implies more complex forms of private ordering. This is the domain of the proto-entrepreneur—who when seeking to coordinate uncertain non-price information with others cannot simply plan, promise or compete—the proto-entrepreneur requires more complex private orderings.

Behavioural Assumption			
Bounded Rationality	Opportunism	Asset Specificity	Implied Contracting Process
-	+	+	Plan
+	-	+	Promise
+	+	-	Compete
+	+	+	Governance (private ordering)
present in significant degree = +; presumed to be absent = 0			

Table 1: Implied contracting processes given different assumptions

For proto-entrepreneurs to coordinate they must create and enforce governance structures to economise on the transaction costs inherent in the particular problem they face. Transaction costs, following Dahlman (1979), are search and information costs, bargaining

costs, coordinating and enacting costs, and monitoring and enforcement costs.[68] These transaction costs of using different institutions to coordinate activities are analytically distinct from the costs associated with the transformation or production costs of making and producing things.[69] Douglass North (1990) proposes that these transaction costs are impacted by the factors of measurement, enforcement, ideological attitudes and perceptions and the size of the market. How can we define transaction costs and therefore understand the proto-entrepreneurial problem within the transaction cost economics framework?

The approach in this chapter is to characterise the proto-entrepreneurial problem using the transaction cost economics framework first outlined in Williamson (1979). In this framework, transactions are defined along three dimensions: (1) the type and degree of uncertainty; (2) the type and degree of asset specificity; and (3) the frequency of transaction. Such an analysis raises a number of questions. What level and type of uncertainty does the proto-entrepreneur face? Are the exchanges of non-price information between proto-entrepreneurs idiosyncratic? Furthermore, how do these dimensions change through time as groups of entrepreneurs exchange and coordinate information and define and crystallise market opportunities? Answering these questions has implications for the transaction cost economising governance structure throughout an innovation trajectory. Before answering these questions, however, we must first define each of the dimensions, and examine why they matter for economic organisation.

First, the presence and level of *asset specificity* matters, as briefly outlined above, because it suggests whether or not the identity of trading partners matter. When an exchange relationship creates specific investments there is an incentive for parties to continue the contracting relationship. Continuity of the relationship is valued because the

[68] Transaction costs can similarly be defined by what they are not—as is the case in Cheung (1990), who defines transaction costs based on those costs that are not conceivable within the Robinson Crusoe economy.
[69] The Coasian definition of a transaction cost is "the cost of using the price mechanism", whereas two distinct meanings have subsequently developed (Allen 1999). In the neoclassical literature transaction costs refers to "the costs resulting from the transfer of property rights", whereas in the New Institutional literature it is "the cost of establishing and maintaining property rights".

quasi-rents generated throughout exchange would be sacrificed if the relationship terminated (Klein et al. 1978).[70] The economic value of these quasi-rents leads to contractual asymmetries, and, in the face of opportunistic behaviour, bring with them pervasive contracting consequences (Williamson 1985a). Second, the level and type of *uncertainty* characterising a transaction determines the extent to which the transaction will face *ex post* hazards. Higher levels of uncertainty create larger contractual gaps and increase the possible need for later adaptations.[71] Uncertainty in the transaction cost economics framework relates to how the future states of the world will impact on the possible completion of the contract as it was drafted, including both exogenous events that impact on the transaction, as well as the strategic opportunistic disclosure or nondisclosure of information from the other party. Finally, the *frequency* of a transaction relationship determines the extent to which the cost of specialised governance structures can be recovered—the more frequent a transaction, the higher potential to recover the cost of a governance structure. Following Tadelis and Williamson (2012, p. 13), however, the frequency of transactions is not examined here because of its "ambiguous implications" for economic organisation.

We can begin our analysis of the transaction costs of the proto-entrepreneurial problem with an examination of the *type and degree of uncertainty*. As outlined above, the economic problem facing proto-entrepreneurs—of discovering actionable opportunities—include various search and information costs due to uncertainty inherent in the problem. The main difference between the production of a widget and the discovery of a market opportunity is that the latter involves the combination and coordination of information under structural uncertainty to produce new knowledge.[72] In this way the proto-entrepreneur faces a higher level of fundamental structural uncertainty than do other forms of production due to its inherent novelty of making choices and coordinating information within poorly defined

[70] As Klein et al. (1978, p. 298) note: "After a specific investment is made and such quasi rents are created, the possibility of opportunistic behavior is very real."
[71] Increasing levels of uncertainty are relatively uninteresting where there are few asset specific investments.
[72] This understanding is similar to the distinction between invention and innovation (Schumpeter 1934), where the former includes the technical knowledge while the latter includes all of the additional information—i.e. non-price, distributed and contextual information—about how to apply that technology in useful ways.

problems. The type of uncertainty facing the proto-entrepreneur is distinct from the concept of uncertainty with the transaction cost economics framework outlined above. In the transaction cost economics framework, it is assumed that market opportunities exist, that contracts have some form of known deliverable, and that the potential parties to an exchange are known. That is, in the transaction cost economics framework the parties to an exchange understand what they are transacting for, and agree on the value—even if that value cannot later be verified by a third party. The type of uncertainty that the proto-entrepreneur faces, however, even extends to include the information over who their potential trading partners are. The proto-entrepreneur faces a type of structural uncertainty in that they do not know who has, or which other people have, the relevant and sufficient complementary heterogeneous information to define an opportunity. Proto-entrepreneurs face structural uncertainty on many fronts, including: the nature and type of information held by other proto-entrepreneurs, whether or not an opportunity will be crystallised from a given exchange, what the value of that opportunity will be if one is revealed, and indeed whether the other party is acting opportunistically in the information they exchange. This type of proto-entrepreneurial uncertainty uniquely characterises the economic problem of initially discovering and then developing a novel idea prior to acting on an opportunity.

The level and type of structural uncertainty for the proto-entrepreneur also changes as the proto-entrepreneur solves their economic problem. As proto-entrepreneurs coordinate information, make judgements, and begin to define opportunities, the structural uncertainty they face regarding that opportunity falls. Part of this fall in uncertainty is because their complementary trading partners, at least to the extent of their perceptions, are revealed. That is, as proto-entrepreneurs discover those who hold complementary information that helps to define market opportunities—and therefore realising some mutually beneficial exchanges of information resulting from the division of knowledge—the level of structural uncertainty shifts towards more classic uncertainty. The type of uncertainty begins to relate to a known problem—where for instance the uncertainty relates to how future states of the world will impact on the exploitation of the perceived opportunity—rather than an

unknown problem. Therefore the type of uncertainty begins to align more closely with uncertainty within the transaction cost economics framework.[73]

The transaction costs of the proto-entrepreneurial problem can also be understood in terms of the *type and degree of asset specificity*. Does the coordination of non-price information with other proto-entrepreneurs generate of asset specific investments? The type of asset specificity within a proto-entrepreneurial transaction primarily refers not to physical capital, but to entrepreneurial human capital as proto-entrepreneurs learn about a specific market opportunity.[74] Idiosyncratic investments need not arise from conscious investments, but arise through the spontaneous interactions of learning by doing (Tadelis and Williamson 2012). Proto-entrepreneurial investments are primarily investments in human capital in the process of discovering a market opportunity. In the earliest stages of the proto-entrepreneurial problem there is little measurable economic value because proto-entrepreneurs lack the necessary information to act on their perceived opportunity. As proto-entrepreneurs engage and exchange information and whittle away this uncertainty they may begin to perceive actionable market opportunities. A continuing relationship between proto-entrepreneurs theoretically comes with human capital investments as information is coordinated and articulated. This suggests asset specificity and perceived quasi-rents have been generated as the contractual relationship has developed.[75] In this way, as a contractual relationship develops between proto-entrepreneurs, the relationship is no longer faceless, and a bilateral or multilateral dependency condition may have been obtained through the generation of idiosyncratic investments from understanding, articulating and defining a perceived market opportunity together. As structural uncertainty declines about trading partners and the market opportunity, the realisation of previously

[73] This interpretation of a decrease in uncertainty can alternatively be described as the movement from a problem primarily comprising of transaction costs—of finding other proto-entrepreneurs and exchanging information with them about market opportunities—to one primarily of production or transformation costs—of exploiting a perceived opportunity.

[74] See Williamson (1979, p. 240) for an illustration of human capital investments: "Specialized training and learning-by-doing economies in production operations are illustrations [of human-capital investments]."

[75] In the management literature (e.g. see Alvarez 2007) a distinction is made between an entrepreneurial rent and a quasi-rent, with the former occurring under uncertainty and the latter under risk. In this chapter I refer to perceived quasi-rents—that is, a perceived future market opportunity in the subjective perception of the entrepreneur—which collapses the two concepts together.

uncertain economic value opens the potential of asymmetric bargaining relating to that opportunity. In this way, when proto-entrepreneurs move from sharing and exchanging information with others in efforts to discover an opportunity ('zero-th phase') to the point when they perceive an opportunity and entrepreneurially act on it ('first phase') there is a shift in the microstructure of transaction costs because, rather than transactions with very little actionable economic value, the proto-entrepreneurs create a new bundle of potential property rights in the form of a market opportunity. The perception of quasi-rents relates to how some economic value that has been generated during the exchange may be foregone if the relationship was severed.

We can connect these intertemporal aspects of uncertainty and asset specificity described here to outline a distinctive intertemporal regularity in the process of proto-entrepreneurial discovery—what I call the entrepreneurial fundamental transformation—which can be understood by first understanding Oliver Williamson's fundamental transformation. Williamson (1979) proposed a 'fundamental transformation' where what begins in *ex ante* competition in markets, where multiple agents bid for a contract, ends in *ex post* bilateral supply as the trading relationship develops. That is, as a trading relationship develops there can be an intertemporal change in the economising governance structure from a situation of large numbers competitive bidding in markets, to one of small numbers bilateral supply in firms. This transformation from competition to asymmetric hazards is largely due largely to the increase in asset specific, leading to asymmetric bargaining powers in later rounds of bidding. Transformation becomes because a scenario of relatively faceless contracting is supplanted with a scenario "where the pairwise identity of the parties matters" (Williamson 1985a, p. 62). In this way, a trading relationship may efficiently begin in competitive markets, but due to the build-up in asset specific investments, and the fact quasi-rents would be foregone if the relationship was severed, integration within a hierarchical firm may become the economising governance solution. That is, the bilateral dependency condition that is obtained due to asset specificity creates the need for "value-preserving governance structures—to infuse order, thereby to mitigate conflict and to realize mutual gain …" (Williamson 2002, p.176). The potential for a fundamental

transformation furnishes the need for a more complex governance structure to be developed in order to realise the gains from exchange. In Williamson's conception of markets and hierarchies, the potential governance solutions to a fundamental transformation range from market-based solutions (and standardisation with the backdrop of the legal system) to integration within hierarchies (substitution of the legal system for internal control).

A similar entrepreneurial fundamental transformation can be seen following the analysis of the characteristics of transaction costs for the proto-entrepreneurial problem. As we saw, as proto-entrepreneurs exchange non-price contextual information with others the microstructure of the dimensions of transaction costs shift. As proto-entrepreneurs jointly discover complementarities between bits of heterogeneous non-price information about capital combinations—and as they move through the 'zero-th' phase of discovery towards the 'first' phase of origination and action—quasi-rents are generated in the form of human capital investments between multiple proto-entrepreneurs in a perceived opportunity. Put another way, the investments in discovering and defining market opportunities in groups makes it more difficult to turn to others, imply those inputs are no longer mobile and homogenous, and that economic value would be sacrificed if the relationship was severed (Klein et al. 1978). That is, "once [a] transaction-specific investment is made by one party, quasi-rents are created which can sometimes be appropriated by the other party" (Monteverde and Teece 1982, p. 322).[76] The collaborative discovery of market opportunities also holds economic value which may be bargained over through opportunism. While both proto-entrepreneurs may both jointly wish to fully realise the economic benefits of the market opportunity—by, for example, founding a new firm—they are also incentivised to opportunistically bargain in future periods. For instance, proto-entrepreneurs face the hazard of bargaining due to asymmetric information associated with the discovery of a

[76] In the absence of opportunism, the contracting difficulties relating to the 'entrepreneurial fundamental transformation' would vanish because as a market opportunity with economic value is revealed, the parties would easily adapt and re-draw contracts so as to divide the future benefits. However, when at least some parties in a population are opportunistic some of the time, we have a bilateral monopoly where "both buyer and seller are strategically situated to bargain over the disposition of any incremental gain whenever a proposal to adapt is made by the other party" (Williamson 1985b, p. 63).

market opportunity. As economic values enter the relationship through the discovery of a market opportunity it is reasonable to suggest that these idiosyncratic investments in human capital "can be realised only so long as the relationship between the buyer and seller is maintained" (Williamson 1985a, p. 62). The contractual hazards that emerge throughout a proto-entrepreneurial exchange relationship come about because of both the human-capital investments throughout the market opportunity discovery process would be "sacrificed if the ongoing supply relation were to be terminated" (Williamson 1985: 62), and as the value of a specific market opportunity is realisable and actionable.[77]

In this sense the entrepreneurial fundamental transformation has similar dynamics to Williamson's fundamental transformation because both end with a bilateral dependency due to an increase in idiosyncratic investments, and therefore the potential for vertical integration within a hierarchical firm to overcome contracting hazards. As proto-entrepreneurs coordinate dispersed contextual entrepreneurial information they shift to a small numbers game where the continuity of the relationship is valued. Therefore, different phases of the innovation process face different economic problems, with different structures of transaction costs. Because quasi-rents are generated between proto-entrepreneurs throughout their coordination process there is an increased likelihood that internal vertical integration will be the efficient governance structure. In the entrepreneurial process of coordinating non-price information with others, uncertainty is whittled away not just about the opportunity itself but also about the contracting relationship between the collaborating agents, suggesting the need for more complex centralised governance solutions to prevent opportunism. As Ménard (2004, p. 354) proposes "the more specific mutual investments are, the higher are the risks of opportunistic behaviour, and the tighter are the forms of control implemented." Put another way, "the greater is the appropriation concern, which grows with the specificity of investments, the more centralized the

[77] These contractual hazards relate to the potential for 'hold up' through opportunistic renegotiation following non-verifiable specific investments. See the work on incomplete contracting theory in this regard (Grossman and Hart 1986; Hart and Moore 1990; Klein et al. 1978; Tirole 1999).

coordination needs to be" (Ménard 2004, p. 354).[78] From here we can see that the post-transformation governance structure fits tightly within the Williamson framework, in a type of hierarchical centralised firm. It is not clear, however, what the pre-transformation proto-entrepreneurial transaction cost economising governance structure is.

What is clear is that the entrepreneurial fundamental transformation does not begin as a competitive bidding process concerned with prices and quality in markets. Proto-entrepreneurs begin with many other potential trading partners who hold potentially complementary information. Further, the information they require faces a division of knowledge and is largely non-price. This suggests two sequential economic problems that constitute the innovation problem: first, to gather non-price information from others and make proto-entrepreneurial judgements over viable market opportunities, and second, to act upon those perceived economic opportunities in search of profits. This can be summarised as an extension of Oliver Williamson's contracting schema outlined in Figure 2 below, adapted from Williamson (2002a, p. 183).

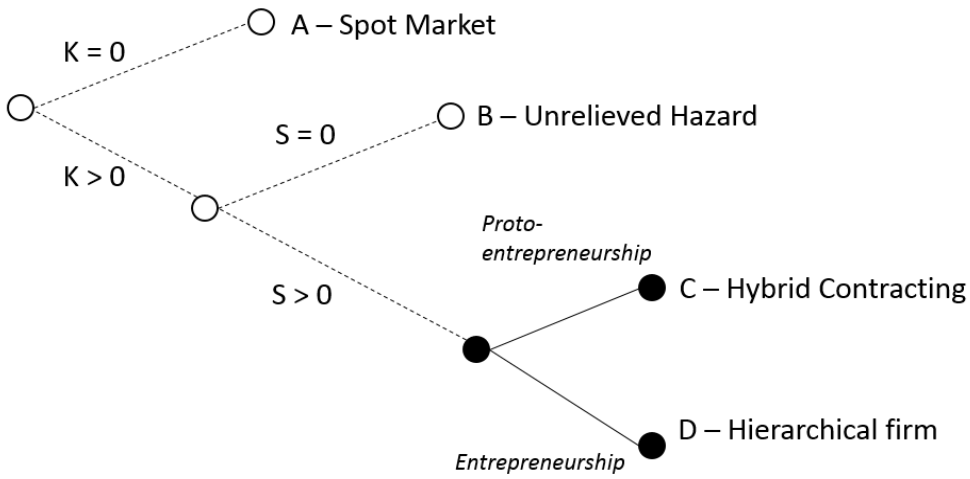

Figure 2: The entrepreneurial fundamental transformation

[78] This transformation to a centralised hierarchical governance structure, however, is not costless—as Klein et al. (1978, p. 298) note: "as assets become more specific and more appropriable quasi rents are created (and therefore the possible gains from opportunistic behavior increases), the costs of contracting will generally increase more than the costs of vertical integration. Hence, *ceteris paribus*, we are more likely to observe vertical integration."

Without asset specificity (K=0) the proto-entrepreneur could create a spot market for the information they require to make judgements and define a market opportunity. In the presence of asset specificity (K>0), however, the proto-entrepreneur has two choices—they could employ no contractual safeguards (Node B) and be at risk of opportunism, or create some form of governance structure—through contracting or a firm. In this section I have proposed the existence of an entrepreneurial fundamental transformation where the proto-entrepreneur begins with one economic problem with a particular microstructure of transaction costs, yet as that problem is solved they begin to face a different microstructure of costs. This transformation can be represented as a shift in the transaction cost economising governance structure from Node C to Node D in Figure 2 above. While this chapter has not enquired into the transaction cost economising governance structure for Node C—prior to the entrepreneurial transformation—this is the task of the following Chapter 3.[79]

2.5. Implications and conclusion

The analytical foreground of the market failure analysis of the innovation problem is a choice-theoretic analysis focusing of the investment and allocation of innovation resources (Chapter 1). The primary contribution of this chapter has been to develop the foundations for the contrasting institutional contract-theoretic analysis of the innovation problem, centred on the entrepreneur and the economic problems they face. My approach has drawn on the theory of the entrepreneur within mainline economic theory, and outlined this understanding within the transaction cost economic framework. The proto-entrepreneur was defined as the economic agent who requires further uncertain, contextual and distributed non-price information to define and crystallise a market opportunity to the point of action. This proto-entrepreneurial economic problem precedes the first phase of the Schumpeterian innovation trajectory. The non-price information proto-entrepreneurs require to whittle away uncertainty about their potential opportunity is distributed about

[79] My main claim in Chapter 3 is that the transaction cost economising governance structure for the proto-entrepreneur—that is, Node C—may be in a hybrid form of contracting within an innovation commons.

the economy in the minds of others. Given non-zero transaction costs, the primary proto-entrepreneurial problem is to coordinate this information with others in a range of comparatively effective governance structures such as firms, clubs, commons or networks. While understanding they must interact with others, proto-entrepreneurs don't know what governance structures are most efficient at solving that problem, or even who their mutually beneficial trading partners might be. The proto-entrepreneurial problem, therefore, is a governance problem.

This new approach to the proto-entrepreneurial innovation problem was operationalized using the transaction cost economics framework by theoretically defining the type and degree of uncertainty and asset specificity that proto-entrepreneurs face as they seek to solve their economic problem. While for the earlier stages of proto-entrepreneurship there is high structural uncertainty (including finding other collaborative agents with complementary bits of information), and low asset specificity (because there is little actionable economic value), as complementary trading partners and non-price information are exchanged and market opportunities become crystallised, the type and level of uncertainty and asset specificity shift. The type of uncertainty moves from structural uncertainty towards more classic uncertainty, and asset specificity increases as quasi-rents build up between proto-entrepreneurs. This suggests a distinctive intertemporal regularity—an entrepreneurial fundamental transformation—where the transaction cost economising structure shifts along an innovation trajectory as proto-entrepreneurs move from discovery of opportunities to acting on those opportunities as entrepreneurs. While the latter post-transformation analysis is familiar within the Williamson framework—vertical integration within a centralised hierarchical firm—the governance structure for the former pre-transformation proto-entrepreneurial problem is unclear, and forms the primary focus of this thesis.

There are several implications of this new contract-theoretic approach to the innovation problem. The specific ways in which idiosyncratic investment, asset specificity and opportunism manifest as problems of private ordering are all consequences of the

transactions costs incurred in seeking to coordinate under structural uncertainty. A focus on the proto-entrepreneurial governance choice means that the innovation problem can be viewed as one of *private ordering* before it manifests as a problem of public goods provision. From a mainline institutional perspective, the basic economics of entrepreneurial discovery consists of entrepreneurial actions to economise on transaction costs by selecting appropriate governance structures to coordinate non-price information under uncertainty. Further, the solutions to the innovation problem expand beyond firms and markets to encompass the potential for a wider range of private ordering solutions.[80] In this way my approach goes beyond the conventional remit of organisational innovation economics—which resides in an institutional environment of firms, markets and states—to incorporate a broader range of governance structures, including commons. This new perspective sets the path for understanding alternative institutions within the entrepreneurial discovery process. Examination of the transaction costs of discovering valuable market opportunities in groups suggests a unique economising governance structure prior to the founding of an entrepreneurial firm in order to reveal market opportunities. Enquiring into the potential for polycentric collective action governance in hybrids as a governance solution to the proto-entrepreneurial problem is the task of Chapter 3.

[80] My approach, following Harper (2008, p. 614) is "'institution neutral' in that it does not presuppose a particular governance structure (such as a start-up firm)." Note however, that my approach to the innovation commons outlined in Chapter 3 does not assume, as is the case in Harper (2008), that the team of entrepreneurs has a 'common goal', except to the extend they face a proto-entrepreneurial problem. In this sense those 'common goals' must themselves be discovered.

Chapter 3: The innovation commons

3.1. Solving the proto-entrepreneurial problem

The innovation process consists of a range of economic problems—ranging from where proto-entrepreneurs are seeking to discover novel market opportunities under uncertainty, to where entrepreneurs act on and exploit those opportunities for profit. Each of these economic problems has different microstructures of transaction costs, and therefore different transaction cost economising governance solutions. This chapter focuses on the early stages of the proto-entrepreneurial economic problem, of coordinating uncertain and distributed information to crystallise market opportunities with others—that is, prior to the entrepreneurial fundamental transformation outlined in Chapter 2. Using transaction cost economics logic, I propose a new potential transaction cost economising solution to this problem, called an innovation commons. An innovation commons is defined and characterised as a polycentric collective action hybrid within which proto-entrepreneurs coordinate the non-price information inputs necessary to solve their economic problem of discovery actionable market opportunities.

First, my analysis applies the 'discriminating alignment hypothesis' from transaction cost economics (Williamson 1975; 1985a; 2005), to propose that the transaction cost economising governance structure for the proto-entrepreneur may be in a hybrid that exhibits the governance characteristics of both firms and markets. While on one hand proto-entrepreneurs require the freedom of interacting with others to coordinate and discover complementary bits of information that are shrouded under uncertainty, on the other hand proto-entrepreneurs face various threats of opportunism in this coordination process. Given these transaction costs, a governance structure with both autonomous and coordinated adaptive characteristics may be required, implying that the economising governance structure may be in a form of hybrid polycentric governance. Hybrid governance structures can incorporate multiple centres of decision-making (that is, polycentrism), effective

monitoring, provision for exit, and fluid contracting. In this way hybrids may be effective for the proto-entrepreneur to coordinate information about market opportunities with others.

The second part of my analysis, together with Jason Potts, introduces and defines an innovation commons based on the common pool resource management literature associated with the Bloomington School (Ostrom 1990, 2005, 2010; Poteete et al. 2010). My main proposition is that the transaction cost economising institutional origin of the entrepreneurial process of discovering opportunities for new technologies may be located within self-organising and privately governed institutional spaces called innovation commons. An innovation commons is a type of hybrid that is collective governed, based on proto-entrepreneurial non-price information resources, in which groups of proto-entrepreneurs coordinate information to alleviate uncertainty around market opportunities. An innovation commons is a governance structure that may economize on the transaction costs of proto-entrepreneurial discovery in the face of uncertainty. In some ways an innovation commons is similar to the existing species of commons, such as fisheries, forests and the law (Frischmann et al. 2014; Hess and Ostrom 2003; Madison et al. 2010; McGinnis and Ostrom 1992), because both an innovation commons and previous types of commons are rule governed spaces that are governed from the bottom-up through collective action decision making. However, innovation commons also exhibit unique behavioural characteristics that stem from the underlying resource: innovation commons exist to process uncertainty rather than deal with perpetually deal with uncertainty; innovation commons are not necessarily about social provisioning, but act as a complementary institutional form to firms and markets; innovation commons are emergent around the early stages of new technologies, industries and general purpose technologies where uncertainty and the potential gains from exchange of proto-entrepreneurial information is highest; and innovation commons are spatially and temporarily mobile, operating at different sizes and scales across the space of economies. The clearest behavioural characteristic of an innovation commons is that, from the perspective of an innovation trajectory, they are likely to be temporary institutional phenomena. An innovation commons is a temporary solution to the proto-entrepreneurial problem because of the entrepreneurial fundamental

transformation described in Chapter 2—the success of an innovation commons in solving its economic problem of facilitating the discovery of opportunities shifts the structure of transaction costs and enables other institutions to outcompete it in later stages of the innovation process.[81]

To be clear, proposing the potential transaction cost economising properties of an innovation commons is not to claim that *all* entrepreneurial discoveries of market opportunities will occur in an innovation commons. Different opportunities will be discovered under different institutional arrangements depending on the institutional choices of the proto-entrepreneur, and the structure of distributed information existing within the system. Rather, my claim is that, following the logic of transaction cost economics, the governance characteristics associated with hybrids and commons regimes—including their relatively flat or emergent hierarchies and polycentrism—may be comparatively efficient processing mechanisms for some proto-entrepreneurial problems.[82] The analytical focus of this chapter, therefore, is on why and how an innovation commons may institutionally align with the economic problem of proto-entrepreneurship, how such a governance structure may institutionally behave, and how an innovation commons relates to the broader political economy of the institutions of innovation.

The existence of an innovation commons has implications not just for innovation economics and entrepreneurial theory, but also in expanding the cases where private collective action governance of common pool resources may be transaction cost economising. In modern economics the institutions that facilitate the process of the development of new technologies are generally constrained to firms, markets and governments.[83] The innovation commons, however, suggest that the economic problem of

[81] This shift is a result of the shifting microstructures of transaction costs as outlined in Chapter 2—as proto-entrepreneurs spontaneously order into complementary groups and begin to define actionable market opportunities, increasing idiosyncratic investments in that contractual relationship come with pervasive contracting consequences.

[82] This efficiency is only to the extent that individual proto-entrepreneurs subjectively perceive the commons to be efficient. See Chapter 7 for a further examination of the subjective costs that are the inputs into institutional choice.

[83] That is, technologies and their applications emerge in governments and firms, and are later adopted and diffused through markets.

the proto-entrepreneur is not necessarily solved through vertical integration within a hierarchal firm, or to trade the information across a competitive market.[84] The analysis in this chapter also forms the scope for examining the mechanisms of hackerspaces as entrepreneurial secession from the innovation system (Chapter 4), and the diversity of innovation commons emerging around the new general purpose technology, blockchain (Chapter 5 and Chapter 6). Expanding the potential for institutional solutions to the innovation problem also has implications for the political economy of the institutions of innovation (Chapter 7).

This chapter proceeds as follows. Section 3.2 first outlines the characteristics of different classes of governance structures within the transaction cost economics framework, before proposing that a hybrid structure may be the optimum institutional solution to the proto-entrepreneurial problem. Section 3.3 focuses on one particular type of hybrid, an innovation commons, by introducing the history of the common pool resource management literature, and then defining and outlining some theoretical behavioural characteristics of an innovation commons. Section 3.4 outlines some implications of the analysis and concludes.

3.2. The hybrid polycentric governance of proto-entrepreneurship

Governance structures comprise of the institutional rules through which exchanges are negotiated, executed, and enforced (Commons 1931; North 1990; Williamson 2005). Transaction cost economics proposes that the structure of these private orderings is a result of efforts to economise on the transaction costs of exchange in comparatively effective ways (e.g. see Williamson 1991). Examining the characteristics of governance structures enables the application of Oliver Williamson's 'discriminating alignment hypothesis' to the proto-entrepreneurial problem.[85] As such, while Chapter 2 above focused on the

[84] In the standard models of innovation economics, there are hierarchically organized innovating firms, contracts for research, and markets for ideas (e.g. Aghion and Tirole 1994; Gans and Stern 2010; Katz and Shapiro 1985).

[85] The 'discriminating alignment hypothesis' is where "transactions, which differ in their attributes, are aligned with governance structures, which differ in their cost and competence, so as to effect a transaction cost economizing outcome" (Williamson 2007, p. 17).

characteristics of transactions, this section outlines the *characteristics of governance structures*, before proposing a potential transaction cost economising governance solution.

The governance characteristics of firms and markets can be understood through juxtaposing the scholarship of Friedrich Hayek and Richard Barnard. Together, Hayek's analytical focus on markets (e.g. Hayek 1945) and Barnard's focus on hierarchies (e.g. Barnard 1938) demonstrate the central problem of comparative economic analysis—the capacity to adapt to the inevitably changing conditions of the future. The institutions of the market process analysed by Hayek best describe the capacity of a governance structure to exhibit *autonomous adaptation*, and the institutions of the hierarchical firm analysed by Barnard best describe the capacity of a governance structure to exhibit *coordinated adaption*.

Markets are emblematic of the governance characteristics of both autonomous adaptation and high incentive intensity. Hayek (1945) proposed that the central problem of an economic system is the adaptation to the changing circumstances of time and place. This view of the economic problem implies that people must adapt to small disturbances in their economic affairs and reposition their contracts accordingly. In markets, this form of autonomous or spontaneous adaptation occurs through adaptation of a constellation of independent people who each hold distributed bits of competing and often contradictory information. Markets are also effective at autonomous adaptation because the action of agents is tightly linked to their incentives—that is, markets exhibit high incentive intensity. The high-powered incentive intensity of markets implies a close connection between economic action and the consequences of that action—that the net receipts of a person and their choices are closely associated with their decision making. High incentive intensity, however, also increases the potential economic gains of opportunistic behaviour, and is therefore sometimes "deliberately supressed" within firms.[86]

[86] As Williamson (1991, p. 280) notes: "Incentive intensity is not an objective but is merely an instrument. If added incentive intensity gets in the way of bilateral adaptability, then weaker incentive intensity supported by added administrative controls (monitoring and career rewards and penalties) can be optimal."

The hierarchical firm is emblematic of the governance characteristics of coordinated adaptation and low incentive intensity. Most generally, the hierarchical firm represents recourse from the market towards administrative governance mechanisms (Coase 1937).[87] In stark contrast to market-based governance described above, the characteristics of the hierarchical firm deal well with the need for coordinated adaptation in a fluctuating environment. Coordinated adaptation was examined by Richard Barnard (1938) relating to administration and the ability of managers to coordinate through conscious design and direction.[88] Intentional adaptation and organisation helps to mitigate some of the contractual hazards of markets, including when asset specificity creates bilateral dependency.[89] For this reason Williamson proposed that the contractual hazards that arise due to the fundamental transformation were best solved through integration within the hierarchical firm.[90] On one hand hierarchies reduce the opportunism relating to the incentive intensity of markets, but at the same time vertical integration imposes costs of bureaucracy associated with administrative control.[91]

Hybrid modes of governance exhibit the governance characteristics of both firms and markets. Williamson (1991, p. 281) first outlined and described hybrid organisations as exhibiting "semi-strong incentives, an intermediate degree of administration apparatus, displays semi-strong adaptations of both kinds." Given this complex mixture of governance characteristics in hybrids, what constitutes a hybrid is now understood to incorporate a wide range of heterogeneous multilateral governance structures (e.g. Masten 1996; Ménard 2004). A hybrid structure may be economising compared to firms and markets for several reasons. Hybrids may be an economising governance structure because on one hand

[87] Ronald Coase (1937) first answered the question of why firms exist relating to the comparative costs of using the market mechanism (in particular there were costs relating to uncertainty) that could be reduced by internalising within a firm.

[88] Indeed, as Williamson (1996, p. 103) notes on coordinated adaptation and Barnard's work: "The conscious, deliberate and purposeful efforts to craft adaptive internal coordinating mechanism were those on which Barnard focused."

[89] See Section 2.4 above.

[90] In order to deter opportunistic 'hold-up' problems the complex and costly governance structures, such as the firm, may need to be built (e.g. see Ménard 2000; Tirole 1999).

[91] This contractual hazard and the need for monitoring and compensation has been examined in the principle-agent literature including Alchian and Demsetz (1972), Hölmstrom (1979), and Grossman and Hart (1983).

markets are not able to bundle and standardise the relevant resources (Teece and Pisano 1994), while on the other integration within hierarchical firms reduces flexibility and creativity (Ménard 2004). One type of hybrid organisation is a common property regime—as outlined by Elinor Ostrom, and introduced in Section 3.3 below. The attributes of markets, hybrids and hierarchies, where the various classes of governance structure are characterised as holding strong, semi-strong and weak of governance characteristics, are outlined in Table 2 below (adapted from Williamson 1991, p. 281).

	Governance Structure		
	Market	Hybrid	Hierarchy
Incentive Intensity	++	+	0
Administrative Controls	0	+	++
Adaptation (Autonomous)	++	+	0
Adaptation (Coordination)	0	+	++
++ = strong; + = semi-strong; 0 = weak			

Table 2: Governance structures and adaptability

Once we accept that different governance structures economise on hazards in different ways, then it is clear that transaction cost economics is a comparative enquiry (Shelanski and Klein 1995) that "tries to explain how trading partners choose, from the set of feasible institutional alternatives, the arrangement that protects their relationship-specific investments at the least cost" (Klein 1998, p. 468). That is, people choose the governance structure that best solves their economic problem. Oliver Williamson (1975, 1979, 1985a) developed a framework which operationalized the understanding of transaction costs by aligning different transactions to governance structures in a discriminating way. The underlying premise of this alignment is that people, including entrepreneurs, will choose governance structures that economise on the sum of both production costs—those costs incurred in executing the contract—and transaction costs—including arranging, monitoring and enforcing the contract. The characteristics of transaction costs (uncertainty, asset specificity and frequency) and governance structures (adaptability and incentive intensity) can be aligned to theoretically determine the transaction cost economising strategy. For instance, while some idiosyncratic and uncertain transactions will best occur within a hierarchical firm, other more highly standardised transactions, with many competing buyers and sellers, may best occur over a market (since the cost of setting up and internalising the

costs may be too large). Given this logic, how should the proto-entrepreneur solve their economic problem of coordinating non-price distributed information under uncertainty? Put another way, what is the economising governance structure for the proto-entrepreneur prior to the entrepreneurial fundamental transformation?

Could the proto-entrepreneur solve their problem through a *market*? Is it possible to write a contract for a contextual piece of entrepreneurial information before neither the value nor the holder of such information is clear? As outlined in Chapter 2, while in established markets prices can coordinate distributed information, when new markets are being created—where the structure of the future market and industry is unclear and uncertain—it is difficult to price such information. The price system may be efficient in re-coordinating extant economic activity, but it is ineffective for future markets because it is only *ex post* that a price may take into account the innovative value (Shane and Eckhardt 2003). As a coordinating institution, the price mechanism does not carry information that relieves proto-entrepreneurial uncertainty, in part because prices in the existing market do not provide information about highly novel business models or information about failed ventures. Coordinating proto-entrepreneurial information also faces a type of information paradox (Arrow 1962b).[92] That is, the proto-entrepreneur cannot price the information until it has been disclosed and combined with other information. Coupled with the high incentive intensity of markets, the information paradox facing the proto-entrepreneur demonstrates an increased threat of opportunism in exchanging non-price contextual information over markets.

Could the proto-entrepreneur solve their problem by integrating their coordination processes within the boundaries of a firm? Conventional innovation economics suggests that the innovation process begins within either a start-up or existing hierarchical firm. A hierarchical firm, however, may be a poor governance structure to coordinate the information necessary to solve the proto-entrepreneurial problem for several reasons. A

[92] As Arrow (1962b, p. 615) notes: "there is a fundamental paradox in the determination of demand for information; its value for the purchaser is not known until he has the information, but then he has in effect acquired it without cost."

firm has a boundary that determines the agents and resources within the organisation. For the proto-entrepreneur, however, the location of the complementary information required to discover a valuable opportunity is shrouded in uncertainty. This leaves the question of whether the necessary complementary information is within the boundaries of the firm, or whether that information could be purchased over the market once a firm has been founded. One of the primary uncertainties facing the proto-entrepreneur seeking to discover market opportunities is to determine who the other people within that firm will be. Indeed, Alvarez (2007, p. 428) argues: "when the economic value associated with a new market opportunity is uncertain, it is difficult to know whether or not a firm should be created, and if it is created, how any rents allocated by a firm should be allocated." In this way the structural uncertainty facing the proto-entrepreneur makes the founding of a firm difficult. Furthermore, firms are characterised by hierarchical administrative controls where individuals are placed within teams or projects. It is unclear *ex ante* how proto-entrepreneurial information, held by distributed people, should be coordinated and combined to reveal valuable market opportunities.[93] Both of these shortcomings of hierarchical firms for the proto-entrepreneur relate to the fundamental structural uncertainty of the complementarity of dispersed non-price information. While the benefits of internalising innovation activities within the firm is the organisational protection from opportunism and high incentive intensity, the nature of administrative control increases the possibility that complementary information necessary to define market opportunities is not contained within the boundaries of a firm, or is not effectively coordinated and combined through the administrative controls of a hierarchy (Ménard 2004). Lacking autonomous adaptation suggests administrative controls may inhibit the spontaneous ordering of proto-entrepreneurial information. In this way firms may be effective overcoming the combined hazards of incentive intensity and asset specificity that builds up throughout the innovation process, but may not economise on the other transaction costs of the proto-entrepreneurial problem.

[93] This problem is returned to later in the context of spontaneously ordering polycentric teams within hybrid organisations (see Section 4.4 on hackerspace governance).

What the above analysis makes clear is that the economic organization of proto-entrepreneurship is constrained from above and below in terms of transaction costs. On one hand, bounded rationality, distributed information and structural uncertainty over the prospect and value of discoveries and complementary trading partners imply that all contracting will be necessarily and often radically incomplete. The organisational solution to this must seek to account for the unknown distributions associated with prospective costs and payoffs, and not create unnecessary hazards for proto-entrepreneurs to spontaneously coordinate information to discover opportunities. In this way a governance structure cannot seek to anticipate all contingencies in the proto-entrepreneurial coordination process, or to administratively control that process due to bounded rationality.[94] On the other hand, the governance structure to solve the proto-entrepreneurial problem cannot be completely free from coordinating mechanisms because, as we saw in Chapter 2, proto-entrepreneurs face various hazards relating to opportunism. Further, proto-entrepreneurs theoretically require some form of signalling mechanism to determine complementary trading partners with which they can reap the gains from coordination in discovering opportunities. These dual concerns suggest a complex trade-off between the governance characteristics of firms and markets and their ability to exhibit coordinated or autonomous adaptation. Given that proto-entrepreneurs require some form of both *spontaneous* and *coordinated* adaptation to solve their economic problem—and therefore possessing some of the governance structures of both firms and markets—one potential transaction cost economising solution is in hybrids.

The governance options for the proto-entrepreneur are not limited to the firm-market duality highlighted by Coase (1937), which aimed to address the particular question of markets or hierarchies.[95] Hybrid polycentric governance structures—that is, governance

[94] These can be usefully arrayed on what Djankov et al. (2003) call the Institutional Possibility Frontier (IPF) as a convex function on axes of the costs of disorder and the costs of dictatorship. This framework is extended and applied in Chapter 7.

[95] The main governance approach in the organizational economics of innovation has been to develop the Williamson make-or-buy problem in the context of *vertical integration* (Pisano 1991; Robertson and Langlois 1995), and more recently *open innovation* (Dahlander and Gann 2010; Lazzarotti and Manzini 2009). Evolutionary and Schumpeterian economists have countered through innovation competencies in the knowledge-based theories of the firm (e.g. Marengo and Dosi 2005; Nelson and Winter 2009; Penrose 1959).

structures that have many centres of decision making and exhibit governance characteristics of both firms and markets—may economise on the transaction costs of the proto-entrepreneurial problem because they simultaneously deal with the structural uncertainty of discovering complementary trading partners, while maintaining some safeguards to protect against opportunism.[96] Further, a polycentric hybrid structure may generate emergent, unplanned properties to match complementary proto-entrepreneurial information. As noted above, the concept of a hybrid governance structure within the context of the institutions of innovation theoretically incorporates a wide range of collaborative forms of governance within the innovation and management literature including open networks (Hagerdoorn 1993; Pisano 1991; Powell et al. 1996; Robertson and Langlois 1995; von Hippel 1986) and collaborative joint ventures (Caloghirou et al. 2003). Much of this scholarship, however, emphasises the links between existing firms and users, or between existing firms. The exception to this is the private collective user-led innovation literature (von Hippel 1986; von Hippel and von Krogh 2003), which tends to emphasise that the collaborative nature is due to some form of social provision, or is some sort of accidental innovation that occurs as groups of people come together. In this way the existing literature of hybrids as a solution to the innovation problem obscures from the institutional choice of proto-entrepreneurs to engage in governance as a transaction cost economising strategy before proceeding to other phases in the innovation process. The remainder of this chapter introduces one particular form of a polycentric hybrid solution—an innovation commons—and emphasises how a commons of non-price proto-entrepreneurial information institutionally compares to the previous forms of commons (based on, for instance, physical resources), and in particular how an innovation commons may be a potentially transaction cost economising institutional solution which the proto-entrepreneur institutionally chooses to solve their economic problem. The following section proceeds by first outlining the

[96] The notion of polycentric governance structures has been developed with the Bloomington School by both Elinor and Vincent Ostrom. In particular, their focus has been on how the polycentric governance of complex economic systems may be the most effective institutional solution for some social dilemmas (McGinnis and Ostrom 2012; Ostrom 1990, 2010; Ostrom et al. 1961).

history of the common pool resource literature, and then introducing and defining the behavioural characteristics of an innovation commons.

3.3. Defining and characterising an innovation commons

The common pool resource management literature emerged through the 1980s and 1990s through the work of Elinor Ostrom and colleagues at the Bloomington School.[97] This research program sought to examine both successful and failed examples of the governance of common pool resources to understand the rules which overcome the hazards inherent in social dilemmas—largely free-rider problems stemming from the tragedy of the commons (Hardin 1968).[98] A range of case studies found that individuals could govern common pool resources through collective action processes, and that these may be institutionally optimal to the economic problems those people face. Therefore this commons literature expanded the solutions to social dilemmas beyond firms, markets and states (Ostrom 2010).[99] Rather than suffering from a tragedy of over-appropriation—to be remedied through state-led solutions ranging from privatisation to regulation—a wide range of cases of common pool resource management showed that collective action governance may be an optimum institutional solution to economic problems. This understanding, however, should not be confused with suggesting commons solutions are some form of panacea.[100] This institutional and political economy analysis of commons can be split into several different categories based on the nature of the underlying resource, and the methodological techniques employed in analysing them.

[97] Analysis of the history of the Bloomington School can be found recently in Aligica and Boettke (2009), Aligica et al. (2017), Herzberg (2015) and Tarko (2016).

[98] Hardin (1968, p. 1244) introduced the concept of the "tragedy of the commons" through a thought experiment of an open access pasture and the differences between individual and group rationality, concluding that "freedom in a commons brings ruin to all." See also Feeny et al. (1990) for a review of the literature stemming from this original article. The study of social dilemmas more broadly relates to the tensions between individual and collective rationality (see Kollock 1988).

[99] As Ostrom (2010, p. 432) proposes: "Thus, in some contexts, one can move beyond the presumption that rational individuals are helpless in overcoming social dilemma situations." Also see Section 7.1 for a broader outline of the sweep of the common pool resource management literature.

[100] As Ostrom et al. (2007, p. 15176) notes: "Practitioners and scholars who fall into panacea traps falsely assume that all problems of resource governance can be represented by a small set of simple models." Also see Ostrom (2007) on panaceas in the governance of resource problems.

The *first wave of commons* literature emphasised shared physical natural resources such as fisheries, grazing pastures and forests, and included commons of artificial resources such as irrigation systems (see Ostrom 1990). Following in this tradition, a *second wave of commons* studies has developed as the literature moved towards examining intangible common pool resources of information and knowledge, such as science (Boyle 2007; Schweik and English 2012) and culture (Frischmann et al. 2014; Ostrom and Hess 2007). This second generation focuses on a variety of topics and resources including open source software (Schweik 2007, 2014), roller derby's (Fagundes 2014), the airplane industry (Meyer 2014), and genetic information and research (Contreras 2014; Lucchi 2013). All of these case studies attempted to apply the ideas of collective action common pool resource management into new area, including the development of a set of design rules for long-enduring common pool resource management.[101] Taken together, these two waves of commons literature have demonstrated that commons can be understood as efficient governance models to minimize transactions costs associated with private order resolutions of collective action problems (i.e. social dilemmas) involved in contributing and pooling resources. When new commons are analysed they are now often based on intangible resources, such as culture, and exist on a larger and broader scale than the original first wave of commons (e.g. Epstein et al. 2014; Hess 2008; Ostrom et al. 2002; Stern 2011). This transition between analysing tangible commons, in which we can see and feel the underlying resource units of fish or trees, to the intangible commons, which are much more difficult to measure—has not been analytically smooth (Poteete et al. 2010). Analysing commons based on ideas rather than commons of things is more difficult for two reasons: it is difficult to understand what the resource is because such resources are often substantially more intangible and dynamic; and because there is a further actor within a knowledge commons who produces and provides the underlying resource (Cole 2014; Madison et al. 2010).[102] In this context, the innovation commons defined and characterised below

[101] The eight design rules of the commons as proposed by Elinor Ostrom (1990) are outlined below.
[102] As Poteete et al. (2010) notes, this shift in the literature has required commons scholars to devise new methods and refine previous concepts about what constitutes a common pool resource and common property regime.

constitute a *third wave of commons* that are potentially transaction cost economising governance structures for solving the proto-entrepreneurial problem of coordinating the information necessary to define actionable market opportunities (Section 2.2).

There are two ways to define and characterise an innovation commons. First, as with other types of commons, an innovation commons can be defined by the resource on which the governance structure is based. Second, we can define an innovation commons based on its behavioural characteristics as compared to other waves of commons. The key resource in an innovation commons is not a technology, but the distributed, uncertain and non-price information about the market opportunities for a technology. That is, an innovation commons is centred on non-price proto-entrepreneurial information that is the information that facilitates the use and application of a new technology to discover value. Much of this information is experimentally acquired, often tacit, non-price, and of little value by itself, but of holds potential value when combined with other heterogeneous complementary information that pieces together the puzzle of how the technology might be applied, and by whom, to do what, in combination with what, and so on (Section 2.2.2). In this way the innovation commons are proposed to act as a potential coordinating governance institution for the non-price coordination necessary to gather the information inputs into entrepreneurial judgement. In this way an innovation commons is proposed to exist in the early stages of the innovation process—and therefore in the early stages of a new technology—when a group of proto-entrepreneurs come together to coordinate and exchange information about that technology to discover opportunities for its use and development. In this way an innovation commons should not be confused with either a technology commons—because the resource is not the technology *per se*, but the information about the technology that facilitates its development—or confused as just another type of knowledge commons—because it is a unique subset of knowledge commons that exists to discover new knowledge.[103] An innovation commons may emerge

[103] The literature on knowledge commons focuses on the management of existing information sources (Cole 2014; Frischmann et al. 2014; Madison et al. 2010), while an innovation commons is concerned with the coordination of non-price information precisely to discover new information. This notion of complementarity in the coordination of the resource suggests it is a unique subcategory of common pool resource.

because proto-entrepreneurs perceive such a hybrid polycentric structure as transaction cost economising for coordinating distributed non-price information to discover market opportunities. Because the proto-entrepreneur does not know what they are producing, or how they are going to do it, or who they are going to do it with, a hybrid and flat polycentric governance structure may be transaction cost economising. Following on from Section 3.2, an innovation commons may be an efficient governance model for early stage economic organisation of discovery and development of an opportunity because it has both coordinating and autonomous adaptation characteristics. An innovation commons may both guard against the hazards of opportunism while simultaneously allowing entrepreneurial discovery (and thus group formation) so agents can interact to discover potentially actionable market opportunities.

The innovation commons may exhibit the same basic design rules as what Elinor Ostrom and subsequent scholars have proposed (Dietz et al. 2003; Ostrom 1990; Stern 2011; Wilson et al. 2013).[104] Owing to the unique nature of the proto-entrepreneurial problem, however, there are several unique defining ways in which an innovation commons theoretically differs from both natural resources commons and knowledge commons. At first an innovation commons appears to emerge due to the altruistic or cooperative behaviour of its participants. The definition of the innovation commons to solve the proto-entrepreneurial problem, however, does not depend on a form of social provision or altruistic behaviour of contribution to the commons. Innovation commons are an institutional solution to economise on the transaction costs to enable proto-entrepreneurs to reap the mutual gains from trade of proto-entrepreneurial information and facilitate the process of entrepreneurial discovery. The innovation commons are not necessarily an institution for the "social production" of innovation, or as some form of political commitment existing "alongside property-based and market-based production", as is the case in Benkler (2006, p.

[104] The similarities of enduring, self-governing commons as outlined in Ostrom (1990) are clearly defined boundaries, congruence between local appropriation and provision rules and local conditions, collective-choice arrangements, monitoring, graduated sanctions, conflict-resolution mechanisms, minimal recognition of rights to organise, and nested enterprises. These rules have also been expanded and analysed elsewhere (see Stern 2011; Wilson et al. 2013). For instance, Wilson et al. (2013) generalised these principles with evolutionary concepts.

3). Rather, the innovation commons acts as a coordinating institution that enables proto-entrepreneurs to solve their economic problem of discovering actionable market opportunities, and to exit the commons and continue in other phases of the innovation process, such as acting to exploit opportunities in firms across markets.[105]

In this way, the core functional role of an innovation commons is to process uncertainty surrounding a potential future opportunity faced by the proto-entrepreneur. This is in contrast to the previous waves of commons, and in particular where perpetual natural uncertainty regarding the supply of the resource, such as due to natural disasters, may make the commons an efficient governance structure. In a natural resource commons the ebbs and flows of nature may create a continuing level of uncertainty, and a common property regime may emerge as a perpetually more effective institution than their market and state alternatives. For the innovation commons, however, given that proto-entrepreneurial information about the use and application of a new technology is dispersed and embedded, the innovation commons exist to coordinate this information and *process* uncertainty through the coordination of information. An innovation commons processes uncertainty, and once the uncertainty passes, so too does the efficiency case for that particular governance structure. In this context we can extend the terminology of Kuchař and Dekker (2017) in terms of innovation commons existing to facilitate non-price coordination to discover "emergent orders of worth". Similar to their examination—where others are drawn upon to warrant the worth of diverse artefacts—proto-entrepreneurs in an innovation commons can draw on the subjective perceptions about potential market opportunities of others to define potentially actionable future market opportunities. An innovation commons, in this view, coordinates the non-price subjective perceptions over future new combinations of heterogeneous capital in order to discover the potential worth

[105] The exit from the commons doesn't necessarily result in subsequent adoption into a market-capitalist trajectory. The decision of which governance structure to act upon an opportunity once it is discovered is in the subjective preferences of the proto-entrepreneur. The benefit of a methodologically individualist approach is that we can remain agnostic about the normative intent of the individuals of where to later institutionalise their discovered opportunity, and focus on the governance structures through which they seek to solve the problem of reducing uncertainty about a market opportunity.

of a market opportunity.[106] That is, the innovation commons exist to process uncertainty through coordination and discover a *novel* order of worth.

The implication of an innovation commons existing to process uncertainty is that an innovation commons is likely to only be a temporary transaction cost economising solution. At the analytical level of the market opportunity or innovation trajectory, an innovation commons is likely to be a transient institutional phenomenon economising on the microstructure of transaction costs associated with the proto-entrepreneurial problem. The temporary nature of an innovation commons is a direct consequence of their prime function being the alleviation of uncertainty, such that when uncertainty dissipates, the basic rationale for the commons substantially weakens. Put another way, the innovation commons are likely to be temporarily efficient at solving their problem because their success—in defining market opportunities—provides the conditions for other institutions to outcompete it. In this way the innovation commons can be understood in the context of the Schumpeterian innovation trajectory, where an innovation trajectory has three phases: (1) entrepreneurial origination; (2) adoption and diffusion; and (3) retention and institutional embedding (see Dopfer and Potts 2007; Dosi 1982). An innovation commons would theoretically emerge before the first entrepreneurial origination phase. This is because the innovation commons coordinates the distributed information before entrepreneurial action is possible. The success of an innovation commons in the pre-transformation phase leads to the post-transformation phase in a standard innovation trajectory. Alternative institutions, such as firms, rely on the reduced uncertainty and stable expectations in order to make plans and investments. While the innovation commons are born of fundamental uncertainty about innovation opportunities, addressing this problem successfully will collapse their functional rationale—uncertainty is what engenders the creation of an innovation commons, and the resolution of that same uncertainty instigates their collapse. Unless some other forces hold it together or prolong it—for instance, a legal tool which holds an idea

[106] The non-price coordination in an innovation commons does attain mutual agreement or approval between different individuals, but to discover the perceived complementarity between bits of heterogeneous capital, and the perceptions of the value of those combinations.

within the commons—the innovation commons will tend to collapse at a point when its functional rationale is achieved, the discovery of a market opportunity and an entrepreneurial fundamental transformation.

Following from this, a further functional role of an innovation commons is their complementary role to later institutions of firms, markets and states. Innovation commons are not just substitute institutions for proto-entrepreneurial discovery, but act as institutional complements to the other institutions of firms, markets and states at later stages of an innovation trajectory. In this way an innovation commons could be similarly conceived as an "institutional placeholder" for discovering later governance structures within which to exploit market opportunities (Alvarez 2007, p. 437).[107] This is consistent with the Austrian theory of the firm presented in Ioannides (1999), where the emergence of the firm is not due to an inefficiency in the market process, but as a product of the market process.[108] Or, in the view presented here, a firm may be the product of a commons process. The recent growth of the literature on peer production (Benkler 2006), open innovation (Chesbrough 2003) and open science (Schweik 2007) are often explained using transaction cost economics—falling transaction costs render information cheap and ubiquitous, enabling more decentralised organisation through civil society. However, this does not explain whether or not these innovation processes are performing the same institutional role as other institutions—what is the economic problem of the agents operating in these organisations? These models implicitly assume that these forms of economic organisation are substitutes for firms, markets and governments, whereas an innovation commons may facilitate a complementary process to other institutions.

[107] Alvarez (2007, p. 437) proposes the entrepreneurial firm in a similar way, of acting as a solution to entrepreneurial uncertainty: "One possible solution to this problem is to think of an entrepreneurial firm as an institutional placeholder through which the identity of the most appropriate holders of residual rights of control can be identified over time."

[108] "Unlike the contractarian theories of the firm, the perspective we have derived from Kirzner's theory of entrepreneurship does not have to rely on some sort of inefficiency of the market mechanism but stems, instead, from the very principle that keeps this mechanism in constant motion: entrepreneurial behavior" (Ioannides 1999, p. 87).

One example of a function of the innovation commons as a complementary governance structure to later phases in the innovation process is institutional matching. Institutional matching may be necessary because one of the distinct uncertainties around new technologies and opportunities is the best institution in which to develop it. New ideas and technologies have a variety of characteristics that make them differentially suited to develop in different institutional forms—some ideas may be better developed in public research institutions, for example, while other ideas may be better developed through private technology start-ups, for example. If each idea had an optimal institution, and if we assumed a world of perfect knowledge and of zero transaction costs, then there would still be no institutional matching problem: each idea would be seamlessly matched with others. In an environment of non-zero transaction costs, however, ideas require a process of institutional matching. An innovation commons may coordinate the information to match potential opportunities and technologies to their optimal institutions for development and subsequent adoption. It also follows, however, that there is no focus here on the on the optimal institutional structure of innovation after an opportunity is discovered—it may be developed within a firm, a government, or a market—but by coordinating information, an innovation commons potentially furnishes an efficient sorting and matching mechanism to increase the likelihood that a new technology subsequently develops under the most effective institutional environment.

In contrast to exiting natural resources commons, an innovation commons will be spatially mobile. An innovation commons is not an economy-wide substitute for other innovation institutions, but a complementary institution that emerges at the beginning of an innovation trajectory, where uncertainty is highest. An innovation commons will exist at many locations in an economy at once, with those locations continually shifting, perhaps frequently. An innovation commons will not exist across an entire economy, sector or region because its location is emergent with respect to the social organisation of the development of a technology. An innovation commons is not a general space—indeed, some of their value will come from their sorting ability as is the case with hackerspaces as described in Chapter 4 and the blockchain innovation commons analysed in Chapter 5. Innovation

commons exist on many scales and levels of organisation as a function of the need for non-price information about the new technology. An innovation commons is predicted to emerge along an innovation trajectory where uncertainty is highest about the pathways through which to develop a new idea or technology. It also follows that an innovation commons governance structure is most likely to emerge where the gains from trade of coordinating non-price entrepreneurial information is highest. This suggests than an innovation commons may emerge not just at the beginning of new technologies, but in particular at the beginning of new general purpose technologies.[109] Here, where proto-entrepreneurs have the incentive to develop governance structures to reveal market opportunities and their value.

The principle of an innovation commons, if we look to historical examples, may stem back further into any situations where agents face structural uncertainty about valuable opportunities. For instance, the Societies for Useful Knowledge, recently described by Lyons (2013), included groups of pioneers sharing information and contextual knowledge not about commercial opportunities, but about how to overcome the institutional problems of agriculture and politics in the New World. Craft guilds in preindustrial Europe also provide a possible example of the pooling of information in order to facilitate innovation (see Epstein 1998). While the innovation commons examined in this thesis are focused on those around a novel and new technology—the opportunity need not relate to a technology, it is simply something *new.* The concept of an innovation commons can equally be applied to other innovations which are less obvious, such as political movements, where agents pool and share information about the integration of a supposed institutional political opportunity with others to overcome uncertainty.[110] Nevertheless, my primary concern in this dissertation is with innovation commons that coalesce around new technologies, as entrepreneurs seek actionable opportunities for those technologies.

[109] For an outline of general purpose technologies see Section 5.1.
[110] See the directions for further research in Chapter 8 for a further discussion of this.

Two further potential behavioural characteristics of an innovation commons are the potential for defence against enclosure and to shake out aspects of the technology. An innovation commons may act as a defence against enclosure into alternative institutional forms. From the perspective of the industry, an innovation commons may act defensively as a governance structure to minimise the risk that the technology will not find a viable market niche, or that it is locked on a particular path. Technologies and markets exhibit path dependency (Liebowitz and Margolis 1995)—the commons provides a mechanism to experiment with the correct path by keeping the pathway open. This mechanism can be observed in the efforts of those committed to open source software to maintain an innovation commons less as a service to potential entrepreneurs, but rather to prevent alternative institutions (in this case private property rights) enclosing the technology and locking it into one particular path of development (e.g. see Von Krogh et al. 2012). The innovation commons may thus emerge as a form of defensive institutional mechanism against entrenched economic interests. The very beginning of an industry, market, or product faces the prospect of political resistance by those who would see it as competition (see Juma 2016). An innovation commons may act as a bulwark against resistance from incumbent technologies and other entrenched interests with rents to protect. The optimal period for an innovation commons may be relatively long, on the order of decades perhaps, in order to best discover or shake-out all the hidden and unintended consequences and costs latent within a new technology (Klepper 1996; 1997). These can be costly when discovered within a private property institutions have attached to a technology, or once the technology is fully in the public domain, because of the destruction of investment, or the tendency to constrain a technology. In this way a commons serves as a space of what Thierer (2014) described as "permissionless innovation".[111] An innovation commons may be able to comparatively quickly and at relatively low cost discover unintended consequences by facilitating small-scale experimental adoption, understood by pooling distributed information.

[111] For an outline of permissionless innovation see Section 5.2.

3.4. Implications and conclusion

This chapter used Oliver Williamson's transaction cost economics framework and Elinor Ostrom's literature on common pool resource management to propose a potential institutional solution to the proto-entrepreneurial innovation problem: coordination in a polycentric collectively governed innovation commons. From the perspective of the proto-entrepreneur, the transaction cost economising governance structure at the beginning of new technologies may resemble a polycentric innovation commons, as proto-entrepreneurs seek to privately govern the process of coordinating distributed information to discover market opportunities. These innovation commons can be understood as transaction cost economising governance mechanisms to deal with the hazards of opportunism and the need for autonomous adaptation to coordinate with complementary others. An innovation commons forms before the subsequent emergence of competitive firms and markets in the 'zero-th' phase of an innovation trajectory, and the possibility of entrepreneurially acting within firms and markets may emerge from the knowledge discovered in an innovation commons. Compared to the previous types of commons, an innovation commons theoretically has some unique behavioural characteristics—likely to be only temporarily transaction cost economising and to emerge at the very beginning of new industries and technologies.

The proposition and characterisation of an innovation commons has made contributions in two directions. The first contribution was to introduce the potential for collective action in the commons into the potential institutional solutions to the innovation problem. In the choice-theoretic conception of the innovation problem there is little room for privately governed institutional solutions by the very definition of the innovation problem as one of market failure—resolved through government intervention and investment. The second contribution goes in the other direction, by introducing entrepreneurial theory to the common pool resource management literature. This involves examining commons that emerge at the origin of new technologies, and adding a third wave of common pool resource to the existing first wave of natural resources and the second wave of cultural and

knowledge commons. That is, my analysis of the innovation commons has the potential to simultaneously extend and enrich commons theory, and to inform the application of innovation policy (see Chapter 7).

To be clear, my analysis must be read with the recognition that there are no panaceas when it comes to the institutions of innovation. Nevertheless, just as Ostrom (1990, p. 14) claimed privatisation and government-control solutions are "too sweeping in their claims", so may be the case in the governance of proto-entrepreneurial discovery. Just as the tragedy of the commons was a misdiagnosis for natural resources, innovation policy may have been misdiagnosed. On one hand the existence of an innovation commons is just another extension of the science of the commons into a new space where it was previously not thought relevant. This extension, however, may prove to be important because, if true, it represents the discovery of a new class of commons at the locus of what economic theory informs us is a fundamental driver of the wealth and prosperity of nations, the growth of new technologies (see Chapter 1). The market failure view of the innovation problem has the immediate implication that new knowledge either had to be enclosed within private property or broadly recognised as the responsibility of government to produce. What is striking is the oversight of community level governance models as possible institutional solutions to the innovation problem, and a lack of focus on the specific economic problems that entrepreneurs face throughout an innovation trajectory.

The overarching contribution of this chapter can be seen in the context of the contemporary status of innovation economics, and with it innovation policy, which looks remarkably like the state of commons research prior to Elinor Ostrom's (1990) systematic rebuttal of Garrett Hardin's (1968) pessimism about the "tragedy of the commons". From the perspective of the market failure approach to the innovation problem, any solution will always be in the form of a reallocation, which will require government coercion to shift incentives (i.e. changing the rules of the game) or to redistribute resources. Private ordering solutions have no part in this choice-theoretic diagnostic schema. While the specific problem differs—from under-produced innovation resources to over-exploited natural

resources—the underlying diagnosis and treatment is the same. Both stories—of the choice-theoretic innovation problem and of the tragedy of the commons—began with a supposed market failure that was resolved along a dichotomy of solutions that amounted to privatisation on one hand, or state regulation and ownership on the other. The introduction of an innovation commons sits in stark contrast to the standard choice-theoretic innovation problem solved through market-based and state-based interventions and corrections to sub-optimal investment allocation. Without any damage done to its underlying assumptions about fixed costs of investment, the earliest stages of the innovation problem have now been reframed through the contract-theoretic mainline of economic thought, making it a governance problem. The following chapters apply the potential of private governance collective action solutions to the cases of hackerspaces (Chapter 4) and blockchain technology (Chapter 5 and Chapter 6), revealing more specific details of the private governance solutions to the proto-entrepreneurial innovation problem.

Part II:
Applications

Chapter 4: Entrepreneurial secession and private governance in hackerspaces

4.1. Introduction

Many hackers are entrepreneurial in the sense that they seek to discover valuable uses for new technologies, and they do so by coordinating information in privately collectively governed hybrids called hackerspaces.[112] The entrepreneurial outputs of these entrepreneurial processes within hackerspaces are clear from their central contribution to the early 3D printing (e.g. Fordyce et al. 2015; Moilanen et al. 2014) and personal computing industries (e.g. Freiberger and Swaine 1999).[113] Academic research into hackerspaces, however, has primarily focused on the physical resources within the space (e.g. Williams and Hall 2015) or the underlying norms and values of the hacking and making phenomenon (e.g. Davies 2017; Manion and Goodrum 2000).[114] This chapter uses available secondary data on hackerspace governance mechanisms to analyse hackerspaces through the contract-theoretic lens of the proto-entrepreneurial innovation problem outlined in Chapter 2. That is, rather than analysing hackerspaces as a collection of physical resources, they are analysed as a hybrid governance structure of collectively developed rules where hackers attempt to overcome uncertainty about opportunities by coordinating non-price information about the potential market opportunities for new technologies. The mechanisms that are revealed from this analysis are examined in the context of their ability to economise on the transaction costs of the early stages of the proto-entrepreneurial innovation problem, and in the context of the eight design rules outlined in Ostrom (1990).

[112] For a brief introduction to the differences between hackerspaces and their variants (e.g. makerspaces) see Cavalcanti (2013).

[113] For example, the hackerspace, *NYC Resistor*, was home to the early collaborations of MakerBot Industries, one of the world's largest 3D printing companies.

[114] Williams and Hall (2015) focus on how technology is used to secure the physical 'space' within hackerspace in the context of three of Ostrom's design rules.

The secondary data includes a range of previous hackerspace and makerspace case studies and analyses (e.g. Lindtner and Li 2012; Schlesinger et al. 2010; Williams and Hall 2015), existing secondary semi-structured interviews with hackerspace experts (Kostakis et al. 2014), and online hackerspace websites, forums, and wikis. Together, these secondary data sources are synthesised into an analytic narrative (Boettke et al. 2013a; Boettke et al. 2005). This chapter is organised around the various mechanisms hackers employ to solve the economic problem they perceive they face. My approach is to examine the hackerspace phenomenon broadly, rather than examining an individual hackerspace, enabling a comparative understanding of alternative entrepreneurial innovation institutional arrangements.[115]

This chapter proceeds as follows. The analysis of hackerspaces is first motivated through the entangled political economy literature in Section 4.2. Hackers are introduced as proto-entrepreneurial agents seeking uses for new technologies in hackerspaces in Section 4.3. Secondary data sources are surveyed and synthesised to outline a range of private governance mechanisms in Section 4.4. The choice of private governance in hackerspaces as an efficient mode of economic organisation is explored in Section 4.5. Section 4.6 concludes.

4.2. Private orderings in an entangled political economy

This section briefly outlines the analytical difficulty of examining private orderings of proto-entrepreneurship, and motivates the analysis of hackerspaces. Richard Wagner's entangled political economy theory has reiterated the classical notion, stemming back to the moral philosophers such as Adam Smith (1776 [1976]), that the political and economic spheres are closely and inevitably entangled (Wagner 2006, 2016a, 2016b).[116] The contrasting

[115] My methodological approach is a trade-off between internal and external validity. The data from a single hackerspace will be more empirically robust and may reveal more fringe and unique governance mechanisms which only exist in a few hackerspaces. A meta-analysis of hackerspaces, which is adopted here, yields more generalisable comparative institutional implications for hackerspace governance, takes advantage of existing case study methodologies and results, enables a current review of the state of research in the area, and enables more general claims about the class of organisations including the political economy implications about other competing organisational forms.

[116] As Wagner (2014, p. 25) notes: "just as market theory is sometimes presented through images of an invisible hand, political activity would be presented in the same fashion."

perspective, additive political economy, assumes economics and politics can be separately analysed, which is an ineffective perspective to explain real social phenomena (Pagenelli 2014).[117] The implication of an entangled political economy is that the processes of politics and economics should realistically be examined as operating together, through time, and on the same institutional landscape (Koppl 2014).[118] The reality of an entangled political economy makes conceiving and analysing purely economic or purely political processes conceptually difficult. Similarly, claims of pure private governance have faced the problem of governments lurking behind ready to enforce agreements (Leeson 2010; Mnookin and Kornhauser 1979).[119] The reality of an entangled political economy is important when analysing the private collective action governance of proto-entrepreneurs because the scope of innovation policy now subsumes government, university, and industry (Godin 2009).[120] Because not all economic and political processes are equally entangled, however, my approach here is to examine the private orderings and private governance of proto-entrepreneurship in hackerspaces. This approach follows the positive political economy literature, which has sought out extreme forms of private governance where economic agents are privately engaged in creating and enforcing rules beyond state-based courts and legal systems (e.g. Benson 1999; Dixit 2007; Ellickson 2009; Leeson 2009, 2014).[121] Empirical examples of private governance have included prison gangs (Skarbek 2012), private police (Bislev 2004), stock exchanges (Stringham 2002), stateless Somalia (Leeson 2007b), and pirate ship constitutions (Leeson 2009).[122] This literature has pushed back on the conventional understanding that mutually beneficial trade rests on exogenous top-down

[117] Wagner (2014, p. 20) describes an additive political economy as "a scheme of thought where economic equilibrium is conceptualized prior to political activity, with political activity then modifying that equilibrium."
[118] See Koppl (2014, p.2): "The nature of a private or public actor is not given independently of the overall political-economy environment. And that means that they are shaping each other. They co-evolve."
[119] The private processes of self-governance of entrepreneurship are best described as economic processes, while the interventions of innovation policy are best described as a political process. The question then is what constitutes a private economic solution to the innovation problem, with the focus in this chapter on polycentric hybrid governance in hackerspaces.
[120] This is also important for the political economy analysis in Chapter 7. Policies such as state-based intellectual property or research and development tax credits mean the political process is interconnected with many of the institutions of innovation. The private choices of entrepreneurs interconnect and co-evolve as innovation policies seek to shift those incentives.
[121] To be clear, anarchy in this sense is not the absence of rules, but rather the absence of government rules.
[122] Also see Leeson and Skarbek (2009) on the functions of constitutions within criminal organisations.

institutional mechanisms (i.e. coercive states) to create and enforce the institutions necessary (e.g. property rights) to maintain civility (Boettke 2005).[123] Even where cooperation was assumed to be unattainable, the positive political anarchy literature has demonstrated that groups have collectively devised rules to exchange (Leeson 2007c). This same analytical approach is adopted in this chapter to examine the private polycentric governance of entrepreneurship in hackerspaces. Indeed, if pirates can run floating corporations around the ocean by developing constitutional rules outside the shadow of the law (Leeson 2007a, 2009), why preclude proto-entrepreneurs from creating their own purely private systems of governance to solve the innovation problem outside the scope of innovation policy? This chapter focuses on hackerspaces as an example of the private collective action governance of the proto-entrepreneurial problem because hackerspaces operate obscurely on the edges of the conventional organisations of firms, markets and states. Examining hackerspaces, then, as a form of private governance, extends the positive political anarchy literature into the study of the governance of entrepreneurial discovery and enables greater understanding of the collective action development of rules to overcome the transaction costs of coordinating non-price entrepreneurial information. In the following section hackers are introduced as proto-entrepreneurs seeking to coordinate information with others, and hackerspaces are introduced as the organisations through which hackers privately govern that process.

4.3. Introducing hackers as proto-entrepreneurs

In the 1960s and 1970s a sub-culture of young college students played practical jokes, or hacks, on one another.[124] Over time these hacks evolved into more elaborate applications of

[123] The conventional assumption in economics is that where anarchy exists, state-based institutions will fill these vacuums with centralised organisation. Moreover, this change is assumed to increase efficiency. Long-held assumptions of the efficiency of states, and the failure of markets, however, does not make for a neutral point of departure for institutional analysis. Indeed, the prospect of efficient entrepreneurial anarchy should be examined empirically, not wilfully assumed away. This chapter contributes to the examination of the anarchic organisation of entrepreneurial discovery within hackerspaces.

[124] A "hack" has become widely misinterpreted as criminals hacking networks, stealing money, and engaging in illegal activities (see Kostakis et al. 2014).

technologies to meet human needs.[125] This hacking process has variously been described as transcending boundaries (Wykretowicz 2013), producing solutions to complex problems (Schlesinger et al. 2010), playing (Guthrie 2014; Hatch 2013) or critical making (Ratto 2011). Hackers have also been connected through the common values of openness, sharing, creativity, experimentation, free speech, meritocracy, and the power of the individual (Coleman and Golub 2008; Kostakis et al. 2014; Lindtner et al. 2014; Taylor 2005).[126] In this chapter hackers are viewed from their role as acting entrepreneurially—pushing novelty and newness into the economic, social and political system through the coordination of information with others. Hackers are therefore a prime analytical example of the private governance of proto-entrepreneurial discovery.[127]

Hacking often takes place in groups within physical hackerspaces (see Guthrie 2014; van Holm 2015). At the beginning of 2016 there were "1233 active hackerspaces around the world, and more than 500 in development" (Davies 2017, p. 11). The history of hackerspaces traces back to the mid-twentieth century with the founding of the Tech Model Railroad Club at the Massachusetts Institute of Technology (Farr 2009; Levy 2001; Schlesinger et al. 2010). The Homebrew Computer Club also hosted many of the world's most influential hackers and entrepreneurs in the personal computing industry throughout the 1970s (Freiberger and Swaine 1999; Lash 2007).[128] Defining hackerspaces has been difficult because they are "…constantly on the move; evolving, mixing, forking, hibernating and dying" (Moilanen 2012, p.1). There are a wide range of definitions and perspectives on the hackerspace phenomenon in the literature.[129] Similar organisations to hackerspaces—

[125] A hack is "an incredibly good, and perhaps time-consuming piece of work that produces exactly what is needed" (Wiki 2004).

[126] The hacking subculture itself is also closely associated with political ideals, with the connection to freedom constituting a moral discourse for hackers—part of what has become known as the hacker or maker ethic or culture (see Coleman and Golub 2008; Lindtner 2012).

[127] Claiming that hackers are proto-entrepreneurs does not say how an entrepreneurial opportunity is later institutionally developed. That is, whether a novel idea is diffused through firms, markets, states, or through other institutional systems, such as open source. Hackerspaces often exhibit strong open source values (i.e. explicitly keeping some innovation open and in the public domain) rather than seeking profits. See Section 4.5 for a further discussion of this tension with commercialisation of discoveries in hackerspaces.

[128] Other famous spaces include the Chaos Computer Club (founded in 1981 in Germany), and *c-base* (Berlin) and *C4* (Cologne), which were both founded in the 1990s (Tweney 2009).

[129] Hackerspaces have been variously described as enabling platforms (Seravalli 2011), shared social studios (Lindtner et al. 2014), collectively governed experimentation (Kera 2012), third places between the home and

such as makerspaces, hacklabs, fab labs and co-working spaces—further complicate organisational definition (Maxigas 2014; van Holm and Student 2015, p. 3).[130] One way to define hackerspaces is by focusing on the patterns, trends and theories as hackerspaces evolve (Farr 2009) despite the fact the indeterminate processes of hackerspaces vary.[131] The most comprehensive definition of hackerspaces in Moilanen (2012) is that they are: owned and run by members in the spirit of equality; are not-for-profit and semi(regularly) open to the public; share ideas, tools and equipment; place strong emphasis on technology and invention; are shared spaces at the centre of a community; and express a "spirit of invention and science, based on trial, error, and freely sharing information." As such, hackerspaces are generally a small social formation of hackers in physical space, such as warehouses and garages, where they can meet and work on their projects, and share software, hardware, ideas and knowledge (Lindtner 2012).

From an institutional perspective, hackerspaces act as a governance structure for individuals to exchange and share information.[132] In this way the underlying resource of a hackerspace is not just the physical resources, but also "group knowledge" (Robertson 2010, p. 5). It is this access to knowledge for hackers as proto-entrepreneurs that is important given the distributed nature of non-price information they require. Indeed, hackerspaces have been described as intermediaries for the "translation between scientific knowledge produced in the labs … and the everyday interests, practices and problems of ordinary people in diverse local contexts around the globe" (Lindtner 2012, p. 1).[133] The information within hackerspaces has also been referred to as folk knowledge, "developed by a given

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the workplace (Moilanen 2012), location-based user-led innovation networks (Robertson 2010), intermediaries between scientific knowledge and everyday problems (Kera 2012), a form of commons-based peer production (Kostakis et al. 2014), and a common pool resource (Williams and Hall 2015).

[130] See Capdevila (2014) for a typology of different spaces according to their "creative approach" and "mode of governance".

[131] Mitch Altman, founder of hackerspace Noisebridge, was quoted in Han (2015) as "All [hackerspaces] are unique because they were founded by unique individuals and different groups based on their own sensibilities. Of course, they draw on the examples of other hackerspaces. They see what works well and what doesn't work well for the other spaces so they can decide for themselves what they want to try."

[132] For instance, hackerspaces have been characterised as a problem solving network with "free exchange of knowledge in order to create *an optimized final product*" (Seckinger et al. 2012, p. 3).

[133] See also Robertson (2010, p. 5), who argues hackerspaces are "place-based innovation networks act[ing] as a bridge between the local economic development planner and user-led innovation".

community as opposed to knowledge generated through universities, government research centres, and private industry" (Kera 2012, p. 2). Following the analysis in Chapter 2 and Chapter 3 on the need for private orderings to govern this information about new technologies, the following section turns to the question of how this knowledge is privately and collectively governed and coordinated by focusing on the institutional mechanisms that overcome the transaction costs of the proto-entrepreneurial problem.

4.4. The private governance mechanisms in hackerspaces

This section proposes four main private governance mechanisms in the hackerspace phenomenon, which are interpreted in the context of institutional theory, common pool resource design rules, and the propositions over the characteristics of an innovation commons outlined in Chapter 3: (1) graduated social ostracism and exclusion; (2) costly signalling as a form of non-price coordination; (3) processes of collective action rule formation; and (4) nested hierarchies of rules. These institutional mechanisms are examined as private governance efforts to economise on the transaction costs in the proto-entrepreneurial problem including the dual threats of free riding, on one hand, and the stifling of autonomous spontaneous adaptation and discovery, on the other. The following sections examine the transaction hazards and costs hackers face and the emergent private institutional solutions to those costs.

4.4.1. Social ostracism and exclusion

When coordinating non-price information with others, hackers may reveal a perceived actionable market opportunity, and, as we saw, the potential value of acting on that opportunity comes with the threat that another hacker may appropriate those quasi-rents, such as by exploiting an opportunity in other organisations.[134] Furthermore, the disclosure of non-price information between hackers is not easily verifiable by a third party, and therefore hackers may have the incentive not to share ideas and resources with others. In this way hackerspaces may suffer from a form of 'free riding' where other hackers fail to

[134] For a discussion of how the microstructure of transaction costs shifts throughout the entrepreneurial process see Section 2.4.

contribute or disclose information. This notion of failing to contribute to commons has been discussed in the common pool resource management literature relating to knowledge commons, including Wikipedia (Frischmann et al. 2014; Hess and Ostrom 2003; Ostrom and Hess 2007). This raises questions of who has access to the resources within a hackerspace, and to whom the products of exchange belong to.[135] Nevertheless, given the potential gains from coordination, hackers may be incentivised to develop private governance structures to overcome these hazards. How do hackers mitigate these hazards in hackerspaces?

One mechanism to overcome such hazards is through ostracising defectors. Ostracism is well known to be an effective mechanism to both induce future cooperative behaviour and to punish defective behaviour.[136] For instance, brokers in the early London Stock Exchange, with no recognition and thus recourse to state law due to the prohibited status of their exchange, would mark on boards those individuals who had cheated others in past dealings (Stringham 2015). This meant defection was a significant cost to the potential defector as there were few other markets they could go to, and this governance mechanism helped maintain cooperative behaviours. Similar mechanisms exist across many private governance forms: in prison gangs ostracism could be deadly because it removes the protection the gang provides (Skarbek 2014); for traders across Africa, ostracism excludes defectors from potentially life-saving food markets (Leeson 2014). Is there evidence of such ostracism in hackerspaces?

Ostracism from a hackerspace requires some form of defined resource boundary because this enables defecting individuals to be excluded from the space.[137] This governance problem was captured in the first commons design rule: "defining the

[135] This is similar to the problem of team production and monitoring of contributions as outlined by Alchian and Demsetz (1972). Given the extreme structural uncertainty as outlined in Chapter 2, however, the economic problem facing the proto-entrepreneur makes it difficult to undertake monitoring within a hierarchical firm, and the emphasis within an innovation commons such as a hackerspace is how this process can be undertaken within a polycentric hybrid structure.

[136] Both this section, focusing on ostracism, and the following section, on costly signalling, operate largely through the mechanism of reputation. Such mechanisms are generally thought to only work in small groups (note Leeson 2004 as an exception), which is precisely what hackerspaces provide.

[137] Other transaction cost economising institutions, such as reputation mechanisms, are discussed in further sections below.

boundaries of the CPR and specifying those authorized to use it can be thought of as the first step in organizing for collective action" (Ostrom 1990, p. 91). Defining resource boundaries is the institutional difference between a commons-like club and an open-access resource. The process of excluding defectors from an innovation commons such as a hackerspace is difficult because of the nature of the underlying distributed, uncertain and non-price proto-entrepreneurial resources. How do hackers effectively ostracise non-cooperative people with hackerspaces, and what is the nature of the boundary they are ostracised to? While a formal legal boundary exists between hackerspace governance and the outside world, a mentality of "openness" and that "everyone is welcome" remains.[138] Hackers face a trade-off between openness—that provides more distributed knowledge which is potentially complementary—and the exclusion of potential defectors—to maintain and incentivise cooperation and coordination of information in the hackerspace. Nevertheless, physical access to hackerspaces and its resources are restricted through different opening times for members and non-members. For example, members may have 24-hour access while non-members are only free to come at other times—that is, some members may receive a key while others do not. Furthermore, operational voting rights are regularly tied to membership, with members gaining participatory rights in the voting process while outsiders do not.[139] Exclusive mailing lists or meetings can only be accessed by some people, normally to those who have contributed most to the space. New technologies, such as radio frequency identification keys, can help maintain the physical security of the hackerspace as a common pool resource (see Williams and Hall 2015). Some hackerspaces impose a formal apprenticeship for new members: "… we don't really have a barrier, but we have come up with a three months 'apprentice-ship' phase, mostly due to the fact that we don't want to give out keys to our place to just anybody" (see Kostakis et al. 2014).

Ostracism and exclusion in hackerspaces, however, is not only physical exclusion through a formal hierarchy, but rather comes from the choice by hackers to coordinate with others.

[138] While hackerspaces are generally registered corporations with "an exclusive right of entry and access" (Seckinger et al. 2012, p. 6), this merely a formal legal requirement and is not enforced in practice.
[139] The process of collective decision making is explored later in the paper.

That is, ostracism and exclusion are applied at lower and more informal level of rules, rather than at the boundary of the hackerspace itself. While almost anyone is let into the space initially, individual agents also determine who they coordinate with based on their own discretion. Hackers pay close attention to new members to form an expectation of their reputation. Given that ostracism is a social barrier, it is a more graduated rather than strict. Indeed, hackerspaces rest on very little command and control through hierarchies and "critiques must take the form of a review of respected peers, rather than commands from a supervisor" (Seckinger et al. 2012, p. 15). This type of graduated social ostracism can be seen as a governance mechanism to overcome the transaction costs of the proto-entrepreneurial problem more effectively than through a hierarchical mode of monitoring.

One of the institutional benefits graduated social ostracism through bottom-up individual action is that individuals in a hackerspace can utilise their local contextual knowledge to perceive a reputation of other agents. It may be comparatively ineffective to establish a top-down mechanism of monitoring and ostracism because defection over the underlying knowledge resources is difficult to determine by third parties, and because such top-down coercion may be too hierarchical in relation to the hacker norms and ethic. The mechanism of graduated social ostracism within hackerspaces is similar to two commons design rules (Ostrom 1990): the development of a rule system to monitor others' behaviours; and the development of a mechanism of graduated sanctions for violators.[140] Bottom-up monitoring, however, also implies a limit on the size of a hackerspace because, as the size of the population within the hackerspaces grows, the capacity for individuals to understand the reputation of other agents diminishes.[141] This graduated bottom-up ostracism is closely linked with a reputation mechanism based on costly signalling, in that

[140] Ostrom (1990, p. 94) outlines these two rules as "Monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators" and "Appropriators who violate operational rules are likely to be assessed graduated sanctions … by other appropriators, by officials accountable to those appropriators."

[141] See Moilanen (2012) for a description of hackerspace summary statistics, including their size. Hackerspaces are generally small organisations.

agents seek to signal their cooperative traits to induce cooperation with others, which is the focus of the following section.

4.4.2. Costly signals as non-price coordination

Hackers face structural uncertainty both over whether another hacker is going to act opportunistically in the future (i.e. whether they are a future cooperative partner) and also whether the combination of their heterogeneous non-price formation will produce value (i.e. because the value of proto-entrepreneurial resources are latent and under a shroud of uncertainty). As we saw in Chapter 2, this is an entrepreneurial form of the classic information paradox, where proto-entrepreneurs do not know if other information is complementary until it has been disclosed and combined (Arrow 1962). How do hackers solve these problems through private governance? A governance structure for these problems would need to coordinate information on whether another person is likely to cooperate or defect, as well as have an indication whether the exchange of information will help to crystallise a market opportunity. One potential solution to this economic problem of uncertainty over value, and the problem of defecting agents, is through signalling.

Costly signalling is understood within the institutional and socio-biology literature to facilitate cooperative trade and behaviour in the face of *ex ante* information asymmetries (Spence 1973).[142] There are several reasons why signalling mechanisms may be necessary to maintain the efficacy of the hackerspace governance. On one hand, costly signals can filter cooperative entrants coming into the hackerspace, and, on a lower institutional level, with whom to cooperate. This signalling is closely related to the previous section on social ostracism and exclusion. Signalling is an input into reputation, where reputation is a spontaneously ordered mechanism of contract enforcement (Leeson 2010). On the other hand, costly signals can facilitate the non-price coordination process of matching agents to

[142] Signalling is also an important concept within the literature on selection within socio-biology and eusociality such as the 'image-scoring game' (Nowak and Sigmund 1998). Further parallels in the conception of hackerspaces as innovation commons with the literature on indirect reciprocity (Gintis et al. 2001; Nowak and Sigmund 2005) and in particular the idea that "the money that fuels indirect reciprocity is reputation" (Nowak 2006, p. 1561).

complementary trading partners. Costly signalling of non-price information may replace the signals of prices within markets to order agents through spontaneous non-price coordination. That is, as a type of ordering mechanism for matching agents based on their skills, experiences and interests.

Costly signalling in hackerspaces takes many forms. For instance, the voluntary teaching of classes—on topics such as soldering, 3D printing, and laser cutting—can be read as a signal of cooperative behaviour and reveal the skills and interests of others. Learning the 'hacker language' and culture, which is a "comprehensive compendium of hacker slang illuminating many aspects of hacking tradition and folklore" (Wiki 2004) can also be conceived as a costly signal and as what Williamson (1983) refers to as "credible commitments."[143] Learning a language is an irreversible, specific investment used to encourage cooperative trade. In hackerspaces, learning the hacker language can act as credible commitment for future cooperative exchange and collaboration.

Signalling may also help to order proto-entrepreneurial coordination and discovery. As individuals signal their skills, talents, and interests, this facilitates ordering between hackers. For instance, running regular hack-a-thons enables individuals to contribute and coordinate knowledge with others (e.g. Press 2013).[144] This process may lead to the discovery of market opportunities, and thus the founding of entrepreneurial firms from hackerspaces. This is a form of non-price coordination between hackers because price signals from markets are insufficient to solve the proto-entrepreneurial problem.[145] These costly signals can act also act indirectly as other hackers within the space view exchanges of information—that is, the costly signalling can act as a multi-lateral signal to many hackers simultaneously. Further, the effect of costly signalling within hackerspaces can also be viewed as a "contribution good".[146] Kealey and Ricketts (2014) argue that because appropriating the research and

[143] For hackerspaces, investing in costly signals can be conceived as a credible commitment in the sense of "reciprocal acts designed to safeguard a relationship" that are "undertaken in support of alliances and to promote exchange" (Williamson 1983, p. 519).
[144] See Chapter 5 for a further discussion of the hack-a-thon phenomenon.
[145] See Kuchař and Dekker (2017) on non-price coordination.
[146] Kealey and Ricketts (2014) develop a model of science incorporating both exclusion and openness, where the prisoners' dilemma game is transformed from a public goods problem to a coordination problem.

products of scientific activity first requires learning the language of science, to reap the benefits of science scientists must contribute to the body of science itself—thus, a contribution good.[147] In a similar way, through costly signalling and learning the hacker language, for instance, hackers must contribute and coordinate non-price information with other hackers. The signals that crystallise in the teaching of a class, or the growth of the hacker culture and language, also contributes to the resources within an innovation commons. In this way, signals may be important in maintaining the underlying common pool of information and preventing hackerspaces from collapsing.

4.4.3. Collective action endogenous rule formation

As Maxigas (2014, p. 4) notes, hackerspaces are "… set up by hackers for hackers with the principle mission of supporting hacking." The operating governance structure of hackerspaces is a flat hierarchy, generally with some form of horizontally-managed democratic collective action process (e.g. see Seckinger et al. 2012). Hackerspaces are often member-owned corporations registered as not-for-profit corporations. Depending on their legal jurisdiction, hackerspaces may have formal boards or members. While formal rules prescribe roles to board members, underlying that is a flat and fluid process of collective decision making. For instance, in an interview outlined in Kostakis et al. (2014) from a hackerspace founder, it is clear hackerspaces tend to eschew clearly defined roles: "… we consciously decided to make it as anarchist as possible, with no leaders, an as few rules as possible". While there are very few rigidly defined goals, the rules that do come to be prescribed are endogenously created through collective group decision-making. This decision-making is based on participants' perceptions of the contributions and reputations of others. This collective action bottom-up process also means rules are endogenously created within each space and evolve over time.[148] There are many descriptions for the different forms of collective action processes within hackerspaces, including merit-ocracy,

[147] Specifically, a "pure contribution good is non-rival over contributors but is not accessible by non-contributors" (Kealey and Ricketts 2014, p. 1015).

[148] See Kostakis et al. (2014): "Decision making evolved quite a bit over the years and is still in evolution. We went from plena where everybody present could vote to decision taking by the council by majority vote, to consensus in a steering group and back and forth."

do-ocracy and act-ocracy. The commonality across these forms of governance is that a hackers' position within the organisation is closely tied to their contributions to the space in the past. As discussed above, this is similar to the contribution goods literature, with the added dynamic that the more an individual does—the more contributed, the more acted—the more implicit power the individual gains within the governance structure. Rather than imposing a strict hierarchy, hackerspaces utilise the local contextual knowledge and opinions of each individual, apropos to their contribution and standing garnered through costly signals. Endogenous collective action rule making is a more decentralised form of power than a hierarchical organisation where defections are policed from the bottom-up. Further, as we will see in the following section, these rules filter up to the higher level of the hackerspace movement and are distributed as best practice rules for other hackerspaces.[149] Collective action rule making enables a lower level of spontaneous rule-making to occur, which can be developed by the hackers themselves. That, is hackerspaces use distinct nested hierarchies of rules which enable a form of institutional laboratory federalism and for the matching and coordination of hackers as their idiosyncratic investments build up and structural uncertainty decline. This endogenous collective action rule making outlined here is similar to Elinor Ostrom's third commons design rule, where those individuals who are affected by the rules can modify those rules. Furthermore, as we see below, there are distinct sub-groups of rules within the hackerspace phenomenon.

4.4.4. Rules are nested in a hierarchy

To understand the complexity of institutional systems it is useful to compartmentalise rules into distinguishable sub-levels. Analysing institutional systems as "holons"—where what is a whole at one level is part of a system at another (Ostrom 2005, p. 11)—helps disentangle complex institutional systems. Mechanisms of governance often require different systems of rules because each level has a different role in solving different economic problems and institutional challenges. The eighth design rule in Ostrom (1990, p. 101) is that "appropriation, provision, monitoring, enforcement, conflict resolution, and governance

[149] For example, see hackerspaces.org website on 'how to set up a hackerspace'.

activities are organized in multiple layers of nested enterprises." This section outlines three levels of rules that constitute the private governance of proto-entrepreneurial resources within the hackerspace phenomenon: a *meta-constitutional* global network of spaces sharing best-practice rules; a *constitutional boundary* of each hackerspace, including the rules that broadly determine the rules of the game; and a *sub-group* level of polycentric projects where hackers collaborate and collectively determine their own rules. Further, it is only from distinguishing these sub-group levels of rules that the entrepreneurial fundamental transformation described in Chapter 2 becomes clear.

Meta-constitutional rules: a global hackerspace community

While survey results from Moilanen (2012) suggest that 91 per cent of hackers were part of only one hackerspace or makerspace community, there is a strong culture of mutual visiting rights between hackerspaces. Hackerspace passports, for instance, were created by one prominent hackerspace, Noisebridge, in an attempt to promote visiting rights to other hackerspaces, increase collaboration and cross-pollination, and encourage mutual support between hackerspaces (hackerspaces.org 2011). This broad global community of hackerspaces share information about governance best practice through "an international network of exhibition fairs, publications, member's clubs, and funding structures" (Seckinger et al. 2012, p. 5). This overarching global hackerspaces community is the highest level of self-contained hackerspace rules: the *meta-constitutional* rules.

The meta-constitutional rules are transferred through a "global and informal network" and relate to their shared "technologies, procedures and values" (Kera 2012, p. 1). This provides overarching governance to hackerspaces themselves, yet has no direct authority over them. This meta-constitutional level is limited to providing information of the existence of other hackerspaces and promoting diffusion of best practice rules. Best practice design rules are often referred to as Design Patterns—a term that emerged in 2007 from a speech at the 24th Chaos Communication Congress in the discussions of creating and running a hackerspace (Ohlig and Weiler 2007). An explicit online thread is dedicated to design patterns on the main hackerspaces website (hackerspaces.org 2016). Underlying this broad

global network of best practice rules and sharing of information are the broad rules of each individual hackerspace, which are outlined below.

Constitutional rules: the broad pre-constitutional rules of the game

The shared community of hackerspaces at the meta-constitutional level described above is made up of self-contained communities of hackerspaces (Moilanen 2012). Each of these hackerspaces creates their own rules at the level of the hackerspace—these are *constitutional* level rules. These rules "provide a community-oriented space, sustainably funded by members, that supports creation and exploration" (Williams et al. 2012, p.18). These rules delineate activities within an outside the hackerspace, particularly in differentiating the institutional system from outside influences. These constitutional rules align with Elinor Ostrom's commons design rule of a defined resource boundary (see Section 4.4.1).[150] Constitutional rules do not direct the goals of hackers as they solve their proto-entrepreneurial problem, but rather enable hackers to coordinate non-price information with others to discover opportunities. Indeed, this constitutional level of rules serves to maintain "arms-length support enabling autonomous creative behaviours" which in turn will "provide the breeding ground for new creative industries to blossom" (Seckinger et al. 2012, p. 9).

The constitutional rules of a hackerspace—including the collective action voting processes discussed above, as well as the informal norms within hackerspaces relating to the sharing of information—are a form of *pre*-constitutional rule making, within which hackers coordinate to solve their economic problem in the *post*-constitutional level below.[151] As we will see in the following section, having broad and fluid *pre*-constitutional rules within which hackers coordinate information may be a mechanism to economise on the unique transaction costs of the proto-entrepreneurial innovation problem. That is, given the non-price coordination problem proto-entrepreneurs face over potential

[150] To be clear, the hackerspace is not impermeable, because such rigid definition would impose artificial boundaries (see Moilanen 2012).

[151] See Buchanan and Tullock (1962) for a distinction between pre-constitutional and post-constitutional analysis, where the former focuses on the rules of the game whereas the latter focuses on the play of the game.

complementary trading partners, it may be transaction cost economising for the rules of the game to remain broad and then later be made more specific and heterogeneous, which is what occurs at the sub-group level. That is, the *pre*-constitutional rules here exist to enable autonomous spontaneous coordination at the lower sub-group level, which is the focus of the following section.

Sub-group rules: heterogeneous rule formation in teams

The dynamic processes of developing technologies within hackerspaces are "typically not coordinated hierarchically, but through collectivist structures" (see Kostakis et al. 2014). The particular distributions, duties and goals of hackers are determined collectively by those within that particular group as they voluntarily enter into informal agreements. Within hackerspaces, hackers collaborate on projects and develop rules to govern those collaborations—these are the *sub-group* level rules. At this level of hackerspace rules, "various groups and stakeholders (can) negotiate their interests directly" (Kera 2012, p. 2). Indeed, within the constitutional level rules described above there is a form of spontaneous proto-entrepreneurial anarchy:

> Anarchy, the way we see it, is people self-organizing to make things happen. People take on positions of leadership within temporary organizing bodies created for given tasks. Whatever temporary organization was necessary to perform those tasks goes away when the task is accomplished, along with the leadership required. (see Kostakis et al. 2014)

Further, as a different hackerspace founder outlined:

> Normally the one that starts the project takes the lead and just starts doing. Starting new project does not require any permissions or such. You just start doing it. If others join the project, goals and efforts and discussed together (even with people 'outside' the project). (see Kostakis et al. 2014)

Sub-group level rules are more specific and heterogeneous than the preceding constitutional level rules, and are more fluid and dynamic. Indeed, as Moilanen (2012, p. 94) notes: "the autonomous micro communities are constantly on the move; evolving, mixing, forking, hibernating and dying". This level of rules is where hackerspaces gain the impression of lacking specifically designed or defined goals, and that they rest on

indeterminate and dynamic processes (e.g. Seravalli 2011). Indeed, according to Seckinger et al. (2012, p. 15) the creative process, due to its necessary failures and revisions "does not deal with administration well". Sub-group levels of rules are similar to the concept of "entrepreneurial teams" (Harper 2008).[152] The sub-groups or teams that form within a hackerspace are best described as exhibiting polycentricism in the sense of Ostrom et al. (1961), where polycentricism is having many centres, but these decision centres sit within a larger framework of central mechanisms to resolve conflicts (Aligica et al. 2017).[153] The sub-group level of rules is a polycentric ordering within the constitutional level of rules described above. In this way the grouping of entrepreneurial sub-groups within a hackerspace—based on the combination of complementary information between proto-entrepreneurs—enables the polycentric decision making to occur at a potentially more efficient scale of decision-making (see Tarko 2016).

Solving the proto-entrepreneurial innovation problem through these polycentric governance structures may economise the transaction costs associated with fundamental structural uncertainty over trading partners, and the costs of trial and error with different trading partners. The benefits of such a polycentric approach, however, may decline as groups of proto-entrepreneurs begin to crystallise market opportunities together. In this way the sub-group level of polycentric collective action rule formation is the level at which the entrepreneurial fundamental transformation takes place (see Chapter 2). At the two levels of rules in hackerspaces discussed above, hackerspaces appear as a more on-going institutional solution to the innovation problem. From the perspective of the choosing proto-entrepreneur attempting to solve their economic problem, however, the polycentric sub-group rules within a hackerspace may only be a temporary institutional solution as the microstructure of transaction costs begins to change as a market opportunity is developed.

[152] The sub-groups of hackers in hackerspaces are "entrepreneurial teams" in the sense that Harper (2008, p. 614) defines "an entrepreneurial team as a group of entrepreneurs with a common goal that can only be achieved by appropriate combinations of individual entrepreneurial actions." As Harper notes, this definition of an entrepreneurial team is extremely broad. In the context of a hackerspace, there may be multiple overlapping polycentric entrepreneurial teams, owing to the fact that the entrepreneurial team itself must be first discovered. See also Cooney (2005) for a review of entrepreneurial teams.

[153] On polycentric governance also see McGinnis (1999), Ostrom (2010) and Andersson (2012).

As hackers begin to work on a project collaboratively in teams they may develop increasingly idiosyncratic investments with the others in the group. The asset specificity here is not necessary in the form of physical investments, but rather human capital understandings of a market opportunity that has quasi-rents as a particular project opportunity is identified and developed, because economic value would be sacrificed if the trading relationship was to be terminated (see Chapter 2). Once proto-entrepreneurs within hackerspaces discover what they perceive to be an actionable market opportunity they may decide to integrate within a centralised firm due to the increase in the potential for opportunism.

Only at level of polycentric sub-group rules can the constitutional rules of hackerspaces described above be outlined as *pre*-constitutional rules enabling the spontaneous ordering and formation at lower levels. The constitutional rules in a hackerspace create a playing field within which hackers can devise and test their own rules, including, for instance, the ownership of the particular project through bargaining. Indeed, as one hacker noted: "In all cases, the hackerspace doesn't lay any claim at all to the projects. It's up to you and the people you work with to figure out who owns what" (see Kostakis et al. 2014). For instance, as (Seckinger et al. 2012, p. 17) suggests: "creatives are constantly coming and going, trading projects and resources the way most others trade currency." In this context the question then becomes why hackers create a constitutional level of rules to undertake polycentric coordinating outside the traditional institutions of the innovation system, including firms and markets. In the following section we will see that hackerspaces themselves can be viewed as a form of entrepreneurial secession—from the entangled institutions of innovation policy—to the private governance structures of the innovation commons.

4.5. Hackerspaces as entrepreneurial institutional secession

This section examines the comparative political economy choice of hackers to secede from the institutions of innovation policy—including its entanglement in markets through, for instance, intellectual property—in favour of the polycentric private orderings in

hackerspaces. This institutional choice of private governance is examined through the analytical framework of "efficient anarchy" outlined in Leeson (2007c). From this perspective, hackerspaces are type of secession from the institutional controls of innovation policy, analogous to economic shatter zones that are "found wherever the expansion of states, empires, slave-trading, and wars, as well as natural disasters, have driven large numbers of people to seek refuge in out-of-the-way places" (Scott 2014, p. 8). Examining hackerspaces as a form of institutional secession raises many questions within comparative political economy. For instance, are hackers explicitly seceding because innovation policy distorts the costs of other institutional solutions? What are the transaction cost conditions under which this choice to secede may be made?[154]

Leeson (2007c) lays out a simple analytical model for thinking about when private governance (i.e. anarchy) may be an efficient institutional choice for rational self-maximising agents. Assume that each person receives some gains from trade when there is a government and some payoffs when government is absent. Further assume that there is a higher level of trade, and thus payoffs, when the government is present. However, given that government is not costless, for a society to prefer anarchy, the cost of government must be lower than the social benefit it brings.[155] Using this understanding of comparative political economy, one possibility is that the costs imposed by innovation policy are comparatively too high for facilitating proto-entrepreneurial economic problem outlined in this thesis. That is, private governance of the proto-entrepreneurial process in hackerspaces may be efficient because the relative cost of governing the entrepreneurial process elsewhere—within the entanglement of innovation policy—may be comparatively expensive. Given that the costs of government are subjectively perceived, to demonstrate the cost of government intervention in this process we can look to the perceptions of

[154] For a further discussion of how institutional choice is a trade-off between the subjective costs of dictatorship and disorder, see Chapter 7.
[155] This assumes a social contract theory of government where the presence or absence of government is in efficiency terms.

hackers themselves: do hackers perceive state-based institutions of innovation policy as effective institutional solutions to the economic problem they face?

Hackers' focus on maintaining governance autonomy can be seen as evidence they are seceding from state-based institutions. Hackers delineate what practices are acceptable within their constitutional rules, and what is only acceptable outside the ordering. This manifests in eschewing of intellectual property rights, subsidies, credit and public funding. Hackers tend to eschew both hierarchical firms (i.e. corporations) and governments (including, for instance, defence departments). For instance, there was controversy over defence funding for hackerspaces in the United States, where it was feared the space would be "co-opted" (O'Leary 2012). Related to this is the general sentiment that hackers would accept funding if the other organisational form is aligned with their goals and values because institutional autonomy would not be compromised:

> A commitment to autonomy is probably the reason why we found little evidence of hackerspaces subject to indicators or metrics of outside agencies and institutions … metrics of performance are challenging when institutions fail to understand the concept in all its open-ended and flexible possibilities. (Smith et al. 2015, p. 15)

How do hackers maintain autonomy? One of the mechanisms maintaining hackerspace autonomy is their funding. The main source of funding in hackerspaces varies, but the financial independence and autonomy is an important principle for hackerspaces (Guthrie 2014). Funding is often sourced from monthly fees or dues and subscriptions, as well as "donations, sponsorships and grants" (Seckinger et al. 2012, p. 6). Furthermore, "company donations (money) are less disagreeable than governmental support, but only slightly" while membership fees "seem to be the most approved source of funding" (see Moilanen 2012). A hackerspace founder also notes: "If a company or organization wants to give a donation with no strings attached, then [hackerspace] will gladly accept — but it must be no strings attached, since there are members of [hackerspace] who feel very strongly about this" (see Kostakis et al. 2014).

The extent of governance autonomy within a hackerspace may also change as the microstructure of transaction costs as they shift throughout an innovation trajectory, where a proto-entrepreneurial hacker may move from a hackerspace, to a fab lab to an incubator, and then on to a start-up firm. This includes gradations of autonomy from a fully privately governed hackerspace to other institutions that may be embedded within a national innovation system. This process of shifting economising institutions, however, creates tension with the underlying norms of hackers. On one hand, there is a sentiment in hackerspaces that the creative process may not "function in the traditional business model, where income generation is the primary measure of success" (Seckinger et al. 2012, p. 9). Indeed, at first it seems that hackers are entrepreneurs because of the revealed sentiment of opposing commercialisation because "commercialization undermines the spirit that drives the space's innovative engine" (Robertson 2010, p. 6). However, there is also evidence that hackers eschew commercialisation within the space, but not outside it: "We dislike intellectual property and I don't think we would keep people from using the knowledge they gained on the 'outside' world. In fact, one of our goals is to enable people to go outside and apply what they learned at the hackerspace" (see Kostakis et al. 2014). It is clear that one of the dominant themes of the maker movement is "open-source, non-proprietary intellectual property," partially because the traditional form of intellectual property protection runs counter to their desires (Seckinger et al. 2012, p. 16). The tension with commercialisation tends to relate more to the use of physical resources within the space for business purposes, rather than using information to form market opportunities.[156] This reveals a clear tension between the open-source principles within hackerspaces, and the commercialisation and diffusion of opportunities discovered in the space. On one hand hackerspaces appear to eschew the commercialisation of ideas—pushing back on the institutions of firms, markets, and governments—while simultaneously understanding that ideas may later enter these institutions.[157] While on the surface it appears that hackers

[156] For instance, interviews in Kostakis et al. (2014) reveal: "It is considered unexcellent to use the resources of the space as a means of production which will lead to financial benefit (i.e. don't run your eBay store out of [hackerspace]), but whatever skills you learn in the space are yours to profit from."

[157] For instance, interviews in Kostakis et al. (2014) reveal: "I see hackerspaces as an opportunity to freely test goofy ideas that might otherwise be left alone. There are no boundaries to cross in hackerspace, people are

eschew the commercialisation of ideas, it seems hackers only *temporarily* eschew that commercialisation. Put another way, hackers first begin coordinating and cooperating within hackerspaces, but, if successful in discovering some perceived actionable economic value outside the space, and as agreed to by other members involved in the project, those ideas—the discovery of a market opportunity—may be commercialised elsewhere. This aligns with the proposition in Chapter 2 that the microstructure of transaction costs changes at the level of the opportunity throughout its trajectory, implying the efficient institution to govern that opportunity will change from a private polycentric opportunity to that of a centralised firm. What begins with cooperation in hackerspaces between many autonomous agents may end in commercialisation within the hierarchical firm of only a few people.

The comparative efficiency of hackerspaces in solving the proto-entrepreneurial problem may have also improved through time through institutional learning. Raymond (1999) suggests that the practice of sharing (referring to open source software) may be prevalent not only because it is the right thing to do, but also because it is an efficient and superior development model for making software (in contrast to intellectual property models). Effective private collective action mechanisms make the benefits of engaging with the institutions that are entangled with innovation policy comparatively ineffective. More effective private orderings imply a smaller benefit from engaged in the state-based system. In this view, this chapter has examined how hackers have discovered unique and contextual sets of institutions to overcome the problems they face. New technologies may also facilitate the creation of hackerspaces—for instance, social media has enabled different hackers to come together and sort themselves into relevant hackerspaces (Seckinger et al. 2012, p. 5). Cheaper and more easily accessible security measures, such as cameras and SSID cards, have aided the maintenance and governance of the physical resources of hackerspaces (Williams and Hall 2015). Further, as elucidated in a case study in Chapter 6, new institution-creating technologies such as blockchains may further decrease the costs of private orderings to coordinate the discovery of value. The private development of

free to do what ever they want. If the ideas tested work, people might even find a product to take further, but outside hackerspace."

institutional solutions to the proto-entrepreneurial problem may comparatively improve over time as proto-entrepreneurs learn.

4.6. Conclusion

This chapter analysed hackerspaces as an example of a polycentric private collective action solution to the proto-entrepreneurial problem. From this perspective, hackers are proto-entrepreneurs who coordinate non-price entrepreneurial information within collectively developed rules to discover market opportunities. Analysing a range of secondary data sources revealed several private governance mechanisms. First, hackers undertake *bottom-up graduated social ostracism*. The barrier to proto-entrepreneurial coordination of non-price information is not just physical or formal, but rather on the individual decision to collaborate with another agent. This mechanism utilises the local contextual reputation of other hackers regarding their perceived contributions to the space. Second, hackers employ various forms of *costly signalling* processes—such as the voluntary teaching of classes—which both signal future cooperative behaviour and facilitate the spontaneous ordering of complementary heterogeneous resources including tacit skills, talents and interests. Third, hackers *create and maintain rules endogenously through collective action* processes. This also acts as a sort of laboratory federalism, akin to policy learning in federations, where rules are endogenously created and then filter up to the hackerspaces movement more broadly. Fourth, hackerspaces have *distinct nested hierarchies of rules*. The meta-constitutional rules coordinate best-practice rules across the thousands of hackerspaces globally. The constitutional rules govern each individual hackerspace, including their constitutions and formal rules, as well as operational rules such as voting, and that act to set the playing field for the creation of further rules at the lower level. The sub-group rules are polycentric and are created at the level of project or team, and which spontaneously emerge from the typically flat hierarchical structure of hackerspaces. At this sub-group level the temporary nature of the innovation commons is clear. That is, where the entrepreneurial fundamental transformation takes place and the change in the microstructure of transaction costs is visible.

Finally, some comparative political economy reasons why hackerspaces may emerge as a form of secession from the institutions of innovation policy were outlined. Coordinating the proto-entrepreneurial process within the institutions of innovation policy—including its entanglement with the market through, for instance, intellectual property—may be comparatively costly. The autonomy of hackerspace governance outside of the reach of innovation policy was evidenced by hackers' explicit eschewing of the efficacy of state-based innovation policy and the hierarchical firm. One further reason for the secession to the private governance structures of hackerspaces may be that the continual development and refinement of innovation commons institutions may make them comparatively effective at solving the proto-entrepreneurial problem.

This chapter contributed to and expanded our understanding of the mechanisms hackers develop to solve the proto-entrepreneurial problem described in Chapter 2, with particular reference to the potential for private polycentric solutions proposed in Chapter 3. The implication of this is to reveal some of the feasible bounds of the institutional possibility set of proto-entrepreneurial coordination. Enquiring into the private governance of proto-entrepreneurial discovery can also be examined from the perspective of a technology, and the diversity and heterogeneity of institutions, including hackerspaces, that emerge to overcome the transaction costs of coordinating entrepreneurial information. Chapter 6 and Chapter 7 below examine a broader view on the private governance of innovation through emphasis of the innovation commons emerging around a new potential general purpose technology, blockchain.

Chapter 5: Blockchain innovation commons

5.1. The nascence and generalness of blockchain technology

Blockchain is a new technology for coordinating distributed ledgers of information, and is predicted to have wide application across many industries and institutions.[158] Thus far academic literature on blockchain technology has emerged in the technical, economic, regulatory and social sciences, and has emphasised the impact blockchain will have on the institutional structure of society and on the economy (Baur et al. 2015).[159] As yet, the blockchain literature has not enquired into the institutional processes through which valuable blockchain applications will be entrepreneurially discovered. This chapter aims to analyse the diversity of private governance structures—that is, blockchain innovation commons—within which blockchain entrepreneurs are attempting to discover those opportunities. Rather than focusing on one particular class of organisation, such as hackerspaces (Chapter 4), this chapter organises analysis around proto-entrepreneurs focusing on blockchain technology.[160]

There are two reasons why blockchain technology is examined here as a case study in the polycentric private governance of proto-entrepreneurship. First, because blockchain technology was only released in 2008 and remains in its nascent stages. When analysing examples of innovation commons it is preferable that a technology is nascent because the emergence of polycentric private governance structures are predicted in the earliest stages of new industries and technologies, to economise on the unique transaction costs of coordinating uncertain and distributed non-price information about market opportunities (Chapter 2). As we have seen, overcoming this proto-entrepreneurial structural uncertainty

[158] The functional role and nature of blockchain technology is outlined in more detail in Section 5.2 below.
[159] Blockchain literature has included the boundary and role of the state (Atzori 2015; De Filippi 2014; Kaplanov 2012; MacDonald 2015; Twomey 2013), the economics of the technology on transaction costs and organisation (Davidson et al. 2016), social contract theories (Reijers et al. 2016), the political economy of crypto-currencies (Hendrickson et al. 2015) and the policy implications for each of these lines of thinking (Brito and Castillo 2013).
[160] This chapter is therefore a further application of the theoretical development in Chapter 2 and Chapter 3.

requires coordinating information about market opportunities with others. Because the future potential market opportunities for blockchain are currently shrouded under uncertainty, this suggests that the proto-entrepreneurial processes of knowledge coordination may be currently occurring, therefore warranting examination.[161]

The second reason blockchain is an effective case study is because blockchains are expected to be a general purpose technology (GPT), with entrepreneurial applications in a wide variety of industries (e.g. Davidson et al. 2016; De Filippi 2016; Mattila 2016).[162] Blockchain technology is predicted to "impact all sectors and layers of society, in a multitude of ways" (Mattila 2016, p. 5) because blockchains may drive the disintermediation, decentralisation and disruption of law, contracts and government (Popper 2015; Swan 2015; Wright and De Filippi 2015).[163] It is now well known that blockchain technology is expected to be highly disruptive (Antonopoulos 2014; De Filippi 2014; Vigna and Casey 2015).[164] Innovation commons are predicted to emerge around technologies which are expected to exhibit generalness (Section 3.3) because generalness implies the need for complementary discovery across multiple heterogeneous industries and sectors (Bresnahan and Trajtenberg 1995; Lipsey et al. 2005)—a process which requires coordination of information with others through private orderings. Potential generalness also creates the economic incentives to develop private orderings to reap the benefits of coordination. That is, because of the

[161] See Chapter 2 for the 'entrepreneurial fundamental transformation'.

[162] Blockchain loosely meets the characteristics of a GPT. There have been many proposed defining features of a GPT. For example, Lipsey et al. (2005) argue that a GPT has a: (1) wide scope for elaboration and improvement; (2) applicability across a broad range of uses; (3) potential for use in a wide variety of products and processes; and (4) strong complementarities with existing or potential new technologies. Bresnahan and Trajtenberg (1995) focus on: (1) spreads to many sectors (i.e. pervasiveness); (2) improves over time and lowering the costs of users (i.e. improvement); and (3) makes it easier to produce new products or services (i.e. spawning of new innovations). Cantner and Vannuccini (2012) suggest the literature has converged on three main points, which they call 'input characteristics': (1) have general applicability; (2) imply technological dynamism; and (3) has innovation complementarities. The precise qualitative characteristics of a GPT and the proxies which effectively measure them remain unsettled in economics (see Moser and Nicholas 2004; Rosenberg 1998; Jovanovic and Rousseau 2005). For the purposes here, blockchain technology is considered a potential GPT.

[163] No claims are made here as to whether this hype is justified or interest is justified, which is a contentious issue. Rather, the concern is with the economics of the entrepreneurial processes attempting to fulfil such hype.

[164] Blockchain technology has been variously been described as a new engine of growth (Crosby et al. 2016, p. 9), a trust machine (Economist 2015) and the technology behind the next major paradigm shift (Tapscott and Tapscott 2016).

complementarity of the applications of GPTs, the potential gains from coordinating with others may be greater and therefore the costs of developing the institutional mechanisms of an innovation commons can be recouped. Even further, enquiring into the institutional development of a general technology such as blockchain is important because GPTs are considered a fundamental driver of economic growth.[165]

This chapter examines the hybrid polycentric private governance structures coalescing around blockchain technology. The data is a range of secondary sources—and in particular self-definitions of the structure and purpose of governance structures—which outlines a diverse range of collaborative blockchain innovation commons, including Bitcoin Embassies, hack-a-thons and conferences. These blockchain innovation commons are separated into different categories based on their institutional structure, and are then institutionally differentiated in relation to their hierarchy, control, and autonomy of agents to exchange and coordinate with others. These examples are examined in the context of the theoretical developments of an innovation commons.[166] This chapter is extended in Chapter 6, which also focuses on the proto-entrepreneurial discovery of blockchain, but through the lens of new development economics and a focus on using blockchain for institutional secession.

This chapter proceeds as follows. Section 5.2 briefly introduces blockchain technology and where it may be entrepreneurially applied. Section 5.3 outlines blockchain innovation commons through analysis of secondary data, and discusses their diversity across multiple institutional dimensions. Section 5.4 concludes.

[165] When GPTs are introduced into an existing technological environment they induce a change in the fitness of that environment generating increasing returns to the new technology through a technological impulse in the face of inducement and feedback mechanisms (Cantner and Vannuccini 2013). The propulsion of economic growth, then, comes through changes in the propensity to innovate and discover, and the complementarity of those applications (similar to Silverberg 2002). For the relationship between GPTs and growth also see Helpman (1998) and Helpman and Trajtenberg (1994).

[166] In Chapter 4 the micro-institutional mechanisms of hackerspaces were outlined as a class of proto-entrepreneurial organisation. The present chapter complements those findings by examining the entrepreneurial problem of developing a new general purpose technology, and indeed the diversity and heterogeneity of organisations emerging to overcome that problem.

5.2. What is a blockchain?

This section introduces the nature of blockchain technology and therefore reveals its potential for general entrepreneurial application. Blockchain technology may disrupt many types of industries and processes, particularly those which act as intermediaries such as banking and government (Economist 2015). The central technical advance of blockchain is the combination of several technologies, including cryptography, to create publicly accessible ledgers, stored in a decentralised way, that provide a trusted source of information far from the control of hierarchies and governments (Barta and Murphy 2014; Swan 2015). The information contained within each 'block' of the blockchain is first agreed to through consensus of the nodes that maintain the system and then added to the history of all other blocks—hence, blockchain. Each blockchain can be understood as a decentralised spread sheet for registering assets with "an accounting system for transacting them on a global scale that can include all forms of assets held by all parties worldwide" (Swan 2015, p. xi). A blockchain can theoretically coordinate any information that would otherwise require a third-party intermediary for verification, and therefore can be conceived as a "value exchange network" (Mougayar 2016, p. 153) with a wide variety of potential applications that "dramatically lower cost, improve speed, reduce friction, and boost economic growth and prosperity" (Tapscott and Tapscott 2016, p. 61). Indeed:

> Blockchain technology offers a credible and effective means not only of cutting out intermediaries, but also of radically lowering transaction costs, turning firms into networks, distributing economic power, and enabling both wealth creation and a more prosperous future. (Tapscott and Tapscott 2016, p. 95)

Bitcoin was released in a whitepaper by a pseudonymous author in 2008 (Nakamoto 2008), and remains the most famous application of blockchain technology (Antonopoulos 2014; Böhme et al. 2015; Godsiff 2015). The Bitcoin blockchain maintains a continuous record of all prior transactions of the cryptocurrency (Luther and Olson 2015), with thousands of Bitcoin 'miners' undertaking complex mathematical calculations to maintain the system

(Barta and Murphy 2014).[167] Bitcoin, however, is just one application of blockchain technology.[168] There is continuing speculation over the "potentially countless" applications of blockchain technology (Atzori 2015, p. 3). Indeed, many scholars are still attempting to list and map applications.[169] Swan (2015) outlines three main categories of blockchain technology applications in Table 3 below.

Type	Description	Examples
Blockchain 1.0	Currency	Bitcoin
Blockchain 2.0	Contracts	Financial services contracts, smart property, smart contracts.
Blockchain 3.0	Justice applications beyond currency, economics and markets	Digital identity, blockchain government, domain name systems

Table 3: Examples of blockchain applications

Discovering the applications of blockchain technology is an entrepreneurial process. The potential scope of entrepreneurial discovery of these applications is a function of the institutional environment in which entrepreneurs coordinate information and act. Indeed, the institutions in which entrepreneurs can apply, test and experiment act as constraints on blockchain generalness.[170] Many blockchains are kept as open source, with the underlying code of public being placed in the public domain—this includes the code for bitcoin which was placed publicly online only one week after the initial white paper was released (BitcoinHistory 2016).[171] The open source nature of blockchain may prove critical for its

[167] Specifically, the novelty of bitcoin is that it overcomes the problem of maintaining a decentralised yet trustworthy ledger of money by solving the Byzantine general's problem and providing a consistent money supply. For some stylised facts see Wolfson (2015).

[168] While Bitcoin has been subject to a tumultuous existence (Wallace 2011), the underlying success of blockchains does not necessarily rely on the success of bitcoin. Indeed, there is a growing divide in their interest, with venture capital firms progressively moving towards blockchain-based rather than bitcoin-based technologies.

[169] For some uses of blockchain technology see Walport (2016), Deloitte (2016), BlockchainTechnologies (2016), LedraCapital (2014) and Soo (2016). Note also Tapscott and Tapscott (2016, chapter 6) who, for instance, list twelve potential areas of blockchain disruption: transportation; infrastructure management; energy, waste and water management; resource extraction and farming; environmental monitoring and emergency services; health care; financial services and insurance; document and other record keeping; industrial operations; home management; and retail operations and sales.

[170] There is a wide literature on the slow diffusion and application of GPTs, including supply constraints and legal constraints.

[171] This trend of public open source blockchains may be shifting towards more private, closed blockchains as the technology is integrated within existing institutions such as banks. For a further discussion of this dynamic see Section 5.3.

development because it encourages competition through laboratory federalism and extends the range of viable entrepreneurial opportunities (Wladawsky-Berger 2016). This sentiment is prominent with the development of, for instance, alt coins, which are alternative cryptocurrencies to bitcoin (Poelstra 2014).

Blockchain technology may disrupt any centralised system which coordinates information by providing a more efficient decentralised alternative as compared to the conventional combination of firms, markets and states. In this way blockchain is an institutional technology (Davidson et al. 2016).[172] The comparative efficacy of blockchains is in coordinating information between decentralised agents. One example of the decentralised processes enables by blockchain is "smart contracts", which Buterin (2014) describes as "systems which automatically move digital assets according to arbitrary pre-specified rules."[173] Smart contracts can reference property or value (Kõlvart et al. 2016) and can: "reference property in a dynamic, often proactively enforced form, and provide much better observation and verification where proactive measures must fall short" (Szabo 1997). Smart contracts may lower the transaction costs of decentralised economic exchange, such as in banking (Peters and Panayi 2016). In this way, blockchains can not only be incorporated into a wide number of products and processes, but also create new decentralised processes which exhibit complementarity with other technologies and institutions. Blockchains are complementary with existing technologies, institutions and organisations (e.g. banks), including with 'economies' such as the physical parts of the sharing economy (Bogdan 2016; Bradbury 2014) and the internet of things (Christidis and Devetsikiotis 2016; Rodriguez 2016).

There is a distinction between 'public' and 'private' blockchains, which exists as a matter of degree of decentralisation (Walport 2016, p. 35). The former 'public' blockchains can be read and updated by any node (within the scope of the code itself) while the latter only gives access to those known a priori, and thus have permission, to update the ledger (Deloitte 2016, p. 6). Public blockchains require tighter forms of security because, which also means that private blockchains tend to be faster and more secure (Walport 2016). A similar distinction exists between 'permissionless' and 'permissioned' blockchains (see Bargar 2016). The core focus of private blockchains has been the financial industry (Buterin 2015a).

[172] See Chapter 6 for a further illustration of blockchain as an institutional technology.

[173] The major facilitator of smart contracts, Ethereum, is discussed further as a case study in Chapter 6.

As we can see, blockchain is a potentially general technology for coordinating decentralised and trusted coordination. Blockchain technology, however, remains nascent because the entire scope of applications is yet to be entrepreneurially tested and discovered. Indeed, the process of entrepreneurial discovery, particularly for GPTs, is well known to involve a lengthy period of trial-and-error experimentation (Griliches 1957).[174] This is similar to the early stages of other GPTs such as computers (David 1990), where productivity improvements are were unclear were shrouded in entrepreneurial uncertainty. The following section examines the polycentric private governance structures in which blockchain entrepreneurs are currently seeking to discover the potential generalness of blockchain outlined in this section.

5.3. The diversity of blockchain innovation commons

5.3.1. Collaboration between blockchain proto-entrepreneurs

Different forms of collaboration within the blockchain and cryptography industry are not an entirely new phenomenon.[175] For instance, attempts to create a digital currency trace back to the early 1980s (see Bargar 2016; Chaum 1983). Blockchain technology emerged from this long-term effort to develop new decentralised governance mechanisms.[176] Yet while the early people within the blockchain and cryptography ecosystem focused almost solely on overcoming technical problems, the present economic problem surrounding blockchain technology, as we saw in Section 5.2, is primarily an entrepreneurial discovery problem. The entrepreneurial discovery problem, as we will see below, continues in a collaborative range of hybrid blockchain innovation commons. These can be understood as private governance mechanisms to facilitate the entrepreneurial process of discovering uses for blockchain

[174] The diffusion of steam power, for instance, took over a century and half to move from the steam-powered pump to textiles (Landes 2003).
[175] Collins (2009) proposes that this collaboration between actors in the blockchain ecosystem may prove vital for its success.
[176] For instance, communication between cypherpunks included mailing lists, one of which has almost every major cryptography figure passing through, including the elusive creator of Bitcoin, Satoshi Nakamoto (Cypherpunks 2016). The mailing list grew to 700 subscribers in 1994 and over 2,000 by 1997 (see Manne 2015).

technology. This section outlines the range and diversity of these blockchain innovation commons, and describes the dimensions along which they differ. My aim is not to provide a comprehensive map or snapshot of the blockchain ecosystem—both because there is no centralised organisational register of blockchain organisations and because the blockchain ecosystem is dynamic. My approach is discursive and based on self-definitions of blockchain entrepreneurs. Utilising an extensive search of existing literature, my analysis outlines the extent of institutional diversity of the organisations within which blockchain entrepreneurs are engaging. To organise my analysis, blockchain innovation commons are segregated into three main categories: (1) physical and short-lived blockchain innovation commons; (2) physical but long-lived blockchain innovation commons; and (3) online blockchain innovation commons. These examples of blockchain innovation commons are outlined below, before examining them across several institutional dimensions.

Conferences, workshops and hack-a-thons

Blockchain conferences, and their variants such as workshops and hack-a-thons, act as places to share entrepreneurial information, and are a central coordinating feature of the blockchain ecosystem.[177] These conferences occur in physical space but only over a short temporary period of time. Conferences regularly happen for less than one week, and often repeat annually. A selected list of examples of blockchain conferences can be found in Appendix A. For example, *DevCon* is a blockchain conference which began in 2015 and runs for 5 days at a time. The conference involves hundreds of presentations and collaborations between developers and academics, and self-identifies as focusing on the "the potential challenges of developing applications on top of the Ethereum platform," as well as the implications of blockchain on the Internet of Things, government, policymakers and investors. The priority of the conference differs each year depending on the core challenges of the industry at that time. For example, the theme of the 2015 conference was on privacy and scalability (Allison 2015a). At the 2016 conference, held in China, there were three main events (Migirov and Garcia 2016)—with one of the central slogans including "uniting the

[177] See CoinDesk (2017) for a list of 2017 events.

[blockchain] networks" involving hundreds of people demonstrating their "blockchain inventions" (see Willms 2016).

Many blockchain entrepreneurs also attend blockchain workshops. For instance, *Blockchain Workshops*, run by COALA, operates worldwide as a "collaborative community" between academics, lawyers, technologists and entrepreneurs, focusing on blockchain technology. There have been at least nine of these conferences, each of which has emphasised the upcoming challenges and opportunities of blockchain technologies. Attendees are encouraged to examine the impact of blockchains on the "current social, economic and political order" with the aim to "support the development and facilitate the deployment of blockchain based applications in today's regulatory framework" (COALA 2017). Another example of a blockchain workshop, *Scaling Bitcoin Workshops,* focuses more specifically on bitcoin applications. For instance, a recent pair of these workshops sought to overcome some technical details of bitcoin, especially the "difficult discussions of how to safely improve the scalability and decentralized nature of the Bitcoin network."

Hack-a-thons—blockchain entrepreneurs often engage in 'hack-a-thons'—also known as codefests, hack fests or hack days—involve gatherings of software developers to collaborate intensively over a short period of time (Briscoe and Mulligan 2014).[178] Hack-a-thons are regularly held or sponsored by software companies (Nandi and Mandernach 2016) and can last from a few days up to a week. While there are hack-a-thons with no specifically defined goal, there are also hack-a-thons with a defined focus, whether that be based on a software application type (e.g. mobile apps), a specific programming language (e.g. Ruby), within a company (e.g. Google), a specific cause (e.g. health applications), or a single application (e.g. blockchain). Hack-a-thons generally begin with presentations about the event before participants suggest possible ideas or proposals for projects before forming teams on their individual skills and interests. From here the 'hacking' begins, which may go for several

[178] Hack-a-thons are distinct from hackerspaces outlined in Chapter 4 because they are a temporary event that occurs over a short period of time.

hours, days, or even up to a week. This ends with teams generally presenting their work, often with a panel of judges selecting a winning team for prizes.

The conferences, workshops and hack-a-thons outlined here all represent examples of blockchain innovation commons, where proto-entrepreneurs come to coordinate information over the potential applications for blockchain technology. These hybrid entrepreneurial organisations facilitate the coordination of information between dispersed individuals who may have not otherwise met—thereby helping to overcome the structural uncertainty facing proto-entrepreneurs as outlined in Chapter 2. Indeed, this aspect of meeting people is emphasised in the literature: "where people who are not normally collocated converge for a few days" (Trainer et al. 2016), and may be used as a mechanism to discover real usable applications of blockchain, rather than abstract theories (Reutzel 2016). As Briscoe and Mulligan (2014) suggest, the collaboration, links, and networks generated through hack-a-thons often extend further than the short temporary focus of the event, often leading to business collaborations. In this way the hack-a-thon acts as a mechanism of proto-entrepreneurial coordination in the 'zero-th' phase of an innovation trajectory. When some potentially actionable value is discovered, however, the economising structure may shift from a hybrid fluid structure, such as a hack-a-thon, towards integration within a start-up firm. This process of group formation—that is, of group formation of complementary bits of proto-entrepreneurial information—has recently received academic attention.[179] The nature of team and group formation is similar to that in hackerspaces—except over a shorter period of time—and outlines the polycentric nature of these blockchain innovation commons. There are several examples of this process in the descriptions of the various hack-a-thons—for instance, the Chainsmith blockchain hack-a-thon in Dublin states that "the whole point is to network and learn; [people] encouraged to mingle and spread in different teams." One novel mechanism to overcome the hazards of the transaction costs of the collaborative process is Hackonomy, which uses blockchain technology itself to create a currency facilitating the collaborative process. This creates a

[179] For instance, see Lederman (2015, p. 80): "Some of the groups showed a tendency to break into sub-groups at different stages of the Hackathons."

"'frictionless' marketplace for start-up ideas, access to developer talent pools and code libraries" (Aitken 2016), coordinated through a new currency called Hacker Gold (hack.ether.camp 2017). The Hackcoin hack-a-thon series focuses on blockchain technology to explore different use-cases, "filling the gap between knowledge and action" and "introducing developers to the blockchain ecosystem." For example, the founder of Blockchain Labs, Bo Shen, says "the focus is on blockchain as a whole" and participants will "achieve a better understanding on the potential of Blockchain applications."[180]

Bitcoin Embassies and Centres

Rather than the temporary nature of a blockchain conference, workshop or hack-a-thon, other blockchain innovation commons are more permanent governance solutions to the proto-entrepreneurial problem—including Bitcoin Embassies, Bitcoin Centres and hackerspaces—which are outlined below (see Appendix B, C, D). Bitcoin Embassies are a global network of membership-based physical locations which aim to bring together "fellow likeminded cryptocurrency enthusiasts to learn about Bitcoin and cryptocurrencies."[181] Each Bitcoin Embassy, while fulfilling this basic role, maintains a high degree of autonomy in the projects and rules it wishes to run by. Indeed, the lead Embassy website suggests that "all locations operate autonomously and independently." The self-identification of many Bitcoin Embassies is to provide a place coordinating information for entrepreneurs and enthusiasts. For example, a Bitcoin Embassy in Amsterdam defines their role as providing "comprehensive and dependable knowledge relating to Bitcoin and the entire crypto-currency ecosystem." They also suggest they provide information about the interaction between formal state institutions and blockchains: "By encouraging dialogue between businesses, banks, the media, and regulators, The Bitcoin Embassy aims to provide guidelines about compliance with Dutch and European laws when dealing with cryptocurrencies." The Russian Bitcoin Embassy explicitly provides information for regulators in drafting legislation around bitcoin, while the Ukrainian Bitcoin Embassy

[180] This concept of focusing on "blockchain as a whole" is further developed in Chapter 6 with the focus on blockchain as a technology to develop the decentralised institutions of the 'crypto-economy'.
[181] A selected list of Bitcoin Embassies can be found in Appendix B.

prepared a document for the National Bank relating to regulation.[182] In addition to providing a location for meeting, collaboration, and the sharing of information in physical space, there are several other organisational roles which many Bitcoin Embassies provide. One prominent example is the Tel-Aviv Bitcoin Embassy in Israel who hosts a café and shop, a gallery, and regular events including a Cryptocurrency Innovation Lab, a consulting firm, a weekly web show, an open weekly panel of experts, and the Bitcoin Diplomatic conference. These are all different institutional mechanisms to coordinate information regarding the future applications of blockchain technology.

Bitcoin Centres are institutionally similar to Bitcoin Embassies, yet it is useful to distinguish the two. Bitcoin Centres are more closely described as incubators and consulting services, and are less focused on socialising. That is, Centres are more representative of innovation 'markets' than are bitcoin embassies, in the sense that more standardised innovation services are provided. For instance, one of the largest Bitcoin Centres in the world, in New York, "aims to be a place where developers can really take their software developments to town, now focusing more on its developers than its public." Compared to Embassies, Centres operate more as a structured co-working space. There is a greater focus on the physical resources in the space—such as the desks, internet connection and kitchen—and on learning resources to incubate start-ups. Centres have a greater focus on companies, and are often for-profit organisations. There is less focus on coordinating and connecting those entrepreneurs who come to the space, and more focus on providing resources and guidance through administration and control. There are also hackerspaces that focus specifically on blockchain, which were covered in Chapter 4. There are also other groups and consortia, such as the Muskoka Group, which aims to provide an "open platform for collaboration, education and innovation to help accelerate and drive the process of blockchain technology for industry, government and society" (Group 2017). Indeed, the

[182] This understanding of the interaction of blockchains with existing institutional structures is examined further in Chapter 6.

application of blockchains within the existing economic system has led to the creation of several consortia, such as R3 and Hyperledger.[183]

Online forums, message boards, and mailing lists

A range of online blockchain innovation commons are ongoing mechanisms to pool information with others, including online forums and mailing lists. As mentioned above, cypherpunks are motivated by the achievement of privacy through cryptography, and have coordinated since the 1980s. While their original mailing list has closed down, there are several current lists which can be traced directly back.[184] The original list "spawned not just commerce but an entire philosophy" (Rodger 2001), as a type of political-ideological crusade (Manne 2015). In 2008 it was on The Cryptography Mailing list which Satoshi Nakamoto published his white paper introducing bitcoin. As such, these people not only advocate the use cryptographic techniques to achieve their goals, but utilise this as a route to social and political change. Cypherpunks see themselves as being in a race with governments on who can outpace each other: as governments create more laws cypherpunks respond by writing more code. These forums hosted a wide range of discussions about cryptography and its implementation. This included technical discussion, but also political and philosophical discussion of the cypherpunk movement. For instance, the main Cypherpunks mailing list exists for "discussing cryptography and its effect on society."

5.3.2. Diversity in blockchain innovation commons

While each of these innovation commons identify as organisations providing a place where people can come to coordinate information and learn about opportunities for blockchain technology, there is a clear diversity in blockchain innovation commons. This section briefly examines some of the institutional differences between these blockchain innovation commons, with a focus on how each of the broad categories of blockchain innovation

[183] For example, R3 is a consortium of over 50 of the world's leading financial institutions explicitly to "work together to design and deliver advanced distributed ledger technologies to the global financial markets" (R3 2016)

[184] For example, the cryptography list (gryptography@matzdowd.com) and financial cryptography list (fc-announce@ifca.ai).

commons ranges in terms of hierarchy, control, and the autonomy of agents to create their own exchange relations with others.

In markets, there are relatively few hierarchies while firms are generally hierarchical organisations (see Section 3.2). The typical firm has a strict hierarchy, is planned from the top down, and interactions are based on authority relations between its agents. While generally there are few hierarchies within blockchain innovation commons, each of the blockchain innovation commons in the previous section differ based on the extent of formal explicit hierarchical control, albeit each of these differ within the lower range as compared to firms. One common aspect across blockchain innovation commons is that where hierarchies emerge they are based on reputational emergence, and thus participant discretion. For instance, in Embassies and hackerspaces, individuals who are more prominent within the space generally have a higher position in the hierarchy. In faires and workshops, on the other hand, there is a very low degree of hierarchy, partially because they are more temporary and there is less time for a hierarchy to emerge. For online forums, the degree of hierarchy depends on the openness of the group, and also on whether there is some form of reputation system in place, which may increase the extent to which some comments are more influential.

Blockchain innovation commons also differ in relation to the autonomy of proto-entrepreneurs to coordinate with others. That is, blockchain innovation commons differ by the autonomy to interact with other agents and share entrepreneurial information about market opportunities for blockchains. In markets, autonomous coordination is high, while in firms autonomy tends to be low, due to the extent of administrative control and monitoring. In blockchain innovation commons there tends to be a high level of autonomy. For instance, within Embassies there is an emphasis of socialisation and collaboration with others. Similarly for hack-a-thons, participants are encouraged to form teams with participants to work on projects based on their own interests and skills in proposed projects. In other types of blockchain innovation commons, such as Centers, there is less individual autonomy. The degree of autonomy for the individual proto-entrepreneur, as outlined in Chapter 2, may be

an important governance characteristic for solving the transaction costs of proto-entrepreneurial information (i.e. high levels of autonomous interaction may facilitate the process of non-price coordination and discovery).

Blockchain innovation commons differ on how goals are set. Within a firm goal orientation is generally explicitly controlled and directed through administrative control, while markets are based on autonomous or spontaneous goal setting. The blockchain innovation commons outlined above have a mixture between the two, but all tend to focus on the goal setting as emergent from individual entrepreneurs and the groups within which they interact. Across most blockchain innovation commons, goals are first generated through an emergent process of interaction, and then potentially later enforced through the creation of a hierarchy around that goal (i.e. through the formation of polycentric teams). In hackerspaces and Embassies, for instance, project groups may create their own goals—to work on a project together—from which some form of hierarchy may emerge within that group to overcome the hazards in organising that group.[185] The process of hack-a-thons, for instance, may begin with a set of projects, which are then voted upon, and then the losing participants merge into the projects of the winning groups.

Blockchain innovation commons also range on the degree and potential for opportunistic behaviour. That is, the extent to which the governance structure allows the detection and enforcement of opportunistic behaviour. Within innovation commons the capacity for opportunism varies greatly based on how they are governed, and the extent to which the governance structure itself exists to detect, punish and deter opportunism. Smaller blockchain innovation commons such as hackerspaces and Embassies have few participants, have multiple interactions with other participants, and exist in a physical place. This is more conducive to monitoring and thus guarding against opportunism, both because agents are more likely to know the reputation of other members (and thus change their exchange behaviour based on *ex ante* reputations with other members) and because punishments for opportunism may more effectively be monitored. Faires and workshops, on

[185] See also Chapter 4 on the private governance in hackerspaces.

the other hand, extend into the thousands of people, are temporary in nature, and interactions are often once off. Underlying this is the inherent trade of that a larger group of entrepreneurial agents simultaneously increases the potential for effective knowledge coordination—and thus solving the proto-entrepreneurial problem—but it also increases the scope for opportunistic behaviour by diluting monitoring through reputation. This trade-off relates to problems of scaling governance mechanisms centred on reputation within smaller hybrids up to greater scales.[186]

We can also classify innovation commons based on the number of participants interacting at once under the governance structure. Innovation commons tend to sit closer to firms in the sense that much of the coordination is multilateral, with the sharing and exchanging of information occurring with multiple agents at once. A higher number of people coordinating at once may relate to the uncertainty of agents in whom they should be exchanging with in the first instance—that is, effectively governed multilateral exchange may more effectively overcome the structural uncertainty inherent in proto-entrepreneurial information exchange. This degree of lateralness of exchange varies within innovation commons—for example, in hackerspaces and Centres there are fewer people working in small teams on projects, while the interactions at conferences and faires tends to be more multilateral. Note that this characteristic also changes based on the category of interacting within each organisation—hackerspaces often have classes where many people are involved, and online forums and communication systems vary by the number of agents within each group, forum, Slack group, and so on. The lateralness of a governance structure also relates to whether coordination is between two individuals, or more indirect between multiple individuals at the same time. This relates to the concept in evolutionary biology of direct versus indirect reciprocity.[187] That is, when undertaking in an innovation commons a proto-entrepreneur could either expect to reap their entire benefits from one exchange, or

[186] The recent emergence of platforms such as *Backfeed* (see Chapter 6) enable the creation of self-executing smart contracts, are precisely attempting to overcome this problem of scaling governance mechanisms dealing with opportunism. For instance, *Backfeed*, as described earlier, is centred on proof of value, which enables the scaling of contributions of individuals to the system.

[187] See Nowak and Sigmund (1998; 2005).

they may be exchanging with that individual to gain from someone else in the group. Such an indirect system of reciprocity may be effective for overcoming the structural uncertainty of coordinating proto-entrepreneurial information. Indeed, blockchain innovation commons tend to be very indirect in nature.

The emergence of blockchain innovation commons can be explained due to their comparative efficacy in overcoming the transaction costs of coordinating non-price information about blockchain opportunities. These private governance structures may economise on the transaction costs of proto-entrepreneurial discovery—both in terms of opportunism and in terms of spontaneous collaboration to deal with the uncertainties of coordinating information. Why might blockchain proto-entrepreneurs engage in a wide range of potential polycentric innovation commons? The diversity of blockchain innovation commons may be a result of the uncertainty surrounding the most effective transaction cost economising governance structure within which to solve economic problems. This notion of the subjective choice over a range of different governance structures, to solve a range of different innovation commons, is outlined further through the institutional possibility frontier (IPF) in Chapter 7.

5.4. Conclusion

This chapter analysed the hybrid innovation commons emerging around blockchain technology. Blockchain was selected both because it is nascent—in the sense it has only recently been developed—and because it is proposed to be general—in the sense there are potentially large gains from trade of engaging in proto-entrepreneurial coordination. The main contribution was to outline the diversity of hybrid governance structures—that is, blockchain innovation commons—within which blockchain proto-entrepreneurs are coordinating information to discover valuable uses for blockchain. These diverse governance structures of workshops, conferences and online forums can be understood as transaction cost economising structures to coordinate the non-price information necessary to discover the uses for blockchain technology (Chapter 2).

A range of secondary data and case studies showed that blockchain entrepreneurs are coordinating the information they require in polycentric innovation commons to reveal the generalness of blockchain technology. My focus was on three main types of blockchain innovation commons—faires and conferences, Embassies and Centres, and forums and message boards. While each of these types of organisation can be broadly classified as hybrid innovation commons, they can also be loosely differentiated across a number of institutional dimensions. I demonstrated that blockchain innovation commons differ based on their level of formal hierarchy or control, the degree to which agents may autonomously interact and exchange, how goals are generated and stated through a hierarchy, and the number of individuals coordinating at once. Each of these characteristics were discussed in relation to how blockchain innovation commons can be understood as transaction cost economising for the proto-entrepreneurial problem.

The diversity of blockchain innovation commons speaks to the proposition in Chapter 2 that the innovation process is made up of a range of economic problems, each of which have their own microstructures of transaction costs. While proto-entrepreneurs face an institutional choice over which institution they wish to solve their problem, those costs are fundamentally subjective (see Chapter 7). In this way, the diversity of the blockchain innovation commons outlined in this chapter can be interpreted as a form of institutional diversity to overcome the uncertainty of which form of blockchain innovation commons is transaction cost economising for the proto-entrepreneurial problem. That is, as a way to overcome the uncertainty of designing and choosing institutions to coordinate information.

This chapter, however, has also proceeded assuming that the institutional environment in which blockchain technology is applied is given. One of the core defining features of blockchain, however, is that it allows a process of institutional exit (secession) to create new institutional systems. Therefore, in Chapter 6 below, we can step away from the assumption of a given institutional environment for blockchain application, and examine the proto-entrepreneurial problem facing blockchain entrepreneurs as a problem of economic development of the institutional structures of the crypto-economy. The implication of the

following chapter, therefore, is to give a higher-order transaction cost explanation for the blockchain innovation commons described in this chapter.

Chapter 6: The private economic development of the blockchain crypto-economy

6.1. Towards entrepreneurial crypto-secession

Blockchain technology, which underpins the digital cash bitcoin, enables entrepreneurs to develop decentralised, trusted and secure institutions to order exchange (Atzori 2015; Swan 2015; Wright and De Filippi 2015). Blockchains are an institutional technology that shifts institutional boundaries by competing with firms, markets and governments (Davidson et al. 2016). The application of blockchain technology, therefore, isn't constrained to integration within the existing institutions of a territorial economy. Blockchain is also a technology for political exit—away from existing territorial political systems such as the law and courts—to create the new decentralised institutions of the crypto-economy. This process of secession is known as crypto-secession and it is an entrepreneurial process (MacDonald 2015). That is, for entrepreneurs to crypto-secede they must first discover the opportunities for how blockchain institutions can outperform other institutional alternatives. In this way the economic problem of crypto-secession and developing the crypto-economy remains a proto-entrepreneurial problem of coordinating dispersed information (Chapter 2). This chapter analyses this economic problem through the lens of new development economics (e.g. Boettke et al. 2008; Coyne and Boettke 2006; Leeson and Boettke 2009).

Analyses of entrepreneurial discovery generally take the territorial institutional environment as given (e.g. Baumol 1990).[188] From this perspective, entrepreneurs discover profitable market opportunities within the existing territorial institutions, such as the law. Entrepreneurship, however, is not constrained to discovering "productive-tier" technologies within the existing institutional structures, entrepreneurs can also act under uncertainty to discover new "protective-tier" institutional technologies (Boettke and Coyne 2009; Leca et

[188] As Leeson and Boettke (2009, p. 252) note: "Conventional discussions of entrepreneurship focus on entrepreneurship at a "lower tier" of economic activity— entrepreneurial activity within a given institutional framework." Indeed, this was the case in Chapter 5 above.

al. 2008; Leeson and Boettke 2009).[189] Institutional entrepreneurs seeking to discover protective-tier institutions face a higher constitutional level problem than entrepreneurs operating within, and constrained by, existing institutions (Kuchař 2016). This chapter focuses on the use of blockchain technology as a tool for institutional entrepreneurship—that is, through the process of crypto-secession—to entrepreneurially develop the new decentralised institutions of the non-territorial crypto-economy. While much of the analytical focus of institutional entrepreneurship has within development economics—where in developing countries entrepreneurs create institutional technologies that "restrict predation in the absence of a well-functioning government" (Leeson and Boettke 2009)—in this chapter I examine the economics of the development of the crypto-economy through using these same insights from new development economics. While Chapter 5 held that the institutional environment in which blockchain entrepreneurs were applying the technology was given—such as within banks backed by a legal system—this chapter steps away from this assumption and analyses the more fundamental service of blockchain as a tool for institutional secession.

My analysis is based on cases of institutional protective-tier entrepreneurship currently being undertaking by blockchain entrepreneurs. This analysis extends understanding of the economics of the entrepreneurial problem of crypto-secession by applying the theories of new development economics and institutional entrepreneurship. The implication is to re-frame the economic problem facing blockchain entrepreneurs and to provide a higher order explanation for the blockchain innovation commons outlined in Chapter 5. Unlike territorial developing nations, the lack of a centralised government within the crypto-economy implies that the discovery and development of the crypto-economy must be privately governed by what Easterly (2006) calls "searchers" (i.e. entrepreneurs) rather than "planners" (i.e. governments). From this perspective, the diversity of blockchain innovation commons outlined above are a form of polycentric private governance of the discovery of the

[189] As outlined in Leeson and Boettke (2009, p. 253): "Productive-tier entrepreneurship is "concerned with investments that improve productivity (innovation) and better service consumer needs (arbitrage)" while protective-tier entrepreneurship is "concerned with the creation of protective technologies that secure citizens' private property rights vis-à-vis one another (governance)."

institutions of the crypto-economy. That is, blockchain innovation commons are a type of private economic development facilitating the protective-tier entrepreneurship necessary to develop the crypto-economy.

This chapter proceeds as follows. Section 6.2 outlines the economics of using blockchain technology as a tool for secession as an economic problem of institutional entrepreneurship. This analysis is facilitated through case studies of blockchain secession to demonstrate that entrepreneurs must develop novel institutional mechanisms to facilitate exchange outside the scope of territorial governments. Section 6.3 uses the insights from new development economics to re-define the economics of the blockchain entrepreneurial problem as an economic development problem of non-price coordination of information about the complementarities of blockchain institutions. Section 6.4 concludes.

6.2. The decision to crypto-secede

An individual blockchain is a technology to process and store information in a distributed way. Blockchains enable more decentralised, public and secure exchange and coordination. In this way, blockchain is not just a new information communication technology; it is also a technology for creating new institutions to govern human exchange (Davidson et al. 2016). As Buterin (2015b) has outlined: “Blockchains are not about bringing to the world any one particular ruleset … they’re about creating the freedom to create a new mechanism with a new ruleset extremely quickly and pushing it out. They’re Lego Mindstorms for building economic and social institutions.” The entire suite of blockchain applications, each of which operate on their own rule systems or protocols, can together be described as forming a new decentralised economy called the crypto-economy. The crypto-economy does not have a geographic location, or centralised political structure or legal system. Rather, the crypto-economy is defined as using “cryptographic techniques to constrain behaviour (in place of using trusted third parties)” (Babbitt and Dietz 2014, p. 1). At first glance the crypto-economy appears similar to other techno-economic paradigms such as the peer-to-peer (Benkler 2006) or sharing economy (Allen and Berg 2014). The crypto-economy is unique, however, because it involves non-territorial political exit away from the institutions of the

state, such as the law and courts.[190] This section focuses on the political economy context of the entrepreneurial application of blockchain technology—by either integrating blockchains within existing institutions, or as a tool to politically exit from them. My aim is to provide a greater understanding of the economic problem of crypto-secession, which is then examined through the lens of new development economics in Section 6.3.

There are two broad types of blockchain application. First, blockchains can be integrated within the existing institutions and organisations of territorial economies (e.g. firms) while maintaining *public* protective-tier technologies (e.g. courts). New technologies are generally applied or integrated within the existing institutional architecture of the territorial state. The steam engine, for instance, did not seek to provide new enforcement or institutional structures; it was gradually integrated into the existing institutions of trade such as the courts, price mechanisms and private property. On the other hand, blockchains can be used by entrepreneurs as a technology for political exit or secession through the creation of *private* protective-tier technologies. Indeed, the unique feature of blockchain is that it allows non-territorial secession away from institutional systems. That is, while blockchains can be integrated within existing firms, markets and states, they can also be used to secede from political institutions as a private protective-tier technology (see Leeson and Boettke 2009). If the latter path is taken by the entrepreneur, they must discover blockchain cryptographic code as an institutional enforcement mechanism that does not maintain recourse to the institutions of territorial states. While the core focus of the present chapter is on the entrepreneurial problem of seceding—that is, of creating the new frontier crypto-economy—it is useful to begin by briefly outlining the political economy choice by the entrepreneur to secede or to integrate.

[190] The crypto-economy is best viewed as a *catallaxy*. Just as the organisation of industry is "dense network of co-operation and affiliation by which firms are inter-related" (Richardson 1972, p. 883), the crypto-economy is an order of networks and complementarities between individuals exchanging across different blockchains. The spontaneous ordering of crypto-economy exchange is generated by the complex and competing interactions of individuals and organisations operating within the constraints of blockchain technology. This draws heavily from the 'catallaxy' definition by (Hayek 1973 [2012]).

Entrepreneurs can use blockchain technology while maintaining resource to state-based public protective institutions. Blockchains can be applied within existing organisations and institutions in the shadow of existing state-based institutions of enforcement (Mattila 2016). Application of blockchain within the organisation of the financial industry, for instance, mainly achieves efficiency gains within the existing financial organisations of banking (e.g. clearing houses). Integrating blockchains focuses on efficiency gains of processes and systems to reduce cost while maintaining territorial states (Deloitte 2016). The impact of blockchain technology is to lower the transaction costs of ledger-generating activities for the firm, with the benefits of decentralisation remaining largely within the centralised organisational structure. For instance, within the financial sector, 'private' blockchains can be used while maintaining governance through the courts or other private orderings. Blockchain may also be used within government, especially where the state acts as a centralised intermediary for the coordination of information for the polity (Ølnes 2016). Examples of blockchain applications with government include listing and recording property titles, managing funding and royalties associated with state-sanctioned intellectual property rights, as well as democratic voting processes.[191]

One unique functional feature of blockchain—and that which I will argue later presents a higher-order entrepreneurial problem to solve—is the use of blockchain technology for political exit or secession. This process of crypto-secession is an entrepreneurial one, involving the development of self-enforcing institutions facilitated by cryptographic technology (MacDonald 2015). Entrepreneurs may apply blockchain in an attempt to push economic exchange away from centralised organisations towards decentralised economic systems (Buterin 2015b). Here, blockchains are not integrated into the public protective institutions, they compete with them. Where blockchains are comparatively effective at solving economic problems—that is, where they more effectively economise on transaction costs—individuals engaging in economic exchange will exit from existing institutions and

[191] See Allen et al. (2017) and Berg (2017) for an outline of the potential of crypto-democracy.

move towards decentralised private blockchain-based institutions.[192] This form of political rupture occurs because blockchain lowers the costs of exit by preventing opportunism, acting autonomously, and being entirely publicly visible yet secure (MacDonald 2015).[193] Blockchains maintain their institutional segregation or sovereignty in several ways. They may exist as autonomous agents or decentralised autonomous organisations. Because these applications are completely autonomous and self-executing, cannot be stopped by centralised entities. Secession is best described, as we will see below, as form of private protective-tier entrepreneurship, and is analogous to the economic problem of economic development.

Why would an entrepreneur decide to integrate or secede with blockchain technology? Integrating or seceding is an economic choice, with costs in both directions. One of the central costs of integrating blockchain can be understood from the motivations of discovering the technology itself. Blockchain was developed as a tool to decentralise hierarchical firms and states to overcome the centralisation of power (see Popper 2015). The initial intention of blockchain was as a technology to create new self-contained and self-executing institutions to replace centralised firms and states. The original intention of applications of blockchains such as smart contracts and decentralised autonomous organisations was to eschew all reliance on legal contracts (Buterin 2014). Integrating blockchains within existing institutions and organisations does not satisfy the underlying motivations of much of the blockchain industry. Indeed, as Mougayar (2016) notes, there was no mention in the original blockchain white paper of integrating within the existing world.

The motivation to crypto-secede can be understood through the institutional possibility frontier (IPF) within new comparative economics (Djankov et al. 2003).[194] The IPF framework

[192] The costs of integration within the existing political and regulatory process are subjective costs and the political context in which blockchains emerged suggest that the costs of integration were perceived to be high (see Chapter 7).
[193] One of the defining aspects of smart contracts on the blockchain is that they theoretically entirely eliminate contractual opportunism. See Chapter 5 for a broader discussion of smart contracts.
[194] This institutional possibility frontier (IPF) is further extended and applied in Chapter 7.

proposed that institutions trade-off the dual costs of disorder (private expropriation) and dictatorship (public expropriation). In this view, blockchain was developed to overcome the costs of dictatorship from governments, and disorder from large firms, which are ever-present within modern market economies. In particular, the cypherpunks who developed blockchain sought to lower the social losses from disorder by developing decentralised yet trusted ledgers that reduced the need to trust and rely on intermediaries. From this perspective it is clear that integration of blockchain technology within existing political economy structures does not necessarily alter the centralisation of power, and may even make the processes of coercion and control more efficient by lowering costs. This is why the idea of using blockchain to integrate within firms and states has been described as "ludicrous" (Ametrano 2017).

There are additional barriers to integrating blockchain rather than just technical difficulties. In addition to technical difficulties, as is with all new technologies, regulatory uncertainty and hostility remain problems within the application of blockchain.[195] Incumbents can lobby to defend their territory and draw blockchain technology within existing regulations. This notion of regulatory resistance with new technologies is well known in other technologies (see Tapscott and Tapscott 2016) including when regulators are captured by incumbents with entrenched interests who suffer future losses (see Juma 2016). Combining this understanding of political resistance with a broader 'precautionary principle' adopted by governments shows that the institutional costs of integration with blockchains are increased (Thierer 2014).[196] Crypto-secession not only lowers the costs of dictatorship—by relying on code rather than the discretionary power of governments—but can also reduce some of these political economy costs of entrenched interests. The pseudonymity and decentralised nature of crypto-secession may substantially increase the transaction costs of rent-seeking from others seeking to hold back blockchain technology.

[195] As Harwick (2016, p. 579) note: "In addition to the intrinsic network hurdles, regulatory uncertainty and hostility also constitute an extrinsic hurdle for intermediation in a way that they do not for the protocols themselves."

[196] The precautionary principle, according to Thierer (2014, p. 1), "refers to the belief that new innovations should be curtailed or disallowed until their developers can prove that they will not cause any harm to individuals, groups, specific entities, cultural norms, or various existing laws, norms, or traditions."

One of the benefits of non-territorial crypto-secession, in this view, is the development of a 'permissionless innovation' environment where entrepreneurs can elaborate and improve applications through trial and error with few constraints (Thierer 2014, 2015). While 'permissionless innovation' is where agents are free to innovate without first having to ask for permission from the state, the unique aspect of blockchain permission is that it doesn't stem from changing the culture of government regulation, but rather by first developing a new jurisdiction with no coercive sovereign state.[197] The institutional choice to crypto-secede, therefore, can be seen as new form of 'technological civil disobedience' or even 'spontaneous private deregulation' (Thierer 2016) necessitated by the regulatory pressures on blockchain (and on governance more broadly).[198]

Crypto-seceding to the crypto-economy, however, is not institutionally costless. Crypto-secession comes with its own set of costs. In particular, there are deeper entrepreneurial costs of crypto-secession, relating to the discovery and development of private governance enforcement mechanisms in order to lower the transaction costs of exchange and to comparatively outcompete the institutions within territorial economies. While on one hand crypto-secession partially overcomes the resistance within the reigning political environment or regulation, on the other hand the additional cost is an entrepreneurial challenge of discovering the crypto-economy. The following examples outline some of the core challenges of entrepreneurially crypto-seceding. These examples precede outlining this crypto-secession proto-entrepreneurial process as facing a similar economic problem to that within 'new development economics' theory.

[197] One drawback from this, however, is when those experimental rules created within the crypto-economy prove ineffective (for instance, a failed smart contract), and agents attempt to fulfil those agreements using the conventional institutions (i.e., courts) of the formal economy. This remains an ongoing legal issue.
[198] Following Thierer (2016), civil disobedience "represents the refusal of innovators (individuals, groups, or even corporations) or consumers to obey technology-specific laws or regulations because they find them offensive, confusing, time-consuming, expensive, or perhaps just annoying and irrelevant." Of course, only time will tell whether territorially based states will, or indeed can, halt or slow the development of blockchain technology by constraining it through regulation. Prominent examples of this include the banning of bitcoin mining and use in Venezuela, or subtler political uncertainty on the future of blockchain regulation.

Take the example of OpenBazaar, which is a peer-to-peer decentralised marketplace, based on blockchain technology, which can be described as a form of crypto-secession.[199] Because there are no restrictions on what can be traded on the platform (OpenBazaar 2016) it has been described as an 'anarchist eBay' (Fox-Brewster 2016). The entrepreneurs behind OpenBazaar sought to develop a decentralised and anonymous marketplace where individuals can trade securely using digital currency bitcoin using blockchain as the core governance mechanism. What entrepreneurial problem did these entrepreneurs have to overcome? To create a decentralised marketplace, OpenBazaar had to form trusted institutions that verify and secure pseudonymous trades without recourse either to state-based institutions (e.g. courts) or indeed any other centralised organisation (e.g. a tech firm). This required the discovery of two main governance mechanisms to economise on transaction costs—a decentralised enforcement mechanism and a decentralised reputation mechanism. The central institutional governance mechanism of OpenBazaar involves two parties (buyer and seller) creating a contract which is sent to a third party (the moderator) who witnesses the contract and creates a multisig bitcoin account.[200] While there are no fees on the system, individuals can decide to pay for dispute resolution, and the third party can receive funds through tips. As a decentralised reputation mechanism, OpenBazaar originally employed a web of trust (WoT) model but have since moved on to a transaction-based reputation model where the reputation of an individual is a weighted average of their transaction ratings (Sanchez 2015).

Ethereum is a publicly available custom-built blockchain and platform facilitating the creation and decentralised execution and governance of peer-to-peer smart contracts, centred on a new currency called Ether. The creation of Ethereum was one of the first major extensions beyond the bitcoin protocol and sought to bring more development flexibility through providing its own Turing complete language. The aim of Ethereum is to decentralise

[199] There were already over 12,000 listings one month after its launch (BazaarBay 2016), and in 2016 had been downloaded over 100,000 times (O'Connell 2016). Further, the company has received several rounds of substantive venture capitalist funding, including prominent Andreessen Horowitz and Union Square Ventures (Allison 2015b).

[200] This is centred on the idea of Ricardian contracts, where the multisig account requires two of three people to sign before the bitcoin is released.

the internet, in the way the internet was "originally intended to work", by developing new decentralised peer-to-peer institutional systems. The role of Ethereum is as a broad platform on which individuals can create their own systems to crypto-secede. Put another way, Ethereum is a crypto-entrepreneurial platform that aims to drive down the transaction costs of exchange for those who wish to crypto-secede, where the code is analogous to a judge in a court (Reitwiessner 2016). Ethereum plays an important role in the crypto-economy because it enables the secure creation of online markets, programmable transactions, and many other functioning applications (Popper 2015). The niche of Ethereum is the development of a custom-built blockchain that enables other developers to develop applications on it—therefore enabling the creation of democratic autonomous organisations, which is a virtual organisation run by code. Ethereum provides a unique addition to the blockchain ecosystem because it enables other agents to run smart contracts on this blockchain based on a tradeable digital token known as Ether. Ethereum also has a built-in 'Kickstarter' or crowd funding function, enabling potential entrepreneurs to source funds for their project on Ethereum using the Ethereum blockchain itself.

Another example of crypto-secession, Backfeed, applies blockchain protocols to coordinate individuals online through economic tokens and reputation scores. The platform facilitates crypto-secession to decentralized and open source collaboration between individuals without the need for hierarchical systems. The novel aspect of the system is enabling the distribution of value through spontaneously emerging networks of peers (Davidson et al. 2016) based on scaling commons-based principles through blockchain technology. When combined with blockchain technology—including the smart contracting capabilities of Ethereum as outlined above—Backfeed enables the creation of spontaneously emerging networks of peers. Agents in the network receive their decision making power based on the value they contribute to the network which is determined other agents in the group.[201] The motivation or inspiration of the platform is from nature, where various species have developed complex social orders based heavily on 'commons'

[201] The distributed private governance system of Backfeed aims to replicate stigmergic coordination found in nature in the more complex case of human interactions and organisation.

principles (Ostrom 1990). The Backfeed system, in other words, aims to scale commons-based meritocratic rules through crypto-secession to a new value system not determined by a manger, but by peers.[202] Scaling cooperation in the commons can be troublesome largely because of the loss of 'reputation' and its role as a proxy for contributions to the group. Backfeed overcomes this problem through a 'proof-of-work' system where the value of a given contribution is evaluated using the contextual information of peers.[203] Those who make contributions which are considered valuable to others will increase in reputation, and effectively evaluating other's contributions in line with the group also increases your reputation. This reputation score is non-transferable and gives a level of influence to that agent.

The entrepreneurial problem of crypto-secession requires the discovery of self-enforcing and self-executing institutional mechanisms to outcompete territorial institutions. In this view crypto-secession is a form of institutional entrepreneurship to economise on the costs of disorder using cryptography. What is clear from these examples of crypto-secession is that they are what Leeson and Boettke (2009) refer to as "protective-tier" institutional entrepreneurship. That is, the entrepreneurial examples of OpenBazaar, Ethereum and Backfeed represent the discovery and application of technologies to create institutions to order human exchange. Furthermore, these examples show the entrepreneurial challenge of discovering trusted decentralised private "protective-tier" institutions of the crypto-economy. In the following section these examples are interpreted within the context of the new development economics literature, which sheds light on the broader proto-entrepreneurial problem facing those in the blockchain industry as they seek to develop the complementary institutions of this new decentralised society, the crypto-economy.

[202] One of the major problems of collective action is its ability to be scaled. Indeed, one of Elinor Ostrom's design rules focused on the size of the group, and so too did the work by Mancur Olson (1965 [2009]) on collective action. The size of the group matters because as the number of participants grows so too do the transaction costs associated with cooperating. More participants make the conventional mechanisms of collective action—particularly reputation based interactions and costly signalling—begin to fall and so too does the effectiveness of governance.

[203] Rather than a *proof-of-work* system (such as in Bitcoin), which relies on actions which are algorithmically quantifiable and verifiable, *Backfeed* employs a *proof-of-value system*, which utilises the local and distributed contextual knowledge of individuals to discover the value of contributions.

6.3. The crypto-economy as an economic development problem

Given that many blockchain entrepreneurs are crypto-seceding to the crypto-economy—such as the examples of OpenBazaar, Ethereum and Backfeed outlined above—this section applies the theoretical understandings from 'new development economics' to better understand the economic problem of discovering and developing the decentralised crypto-economy. What we see is that the economic problem facing blockchain entrepreneurs is analogous to the new development economics understanding of coordinating knowledge to discover complementary "protective-tier" institutions. Rather than this process occurring hierarchically through government planners, such as may be the case in territorial nation states, in the case of the crypto-economy—given the lack of government—this process may be occurring through private governance structures, such as in the blockchain innovation commons outlined in Chapter 5. Therefore, the application of new development economics below provides a further explanation of the polycentric private orderings as a type of private economic development, thereby further expanding our understanding of the private governance of entrepreneurial discovery. We can first begin, however, by tracing the history of development economics.

The arc of thought in the economics of development ranges from the mainstream approaches of the mid-twentieth century 'old development economics' (e.g. Chenery and Strout 1966; Domar 1946; Harrod 1939) to the mainline approaches of 'new development economics'. The resurgence of the mainline tradition of economics brought new perspectives to the forefront of development economics. Some of the drivers of economic growth came to include the complexity, stickiness and path dependence of both formal and informal institutions, the epistemological limits of allocating investment through centralised governments, and the importance of bottom-up entrepreneurial discovery for overcoming uncertainty (e.g. Bauer 1976; Boettke et al. 2008). Given that development comes through economic growth, theories of economic growth are also theories of economic development.[204] When development economics emerged as a sub-discipline in the 1950s

[204] For example see High (2009) on Holcombe (1998).

(see Engel 2010), the sources of economic growth centred on the allocation, investment and accumulation of capital (e.g. Domar 1946; Harrod 1939; Rostow 1990; Swan 1956).[205] As the story went, given that developing nations had a savings-investment gap (Chenery and Strout 1966) the key to economic development was through increasing savings. That is, the source of economic growth for developing countries was seen to come through increased foreign aid.[206] The relevant question for a developing country was, first, whether they saved enough to invest, and second, how that gap could be ameliorated through aid or intervention. This connection between savings, capital investment and growth is the key reason for the close relationship between development economics and government intervention.

One example of the analytical approach of this old development economics is need for a "big push" of state-led investment (see Murphy et al. 1989; Rosenstein-Rodan 1943, 1961; Sachs and Warner 1999). While the big push theory also attributed underdevelopment to insufficient investment, its unique addition was that economic development requires several coordinated investments in different sectors of the economy because the marginal product of investments was higher when made simultaneously (i.e. investments exhibit complementarity).[207] Because it was theoretically irrational for individual agents to privately coordinate investment, countries would become stuck in a second-best poverty trap. A big push required not just foreign aid to meet the minimum level of investment, but also some centralised government planning of those investments (see Jomo and Reinert 2005). That is, there was a problem of where to coordinate and allocate those investments within the economic system.

The new development economics outlined and sought to remedy many shortcomings of this capital-centred and planning-centred approach to economic development. Indeed,

[205] See footnote 1.

[206] As Chenery (1967, p. 268) notes in the first paragraph: "For most underdeveloped countries, foreign assistance is already a critical source of development finance and one of the main hopes for accelerated growth in the future."

[207] Complementary investments are investments which raise any potential profits (or generally, success) from the use of a new technology (that is, an increase of investment A leads to an increase in the productivity of investment B). As Murphy et al. (1989, p. 1004) note: "spillovers give rise to the possibility that coordination of investments across sectors—which the government can promote—is essential for industrialization"

William Easterly (2006) referred to the concept of the big push as a "legend". Focusing solely on investment and capital accumulation ignores the reality that information is imperfect and economies are complex. How will investments, including through aid, be coordinated and allocated to their most efficient use? As such, many criticisms of 'old development economics' revolve around the idea that while a minimum quantity of investment may be a necessary condition for development, it is not a sufficient one:

> The allocation of investment, however, unlike the allocation of given stocks of consumer goods (equilibrium of consumption), or of producer's goods (equilibrium of production) is necessarily an imperfect market, i.e. a market on which prices do not signal all the information required for an optimum solution. Additional signalling devices apart from market prices are required. (Rosenstein-Rodan 1961, p. 2)

As outlined in Chapter 1 and applied elsewhere in this thesis, throughout the 1980s there was a resurgence of fields of mainline of economic thought (see Boettke 2007; 2012) and a range of historical failures of centralised planning, such as the Soviet Union. Combining these advances with the falling of the neoclassical consensus led to the realisation that investment and centralised planning wasn't the standalone key to development (Coyne and Boettke 2006). It became increasingly clear that the study of economic development needed to incorporate institutions and entrepreneurship. This mainline understanding of knowledge coordination and entrepreneurial discovery were the starting point for what has become known as the 'new development economics', which "builds directly on the voluminous body of research that examines the emergence, operation, and effectiveness of spontaneously ordered institutional arrangements" (Boettke et al. 2008, p. 333). New development economics emerged on a different set of analytical principles and intellectual traditions (Fine 2006; Boettke et al. 2008; Coyne and Boettke 2006; Rodrik 2008), following advances in entrepreneurial theory (Kirzner 1978a, 1982, 1997), new institutional economics (North 1990; Williamson 1975, 1985b, 2005), and Austrian economics (Kirzner 1978a; Mises 1949). In particular, institutional analysis, governance and knowledge coordination were brought to the foreground of the economics of development and growth (e.g. Acemoglu and Robinson 2010, 2012; Nabli and Nugent 1989). This new understanding of economic

development sat in tension with the old growth economics, returning development economics back to the mainline of economic thought (Ruttan 1998), which itself has always been concerned with growth, and thus development. The implication of the new development economics was that economic development was no longer driven solely by investment, allocation and central planning, but emphasised how distributed and dispersed contextual information can be coordinated through institutions and put to use to meet human needs (Glaeser et al. 2004).

Persistent critiques of the role of government in economic development slowly severed the connection between central planning and development. Effective state-led investment requires both an omnipresent state (to overcome the complementarity and allocation of investment problem) and an omniscient state (to know those sectors or investments which are necessary for success). Governments are made of individuals, who are neither omnipresent nor omniscient, and therefore widespread intervention can destabilise existing institutions and investments. One prominent critic of this centralised approach to development was Peter Bauer (1976). For Bauer, the central problem with foreign aid was a knowledge problem: how could a planner ever hold the necessary information for aid to be successful and effective? This implies that development was a discovery problem and the determinants of development had been "underrated, or even ignored, in most of the development literature … These determinants are not among the familiar variables of economic analysis; they are not readily quantifiable; and they cannot easily be manipulated by official policy" (Bauer 1976, p. 80). Bauer's development economics analysis incorporates many of the core methodological understandings of mainline and Austrian economics—of radical uncertainty, knowledge coordination, and heterogeneous capital combinations—which stem back to Menger (1871) and Böhm-Bawerk (1891), as well as more recent scholars included Mises (1949) and Hayek (1945). The work of Austrian economists—particularly relating to the market mechanism and the role of entrepreneurship—re-introduced the idea of privately ordered spontaneous institutions into the economics of

growth. The entrepreneur became the driving force of the economic system—a premise which is now widely accepted within the development literature (Kasper and Streit 1998).[208]

It's largely through the Austrian conception of development economics where the analogies with the economic problem of the crypto-economy surface. In Austrian development economics, development comes from entrepreneurial discovery of the complementarity of various combinations of heterogeneous capital (Leeson and Boettke 2009; Manish and Powell 2015). Particularly because blockchain technology is extremely fast moving (Atzori 2015, p. 5) entrepreneurial discovery of the institutions of the crypto-economy occur under fundamental and radical uncertainty (see Lachmann 1976; Shackle 1992).[209] Blockchain entrepreneurs require information about future changes in the state of the world, business models, financing, timing, and consumer demand, competitors, failed ventures, and so on. The development of the blockchain crypto-economy, like all entrepreneurship, is a knowledge coordination problem, and, as we will see below, is analogous to the economic problem facing territorial developing economies as examined in the new development economics literature.

The notion that a new industry, and the entrepreneurs within it, face a different set of challenges than a completely formed industry is not a novel concept (e.g. Aldrich and Fiol 1994). Blockchain proto-entrepreneurs, in the earliest stages of the new industry, can be seen to be navigating "an institutional vacuum of indifferent munificence" (Aldrich and Fiol 1994, p. 645). However, on deeper inspection, and in the context of the findings in the previous section of the entrepreneurial challenge of crypto-secession, there are multiple economic problems facing the blockchain entrepreneur. Indeed, in the same way that entrepreneurship manifests itself in many ways in the formal economy—from starting a new corner store, developing a new smart phone application, or arbitraging foreign exchange markets (Boettke and Coyne 2009; Parker 2005)—blockchain entrepreneurship

[208] This is in contrast to the earlier old development economics, where Leff (1979, p 47) explains how "since approximately the 1970's, the topic of entrepreneurship has virtually disappeared, suggesting that in some sense the problem has been 'solved'."
[209] See Section 2.2 for an outline of the structural uncertainty facing entrepreneurs.

manifests itself in many different ways (Arthur 2009; Ziman 2003). On one hand, when blockchain entrepreneurs *integrate* they must look to the institutions of the formal economy for information over price points, products, opportunities, complementary investments, and so on, which, when arranged in the right order, will define market opportunities for blockchain integration. On the other hand, when blockchain entrepreneurs *secede* to the crypto-economy, they face a different higher-order entrepreneurial challenge.

It is from this perspective of crypto-secession that we can see the connection with development economics—as blockchain entrepreneurs seek to discover, create and test novel institutional structures and mechanisms that act as the core ordering principle of governance in this new frontier society. As we saw above, crypto-secession requires the discovery of self-contained and self-executing mechanisms of blockchain governance that are not embedded in the existing institutional environment. Crypto-entrepreneurs lack precedent over the institutional structure in which they operate and are seeking to change. As such, the main proposition here is that the entrepreneurial process of crypto-secession is best viewed not just through the lens of a new industry, but rather from the perspective as a developing the protective-tier of a new economy.

As noted in the introduction, Leeson and Boettke (2009) define two-tiers of entrepreneurship which are necessary for economic development: (1) the discovery of productive technologies necessary to better support human needs; and (2) protective technologies that are institutional mechanisms to secure property rights and trade. While the former occurs within a given institutional environment—which is the conventional view of entrepreneurial activity—the latter does not take the institutional environment as given: the institutional environment itself must be discovered by entrepreneurs. While integrating blockchains is more accurately a problem of productive-tier entrepreneurship, crypto-secession to the crypto-economy is better represented as a protective-tier economic problem. What is this economic problem of crypto-secession?

Crypto-entrepreneurs must develop a 'protective-tier' of institutional solutions that outcompete existing state-based institutions. Indeed, the development of the crypto-economy is perhaps the most explicit form of protect-tier entrepreneurship yet, or at least amenable to analysis, given that there are no existing protective institutions, and that those institutions must be publicly secure and verifiable, as well as trusted. As the cases of crypto-secession in Section 6.2 revealed, crypto-secession requires the discovery of institutions necessary to enforce exchanges of information on distributed and secure public ledgers. For the crypto-economy, the protection of property rights (and the values of that property) must first be determined through entrepreneurial application and discovery of codes. This economic problem faces higher structural uncertainty than integration because crypto-entrepreneurs must discover an entirely new set of institutions which is detached from the formal economy. This aligns with Williamson's hierarchy of institutions and entrepreneurship, as outlined in Bylund and McCaffrey (2017). At deeper levels of institutional entrepreneurship—of shaping public affairs and institutions—entrepreneurs face a higher level of entrepreneurial strucutral uncertainty. Indeed, to crypto-secede and develop the crypto-economy requires its own knowledge structures, enforcement, and incentive mechanisms built in. The institutional environment cannot be taken as given, it must be created.

To develop the crypto-economy, entrepreneurs not only have to discover the enforcement mechanisms of each blockchain application, but also the most basic institutional structures that connect those applications together. In this way crypto-secession requires the discovery of blockchain *complementarities*. Blockchains exhibit complementarity both with existing technologies (e.g. the internet of things) and institutions (e.g. firms and government), but also with other heterogeneous blockchains within the crypto-economy. Capital goods are heterogeneous and exhibit complementarities in the sense that they satisfy different plans for human actors. They also have "multiple specificity" in the sense that capital can be put to use in different plans (Lachmann 1956).[210]

[210] As Lachmann (1956, p. 114) outlines, multiple specificity implies that "their mode of use changes as circumstances change."

The range of blockchains within the crypto-economy similarly exhibit heterogeneity and multiple specificity. Blockchain technology, as demonstrated in the previous section, can be applied to multiple problems, and they can also be combined and used in multiple plans. The entrepreneurial development task, then, is to ask how these bits of capital will be structured to form the crypto-economy. This is an entrepreneurial problem requiring discovery of how each potential application for blockchain (for instance, utilising bitcoin) will fulfil a need, yet also discover how the other blockchains within the crypto-economy will interact with the new institution. Blockchains also exhibit complementarity with other blockchains within the crypto-economy because the technology multiplier applies on inter-blockchains interactions (an investment in one application of blockchain will alter the return of a different blockchain). Multiple decentralised processes of blockchains in the crypto-economy can interact, which lowers the cost of additional blockchain applications (i.e. a multiplier effect).

The entrepreneurial problem facing blockchain entrepreneurs involves simultaneously satisfying the discovery of both the protective-tier and the productive-tier. For example, as we saw above, the decentralised marketplace OpenBazaar is a complementary application to the cryptocurrency bitcoin. The success of a remittances business not only relies on transferring value between different individuals, yet also requires exchanges in each jurisdiction. The complementarities between these protective-tier technologies, however, are yet to be fully discovered. Similarly, BitNation is another example of secession using blockchain technology. Indeed, the platform explicitly seeks to replace many of the tasks of government. The BitNation platform self-describes as providing “all the services traditional nations state governments provide, or are supposed to provide” (BitNation 2016). This is an attempt at crypto-secession to replace the governance functions of the traditional nation state. BitNation serves as a collaborative platform for its users to develop their own governance functions. One of the major features is in providing a ‘one stop governance shop’ for its users in response to the worry that, without nation states, there will be many

privately competing providers.[211] The *BitNation Pangea* has tried to create a form of self-enforcement (Marty 2014) and has been explicitly tied with the establishment of an entirely novel virtual nation that directly competes with nation states.[212]

The process of discovering the structure of the protective-tier technologies of the blockchain crypto-economy, however, requires non-price coordination of distributed Hayekian information about potential blockchain applications—it is a proto-entrepreneurial economic problem as outlined in Chapter 2. In some ways this is similar to the entrepreneurial problem of developing a territorial nation state, as has been the focus in the new development economics literature. There are, however, two critical differences between the economic development of a territorial economy and the economic development of the non-territorial crypto-economy. First, the crypto-economy has few existing institutional systems. While development economics tends to recognise that the existing indigenous institutions matter—including for instance skills, culture and conventions—this is unique for the blockchain ecosystem because there are no clear existing institutions.[213] Indeed, crypto-secession could be understood as a private effort to 'shock' and overcome the path dependence of existing sovereign institutions (Boettke et al. 2008).

Second, there is no central planning authority to guide the discovery of institutions. While, as discussed above, the economics of development shifted from a focus on capital and investment towards institutions and change, the question of precisely how those institutions change given issues such as stickiness and path dependence remains unanswered. Recent efforts include the use of private cities (e.g. Allen 2015; Narain 2009; Rajagopalan and Tabarrok 2014) and charter cities (Fuller and Romer 2012), both of which are attempts to push significant shifts in institutional mechanisms through developing

[211] The Pangea acts as a "decentralised P2P client, with encrypted communication, ID and reputation system, dispute resolution and a DApp Library with an API, so people can create and sell their own Do-it-Yourself Governance Apps and DApps" (BitNation 2016).
[212] This development is informed by "substantial insights on what components of government are considered important by people" (BitNation 2016).
[213] See Coyne and Boettke (2006) for a discussion of the importance of indigenous institutions.

special economic zones. However, such territorial special economic zones require state-based political change. Crypto-secession, on the other hand, requires no sovereign permission to change institutions—it is a privately driven entrepreneurial process—but can still be viewed through the same lens of changing existing institutions. The entrepreneurial process of discovering the institutions of the crypto-economy, however, does not occur within an institutional vacuum. Blockchain entrepreneurship, like all early-stage proto-entrepreneurship, requires non-price coordination of distributed information about market opportunities. Indeed:

> Economic development is an eternal process of innovation, in which economies make progress as they discover a better combination of activities, or a better system of coordination. The discovery of any new system, by its nature, cannot be designed or even anticipated; all we can do is to design a better search mechanism or discovery procedure. (Matsuyama 1997, p. 149)

When William Easterly (2006) criticised the old development economics paradigm he shifted attention away from "planners" towards "searchers" in directing this development process. Searchers are entrepreneurs and are necessary because of the inherent epistemological challenges in economic development. The blockchain crypto-economy does not have a central planner—it is entirely governed by the consensus of the nodes maintaining the system through various blockchain protocols. Although attempts have been made to create quasi-state bodies, such as the Bitcoin Foundation, to coordinate some aspects and facilitate debates the crypto-economy itself has no sovereign. This is despite the fact regular debates within the blockchain and bitcoin community concern the most effective mechanisms to maintain the robustness and efficiency of the crypto-economy (e.g. see van Wildum 2016).

Because there is no centralised sovereign state within the crypto-economy, the entrepreneurial development process must be *privately governed* by 'searchers' rather than *publicly governed* by 'planners'. The implication of having no sovereign state within the crypto-economy—given that it is more accurately described as having sub-components entirely of sovereign states—is that the development of the crypto-economy must entirely be a bottom-up 'searching' process. While the new development economics literature has previously examined how the private governance of development may be optimal (i.e.

development under anarchy), as compared to poorly performing states (Leeson and Williamson 2009), the discovery and development of the blockchain crypto-economy is unique because by definition it must be privately governed.

Entrepreneurial coordination within the blockchain ecosystem requires comingled discovery of protective-tier technologies. Blockchain entrepreneurs are not only concerned with their own market opportunity, but are also concerned with how other agents are acting on their opportunities. The question, then, is how blockchain entrepreneurs are solving this problem. Initial evidence suggests that blockchain entrepreneurs are collaborating and coordinating in private governance mechanisms. These blockchain innovation commons, such as Bitcoin Embassies, hackerspaces and conferences, involve entrepreneurs pooling and coordinating non-price information about discovering and developing the crypto-economy under collective action rules.

Through the findings of this chapter, the collaborative nature of the blockchain ecosystem can be viewed as a robust system of private institutional controls in order to develop the crypto-economy. In this way there are in fact two levels of protective-tier technologies within the development of the crypto-economy. The lower level of the protective-tier is the collectively developed rules within innovation commons where blockchain entrepreneurs govern non-price information necessary to apply blockchain technology. This level of protective-tier technologies include the reputation mechanisms, signalling and nested hierarchies of rules that constitute Bitcoin Embassies, hack-a-thons, online forums and mailing lists.[214] Each of these involve protective-tier entrepreneurship in the sense that proto-entrepreneurs must overcome the hazards of coordinating non-price information of which the state is comparatively ineffective at protecting. The higher level of protective-tier technologies are the technologies that were the main body of this chapter, which enable individuals exchanging within the crypto-economy to enforce and coordinate their economic activities outside of territorial nation states—that is, entrepreneurial discovery to secede.

[214] See Chapter 5.

6.4. Implications and conclusion

This chapter enquired into blockchain entrepreneurial discovery where the institutional environment was no longer taken as given. That is, examining how blockchain entrepreneurs are discovering the complementary institutional structures to form a new decentralised frontier society, the crypto-economy. The implication of this was to provide a higher order explanation of the blockchain innovation commons in Chapter 5. The central ordering principle of the crypto-economy is using blockchain technology to facilitate economic exchange through decentralised self-executing and self-enforcing institutional mechanisms. My analysis began outlining the entrepreneurial choice to either integrate blockchains into institutions of the territorial state, or to undertake a process of political exit and crypto-secession to the crypto-economy. Through several case studies of crypto-secession we saw that blockchain entrepreneurs are currently developing the decentralised institutional mechanisms necessary to define value systems and enforce trade outside of the scope of formal state-based institutions. In this way, the economics of the entrepreneurial problem of crypto-secession to the crypto-economy is analogous to the insights of 'new development economics', and the Austrian approach of focusing on entrepreneurial discovery of complementary combinations of heterogeneous capital.

There were two main findings from theoretically connecting new development economics and the entrepreneurial problem of the crypto-economy. The first was that the economic process of crypto-secession is analogous to an *economic development problem* of 'protective-tier' entrepreneurship (Leeson and Boettke 2009), which requires discovering the institutional mechanisms of the crypto-economy through entrepreneurial coordination of dispersed non-price information. Crypto-entrepreneurs cannot take the institutional environment as given, they must create it. The second was that, given there is no over-arching sovereign state to coordinate and direct investment within a decentralised crypto-economy, the process of economic development of the crypto-economy must be *privately governed* by entrepreneurs ('searchers') rather than by governments ('planners'). The implication of these findings is to provide a further explanation for the diversity of

blockchain innovation commons in Chapter 5 as mechanisms of private entrepreneurial development of the crypto-economy through non-price coordination.

In blockchain innovation commons, crypto-entrepreneurs can engage in non-price coordination over the information necessary to make coordinated complementary investments in blockchain technologies. It may be that this heterogeneity of hybrid institutions is a way to overcome the problem of developing the private governance mechanisms within which entrepreneurs can develop a new economy—a crypto-economy. It follows, however, as the structure and shape of the crypto-economy is revealed, the extent of blockchain innovation commons may collapse. If it is indeed true that the economics of utilising hybrid entrepreneurial organisation is to overcome uncertainty about the complementarity of institutional jurisdictions, then it follows that, as these opportunities are developed, the economic problem facing blockchain entrepreneurs may shift from more fundamental structural uncertainty towards more classic Knightian uncertainty.[215] At the level of the industry, then, the as the blockchain ecosystem develops, we would expect the comparative efficacy of the knowledge-coordinating blockchain innovation commons to decline. That is, the existence of many entrepreneurial fundamental transformations—as blockchain entrepreneurs reveal market opportunities for blockchain technology—may decrease the number of blockchain innovation commons.

[215] While no entrepreneurial opportunities can exist objectively (and thus be represented as probabilistic risk) in the mind of the judging entrepreneur the perception (albeit subjective) that opportunities have been tested in the past (e.g. remittances or exchanges) will provide additional information feeding into their entrepreneurial judgement.

Part III:
Political economy

Chapter 7: The subjective political economy of innovation

7.1. The subjectivity of institutional costs

Economic thought on the governance of common pool resources can be divided into two stages. The first stage, building on Gordon (1954) and Scott (1955), was outlined in the parable of an open access pasture as the "tragedy of the commons" (Hardin 1968). This view assumes that individuals will fail to pull themselves out of social dilemmas, such as those in open access fisheries and forests, because the costs of developing self-governing solutions to overcome free rider problems are prohibitively high. This led to recommendations for state-based institutional intervention through privatisation or regulation—on one hand, privatisation could internalise the costs of individual actions and lead groups away from tragedy, on the other hand, government regulation could prevent over-appropriation through coercion and control. These market-based or state-based interventions were seen to minimise the social losses from the commons as the institutional solutions to social dilemmas.[216]

Nearly fifty years on, since the recent expansion of the economics of common pool resources, the political economy thinking about the social dilemmas of common property has decisively shifted.[217] This second stage of thinking, which took off largely in the 1990s through the work of Vincent and Elinor Ostrom within the Bloomington School, developed a new understanding of polycentric commons and their comparative efficacy (Aligica and Boettke 2009; Boettke and Coyne 2005; Boettke et al. 2013b). The optimal suite of institutional solutions to social dilemmas was shifted beyond markets and states through empirical research into fisheries, forests and irrigation systems, as well as game-theoretic analyses of how individuals cooperate (Mitchell 1988; Ostrom 1990, 2005, 2010; Tarko

[216] See Ostrom (1990, p. 2) for an outline of the influential models in this line of thinking, including the tragedy of the commons, the prisoners' dilemma, and the logic of collective action.
[217] See also Section 3.3 above for a brief history of the commons literature.

2016). These studies revealed that while ameliorating social dilemmas through polycentric private orderings and collective action was no panacea, it could be comparatively optimal (Cole 2014; Feeny et al. 1990; Hess 2008). Over time, those findings translated into policy prescriptions (Boettke et al. 2013b), albeit with differing efficacy. How did such a dramatic shift in comparative institutional thinking come about?

The change in the institutional solutions to social dilemmas did not come from new and more effective types of self-governing institutions. From the mountain grazing villages in Japan to the Alicante *huerta* irrigation systems, much of the empirical work in Ostrom's landmark *Governing the Commons* focused on historical "long-enduring, self-organizing, and self-governed" common pool resources (Ostrom 1990, p. 58)—that is, the objective costs of institutional solutions didn't change. Rather, the core change was a shift in the subjective perceptions of the costs of various institutional solutions. While it was previously assumed that the transaction costs of developing self-governance solutions to social dilemmas were too high, the new commons research program revealed that the social losses to common property—at least to the individuals within the game itself—may be lower than privatisation or regulation. The Bloomington School, through robust empirical and theoretical analysis, convinced and persuaded others of the potential for polycentric commons-based solutions. These lessons, and in particular the understanding of the political economy of institutional diversity, stretch beyond natural resource commons, shedding light on broader questions of comparative institutional choice and political economy, and, as we will see below, helps explain political economy of the innovation problem, and the choice of proto-entrepreneurs to develop and coordinate within innovation commons.

This chapter synthesises the preceding findings on the economics of the proto-entrepreneurial innovation problem within its political economy context. As such it is first useful to briefly summarise these findings. A contract-theoretic institutional perspective of the innovation problem suggests that from the perspective of the proto-entrepreneur the innovation problem is primarily one of comparative institutional analysis (Chapter 2). Polycentric collective action governance in the innovation commons was then proposed as a

potential transaction cost economising solution to the proto-entrepreneurial innovation problem (Chapter 3). This led to the analysis of the micro-institutional mechanisms of one example of an innovation commons, hackerspaces (Chapter 4), and the diverse innovation commons coalescing around blockchain technology to coordinate the development of the crypto-economy (Chapter 5 and Chapter 6).

Examining the choice of proto-entrepreneurs to govern their coordination problems within private collective action structures is not to say that the innovation commons are a comparatively optimal solution to the innovation problem in any *objective* sense. A methodologically individualist governance approach to the innovation problem reveals institutional choices by groups of entrepreneurs over what institutional solution they perceive to be their economic problem. Given these subjective perceptions, how do the innovation commons sit within, and interact with, the various institutions of innovation policy? The central question of this chapter is how the decision to enter into an innovation commons can be understood within its broader political economy context. As we will see below, the costs of institutional solutions are subjectively perceived in the minds of the individual making the institutional choice. Proto-entrepreneurs who chose the innovation commons as the solution to the economic problem they face are revealing their comparative institutional preference.

My aim in this chapter is to examine the shift in thought of the institutional solutions to the innovation problem—in particular the relationship between private and public solutions—through the theoretical lens of new comparative economics and the institutional possibility frontier (IPF). My intention is not to draw specific policy implications. Such policy claims would go beyond the logical remit of my findings. Rather, my aim is to examine how private governance in the innovation commons can be squared within the political economy of innovation policy using the institutional possibility frontier (IPF) as introduced by Djankov et al. (2003). The IPF rests on the basic premise that institutional controls are imperfect and face a trade-off between the costs of dictatorship (from private appropriation) and from the costs of disorder (from state expropriation). The simplicity of the IPF framework has led to it

being applied to the institutions of innovation policy (Davidson and Potts 2015), as well as a range of more specific policy questions including media regulation (Berg and Davidson 2015), productivity reform (Davidson 2013), tobacco control (Davidson 2016) and free speech (Berg and Davidson, 2016), as well as being connected with other theoretical perspectives such as total factor productivity (Lokshin 2015).

This chapter proceeds as follows. First, the institutional possibility frontier (IPF) framework and its shortcomings are outlined (Section 7.2). Together with Chris Berg, the IPF framework is then extended to incorporate subjective costs (Section 7.3). This forms a subjective political economy framework, which is then applied to the new mainline approach to the innovation problem developed in this thesis, thereby outlining the implications of the innovation commons within the context of innovation policy (Section 7.4). Section 7.5 concludes.

7.2. The institutional possibility frontier

The institutional possibility frontier (IPF), first introduced in Djankov et al. (2003) and then Shleifer (2005), is a theoretical framework representing institutional choice over the social losses of various forms of governance. The IPF shows that, through politics, societies implement institutions in order to control the dual costs of dictatorship, on one hand, and the costs of disorder, on the other. While institutions lower the disorder costs of the supposedly nasty, brutish and short life of statelessness (Hobbes 2006 [1651]), institutions also increase the costs of dictatorship from state coercion. That all institutions imperfectly minimise social losses is the analytic core of the IPF framework as one of comparative institutional choice.

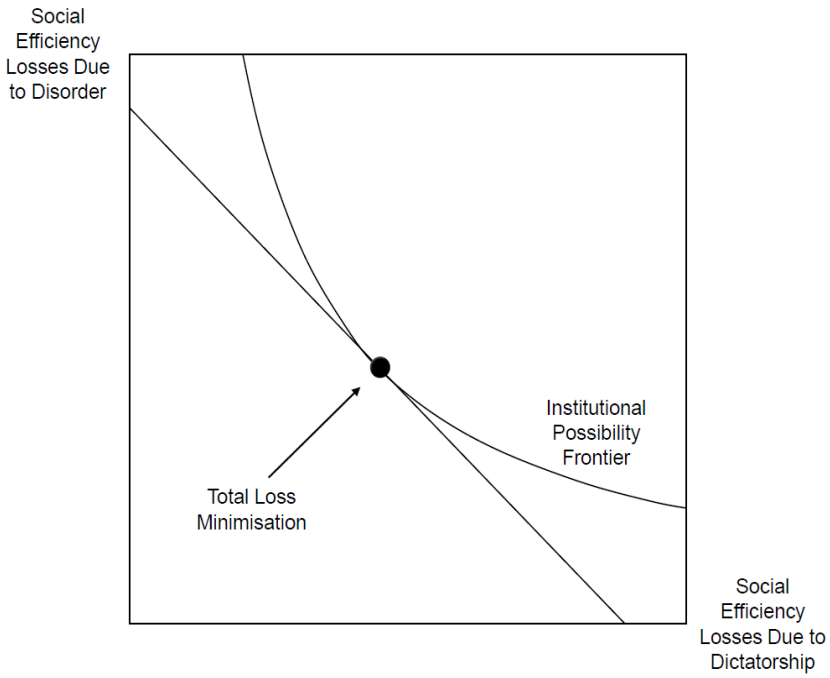

Figure 3: A basic institutional possibility frontier

There are two types of costs in the IPF framework. First, when governments intervene into the polity there are social losses relating to the *costs of dictatorship* such as the "risk to individuals and their property of expropriation by the state and its agents in such forms as murder, taxation, or violation of property" (Djankov et al. 2003, p. 7). While some dictatorship costs are clear, such as a communist regime, others are subtler, such as individuals using the power and enforcement mechanisms of the state to control others through regulatory capture (e.g. Dal Bó 2006; Laffont and Tirole 1991; Peltzman 1976; Stigler 1971). Second, when private individuals impose costs on each other through private expropriation there are social losses from the *costs of disorder*. That is, there is a "risk to individuals and their property in such forms as banditry, murder, theft, violation of agreements, torts, or monopoly pricing" (Djankov et al. 2003, p. 6). These costs come from the development of private orderings, often stemming from asymmetric information or unequal power or bargaining between private agents.

Given that no institution is perfect, a space of institutional possibilities can be traced through the points at which a given institution trades-off the costs of dictatorship and disorder, thereby forming the IPF (Figure 3 below). While the costs of institutional controls

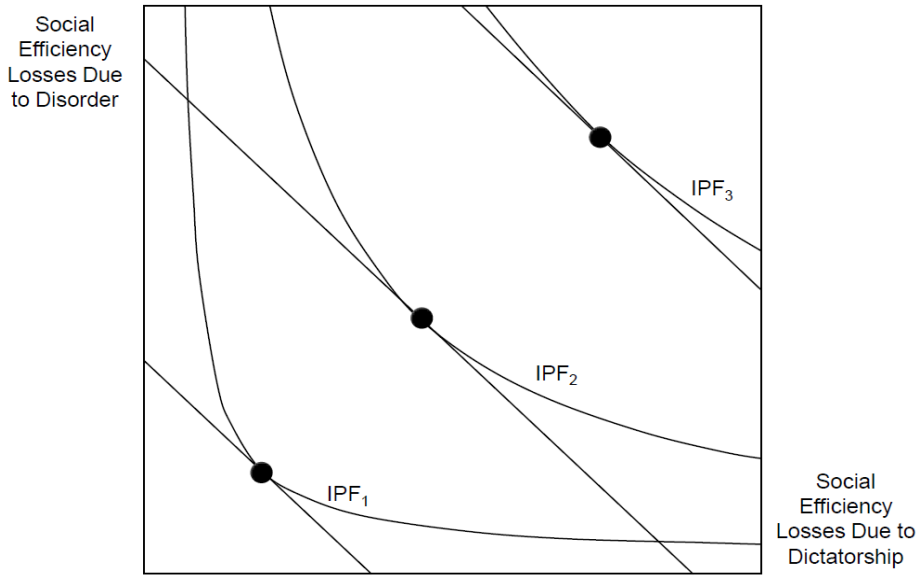

Figure 4: IPF distance to origin

within a political economic system can never be completely mitigated, the convexity of the IPF implies a cost minimising point where the costs of dictatorship and disorder are minimised. The convexity assumption is based on the comparative properties of different institutions (hence, 'new comparative economics') and enables an interior efficient solution to a constellation of dictatorship and disorder threats. Djankov et al. (2003) loosely claims the distance of the 45-degree line from the origin represents a function of the "civic capital" within a given society.[218] Such an amorphous interpretation of the relationship to the origin, however, has rightly been criticised as "poorly defined, if not downright flimsy" (Rosser and Rosser 2008, p. 95). Nevertheless, despite the ambiguity of the distance from the origin, it remains that different societies begin with different available institutional possibilities within the IPF space, and, even further, because the institutional space is unstable, the availability of these points will change through time.

The nature of the IPF will alter depending on the time horizon. In the shorter-term institutional possibilities remain fixed. In the longer-term, however, a number of factors

[218] The 45-degree line within the IPF framework should not be confused as being representative of some objective institutional possibilities. Rather, it is an analytical tool for an individual to solve the point closest to the origin.

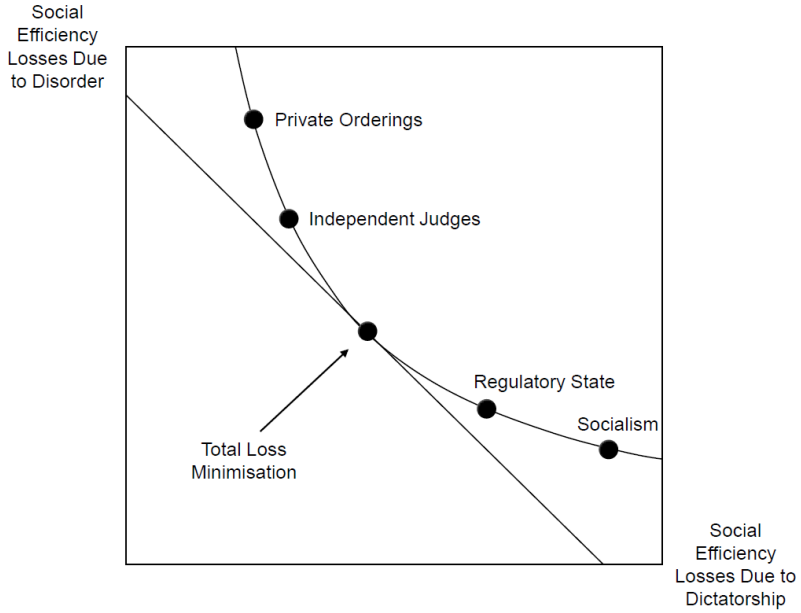

Figure 5: The institutional possibilities of business regulation

change the shape, the slope, and the position of the curve. In the same way as the more familiar production possibility frontier (PPF), shifts in the IPF are a result of multiple complex factors, many of which are out of our control (Boettke et al. 2005). Societies also begin with different institutional possibilities. For instance, in Figure 4 on the previous page, the society represented by IPF_1 has a potentially more efficient suite of institutional possibilities than the societies represented by IPF_2 and IPF_3 respectively. The differences in the cost minimising solution, and the available space of institutional change, may be a result of different social fabrics or civic capital.

The IPF is an ordering of institutional possibilities, not an absolute representation of the social losses they seek to mitigate. Moving from 'private orderings' (e.g. firms) on the top left, down and across to 'public orderings' (e.g. socialism) on the bottom right, corresponds with rising costs of state intervention and declining powers of the individual. That is, while moving from top left to bottom right, social losses stemming from disorder fall while the social losses from dictatorship rise (Djankov et al. 2003; Shleifer 2005). A society may implement an institution at some point either side of the cost minimising tangency, thereby utilising a set of institutions that are "inefficient" (Shleifer 2005). Figure 5 above, for

instance, which represents the regulation of business, implies that independent judges and the regulatory state are both inefficient solutions. This is an example of implementing a representative set of institutional systems at a society wide level, where, for instance, socialism produces inefficiencies due to the costs of dictatorship, while purely private orderings produce costs relating to disorder and private appropriation.

From here we can examine some of the shortcomings of the IPF framework. These shortcomings relate to the dynamics of institutional change, which are described below in two ways: the *transition* between institutional points and the *discovery* of those points.[219] First, how does a group, such as a territorial nation state, transition towards the theoretically efficient loss minimising tangency point? Put another way: is it true that, through time, a society will move through an evolutionary process? While we further examine this question in the following section, Dallago (2004, p. 68) note at least four possibilities: spontaneous evolution, the activity of interest groups favouring efficiency, Coasian bargaining, and democratic voting. Institutional evolution and selection, however, is well known to be slow and perhaps inefficient (Nelson 1995) due to transaction costs. For instance, Rosser and Rosser (2008) argue that convexity of the IPF in societies who hold different aversions towards dictatorship versus disorder may lead them to become "trapped" at certain points. There may also be forms of institutional stickiness or path dependence in institutions (Boettke et al. 2008; Glaeser and Shleifer 2002; La Porta et al. 2008), problems of multiple equilibria by a "failure of convexity" (Djankov et al. 2003; Rosser and Rosser 2008), or public choice suggestions that politicians will make choices to keep themselves in power rather than seeking the efficient point (Berg 2016; Buchanan and Tullock 1962).

Assuming that the institutional transition process is efficient—that is, societies will move towards what the social loss minimising point—still leaves a deeper epistemological

[219] Several criticisms of the IPF framework have been outlined in the literature. For instance, the IPF provides "no endogenous reason or mechanism leading to institutional inefficiency" and the new comparative economics more broadly "really overlooks the qualitative aspects of the issues … we must account also for consistent (systemic) qualitative differences in the nature of the state and the actors operating within it" (Dallago 2004, p. 65).

question: how does a society determine the location of institutional possibilities within the IPF space? This is a question of the uncertainty of institutional optimality. Given the dispersed and contextual information necessary in order to help discover the point of tangency the IPF is representative of the knowledge problem of the nation state (Hayek 1989). The institutional controls of a regulatory state or a legal system must themselves be discovered. This discovery could come through a form of political entrepreneurship to overcome the instability of the institutional space (Koppl et al. 2015).[220] The following section extends the IPF framework to incorporate subjective costs, which both helps to mitigate some of the shortcomings outlined here, and enables the new subjective political economy framework to be applied to the innovation problem.

7.3. The subjective costs of innovation institutions

7.3.1. Introducing the institutions of innovation

Innovation policies are generally examined on the basis of benefits. That is, of the positive spill overs (Griliches 1991) and the societal gains from economic growth (Lucas 2009; Romer 1990) that spread throughout society due to innovative discoveries. From the perspective of an institutional approach to the innovation problem, however, institutions also impose and economise no costs. In the context of the IPF, innovation policies can be conceived in terms of social losses. In this light, Davidson and Potts (2015, 2016) arrayed innovation policies as institutions along an IPF curve (see Figure 6 below). The main benefit of this new institutional approach to innovation policy is not just to recognise that innovation policies impose costs, but that those costs are not equivalent. The innovation IPF is a depiction of the institutions applied in an effort to ameliorate the innovation problem.

[220] This understanding, of uncertainty relating to the efficient set and the possible set of institutions, is clear in new development economics, and in particular the Austrian conception of development economics as it was explored in Chapter 6 (Bauer 1976; Boettke et al. 2008; Leeson and Boettke 2009; Matsuyama 1997).

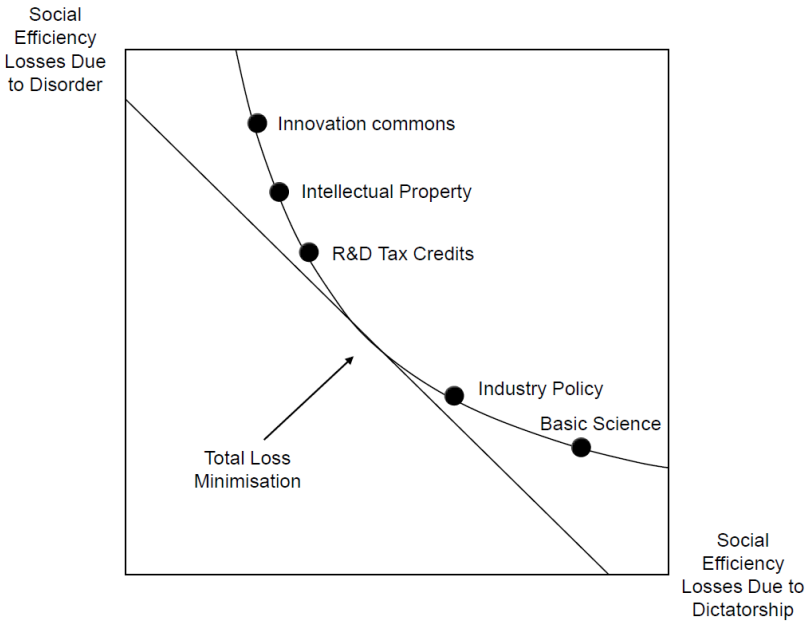

Figure 6: An innovation institutional possibility frontier

What are the institutions of the innovation problem? In the upper left portion of the IPF the costs of private orderings relate largely to the costs of private appropriation from a lack of state-based control (Davidson and Potts 2015). The social losses here relate to disorganisation, whether that disorganisation leads to underinvestment or overlapping of investment, or predatory opportunistic behaviour in the sharing of ideas. Moving down the curve is intellectual property (IP), which has theoretically fewer costs of disorder as compared to private orderings, but also has dictatorship costs. Intellectual property rights, such as patents and copyright, are a form of intellectual privilege monopoly rights (Bell 2007, 2014). As they are implemented there is a trade-off between static and dynamic efficiency (Wu 2006) where the ability to "stand on the shoulders of giants" (Scotchmer 1991)—including the emergence of the anti-commons (Heller 1998) and patent thickets (Shapiro 2001)—is traded off against increased appropriability for innovators (Boldrin and Levine 2008). There are also disorder costs relating to the use of intellectual property for patent trolling (e.g. Bessen et al. 2011; Dourado and Tabarrok 2015). Moving further down the IPF curve are innovation policies administered through the tax system. Research & Development tax credits, for instance, act as a subsidy to fund innovative activity. As with all innovation polices, it is an empirical question whether these R&D tax policies are effective

(Bloom et al. 2002). Further down the curve is industry policy, which targets innovation funding towards particular industries. The social losses from industry policy are largely in the form of dictatorship costs, including regulatory capture (Stigler 1971), rent seeking (Krueger 1974), identification of externalities (Davidson and Spong 2010), and agency problems (Hölmstrom 1989).[221]

While the innovation IPF is useful to outline and discuss the various institutions of the innovation problem, it fails to explain how the curve shifts through time or how the institutional solutions to the innovation problem come about. This also raises a problem of placing the findings of this thesis within the innovation IPF framework. How can proto-entrepreneurs seceding from the conventional institutions of innovation policy—as we saw in Chapter 4 in hackerspaces, for instance—to their own collectively and privately governed institutions be understood as a point within the IPF space? Furthermore, how can an entrepreneurial fundamental transformation and a change in the microstructure of transaction costs for different economic problems—as we saw in Chapter 2—be placed on a static society-wide innovation IPF? Rather than discarding the analytical framework of the IPF, the framework can be extended to incorporate the Austrian notion of subjective costs over individual economic problems. By maintaining the underlying valuable concept of a trade-off between dictatorship and disorder, but extending the framework to incorporate subjectivist and therefore methodologically individualist underpinnings, the simplicity and clarity of the IPF can be maintained, but its flexibility, nuance and explanatory power can be expanded.

7.3.2. The subjective costs of institutional solutions

The IPF represents the potential institutional solutions to a particular economic problem. To develop a representation of the proto-entrepreneurial problem we must recognise that there is not one IPF for the entire suite of the institutions of innovation. Indeed, the notion

[221] Indeed, a public choice approach to innovation economics has long been understood (Link 1977) where, for instance, increases in government research and development have been shown to significantly increase the wages of scientists, suggesting that government funding directly crowds out private behaviour (Goolsbee 1998).

that IPF curves are heterogeneous is outlined briefly in the original analysis: "[t]he shape and the location of the IPF—and hence the efficient choice—various across activities within a society, as well as across societies" (Djankov et al. 2003, p. 9). Further, Dallago (2004, p. 71), noted that "the portion of the IPF that is relevant for particular societies would be different."[222] Because the IPF is generally drawn as a continuous function depicting all innovation policies, however, this implies one economic problem, with one optimal solution to those problems at the cost minimising tangency point. While representing the IPF as a continuous function, as is the case in Davidson and Potts (2015), is useful to demonstrate there are indeed different institutions within the innovation system and that they occupy different locations within the IPF space, this conception is not reconcilable at the more granulated level of each of the different economic problems within the innovation problem. The innovation problem consists of multiple economic coordination problems—there is no one cost minimising tangency point for the innovation system. The threats of dictatorship and disorder are of a different structure for a multinational company with a large Research and Development lab, for instance, compared to the hacker in a hackerspace (Chapter 4) or the proto-entrepreneur seeking valuable uses for a new general purposes technology (Chapter 5), or even further for the needs to expensive basic science research (e.g. Kealey and Nelson 1996; Kealey and Ricketts 2014). That the institutions of innovation are interrelated throughout the innovation process has been a key to the innovation systems literature (e.g. Freeman 1995; Lundvall 1992, 2010). With its view that innovation process is a non-linear process with various complex feedback mechanisms between, for instance, firms, markets and government, the innovation systems approach suggests that different institutions deal with different problems in different ways and that there are different sets of institutions for each economic problem throughout the innovation process.[223] For the institutions of innovation, Davidson and Potts (2015) propose that different types of innovations—for instance the development of nuclear weapons compared to the

[222] Furthermore, in relation to economic development, which is at its heart the comparative institutional economics of growth, Leeson and Boettke (2009, p. 256) note that "the efficient 'mix' of more or less reliance on private vs. public protection technologies will consequently depend upon the specific case".
[223] See Chapter 1 for an introduction to innovation systems theory.

development of new business models—face different costs of disorder and dictatorship. Indeed, as we saw in Chapter 2, the transaction costs of economic problems change throughout an innovation trajectory, suggesting different cost minimising institutional solutions. Each of the different economic problems that constitute the process of innovation face different constellations of economic costs.

The innovation IPF should be represented differently for each coordination problem because each of these are different economic activities with different cost structures. This involves a disaggregation of the IPF down from the level of the entire innovation system—which incorporates all IPFs within one single institutional space—to the level of the economic problem. Therefore, the innovation IPF would represent a class of economic problem, where a range of institutional controls could be implemented—ranging from private to public—in order to minimise the social losses of that problem. While disaggregating the innovation IPF enables us to examine the specific economic problem associated with early stage entrepreneurship, it fails to explain the nature of the costs of institutions themselves. That is, how do proto-entrepreneurs discover the costs of various institutional solutions their economic problem? The nature of the costs underpinning the IPF is critical because the framework is fundamentally a representation of individual institutional choice. This examination reveals a further extension of the innovation IPF—integrating the Austrian notion of subjective costs.

The shape or position of any given IPF can never be represented objectively. This is not only because of the complexity and uncertainty relating to the choice of institutions, but also because that all perceptions of costs are based on opportunity costs, which are fundamentally subjective. Indeed, the costs of disorder and dictatorship are subjective both to the actors which impose them and the societies which endure them. Since Menger (1871) developed a subjective theory of value, the concept of subjective costs has sat at the centre of the Austrian school of economics (see Buchanan and Wagner 1977; Yeager 1987). A subjectivist view focuses on the mental states and subjective determinations of each of the members within a society, rather than some objectively verifiable measure of society

(Lachmann 1990). Most generally, costs are subjective accounts of the preferences of individuals (Stringham 2010). Subjectivism, therefore, has extended beyond the idea of value, to knowledge more broadly (Horwitz 1994). Some of the deepest questions in economics stem from subjectivism, and the level to which an individual economist is willing to extend their commitment to subjectivism (see Horwitz 1994; Shackle 1992; Stringham 2010).

Costs are subjective by their very nature because they rely on opportunity costs of institutional implementation that are perceived in the minds of the individual agent. As Buchanan (1979, p. 43) argued: "(1) Cost is subjective; it exists in the mind of the decision maker and no-where else. (2) Cost is based on anticipations; it is necessarily a forward looking or ex ante concept." Similarly, it is true that individual perceived costs of society's social losses to any given institutional arrangement are deeply and necessarily intertwined with their subjective preferences. That is, the notion of subjectivism can not only be applied to a good or service, but more broadly to the perception of the costs of institutional choice. The costs of dictatorship and the costs of disorder represented in the IPF space are subjective costs in the mind of the individual agent perceiving them, and can never be objectively known. This implies that the particular location of a given institution within the innovation IPF space is based on the decision-makers' anticipations over the constellations of available institutional set ups (Pasour Jr 1978), and that those subjective costs are the inputs into institutional choice. This subjectivity is apparent because the costs of any given institution are highly distributed and intangible, and are highly framed by the ideological assumptions of the individual.

Introducing a subjectivist understanding into the institutional costs of the IPF helps to overcome some of the persistent shortcomings of the IPF including its bluntness, clumsiness, and lack of general theoretical applicability. For instance, the IPF, even disaggregated to each individual economic problem, would strain to understand the various 'traps' between South Korea and North Korea:

> societies may well choose to be far from such cost minimization and democratic choice. Once could reduce this into a discussion of social welfare functions and how some societies prefer more individualism and others prefer more collectivism. (Rosser and Rosser 2008, p. 86)

While subjectivity of costs is alluded to in Rosser and Rosser (2008, p. 87):

> even if it is very fuzzy and imperfect, if we observe reasonably functioning democracies, and we observe them consistently over long periods of time choosing to have very different balances between their public and private sectors, we would not be too unreasonable in asserting that these political outcomes may to some degree indicate differences in preferences among at least broad sectors of the populations in the respective countries.

it is only mentioned once elsewhere across the new comparative economics literature, by Whitford and Lee (2012) when they attempt measure perceived government effectiveness. Shleifer (2005, p. 3), however, comments such as "the Chicago School's confidence in private orderings and in courts is excessive" clearly demonstrates the implicit nature of subjective costs.

While the claim that institutional costs are subjective is a simple observation, it has major implications for the understanding of the institutions of innovation and for the usefulness of the new comparative economics approach more generally. Given that costs are subjective, societies do not make institutional choices, individuals do. The dynamics of individual disagreement and bargaining over institutional costs become analytical heart of comparative institutional analysis. Introducing subjectivity over the costs of institutions brings the idea of discovery of those institutional costs to the forefront. Following Hayek (1937; 1945; 1948; 1989), the economic problem is then one of which political economic process—such as a democracy, or catalytic processes, such as markets—coordinates the non-price information of subjective perceptions. To be clear, while information reduces uncertainty (Shannon 1948) that uncertainty relates to mental states not objective truths.

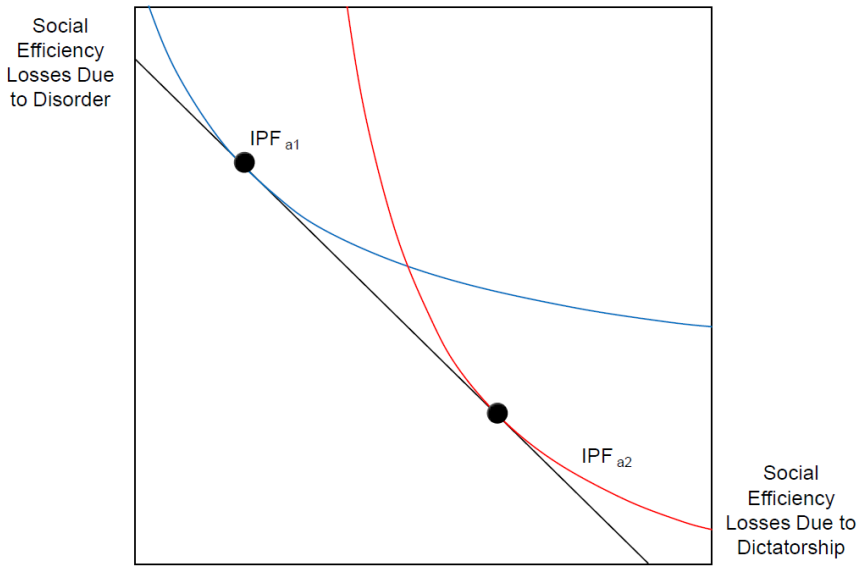

Figure 7: Different IIPFs given subjective agent perceptions

This process of coordinating information about institutional costs plays out within a political economic system. While in aggregate the IPF may appear to be a single, society-wide IPF, it is better understood as the outcome of a process of inter-agent bargaining and coordination between people, and the groups, networks and factions within which they engage. As there are no objective dictatorship and disorder costs—institutional costs are mental states rather than objective facts—any observed institution 'emerges' as a function of both a diverse range of ideas about the costs of those institutions and a social bargaining process. Institutional costs are a function of both the institutional environment in which they emerge, and the economic coordination problem that is being solved, but also the perception of those agents making the choices within a complex and entangled political economy (Wagner 2006; 2016a; 2016b). It is individuals who perceive costs, not societies. Because the costs of disorder or dictatorship are complex, uncertain and subjective, their perception is strongly influenced by the ideology of those analysing the policies.[224]

[224] Almudi et al. (2017), for instance, describes civilisation as the result of a contest between competing utopian visions.

We can also graphically represent some of the implications of the new subjective underpinnings of the IPF. If any given institutional possibility on the IPF is subjectively determined by individual agents, and that these are dynamic, the IPF should not just be disaggregated down to each economic coordination problem within the innovation process, but also disaggregated down to incorporate the perceptions of each individual agent. In this view, each individual holds their own distinct perception of the shape of the IPF based on their subjectively determined costs of dictatorship and disorder. This does not imply that analysis should end at the individual. Rather, we must we must begin at the level of the choosing individual, from a perspective of methodological individualism, and their subjective perceptions over the institutions of innovation, and then move upwards into the meso and macro levels, in order to understand the implementation of innovation policies.[225] Without beginning with the individual, the discussion of the IPF remains as one of objective costs, of which there are none. Therefore, each economic agent will have a different curve relating to the same economic problem (see Figure 7 above), with different perceived cost minimising points.

[225] This concept of methodological individualism was at the heart of the Bloomington school (see Boettke and Coyne 2005; McGinnis 2005). Also see Section 1.3.

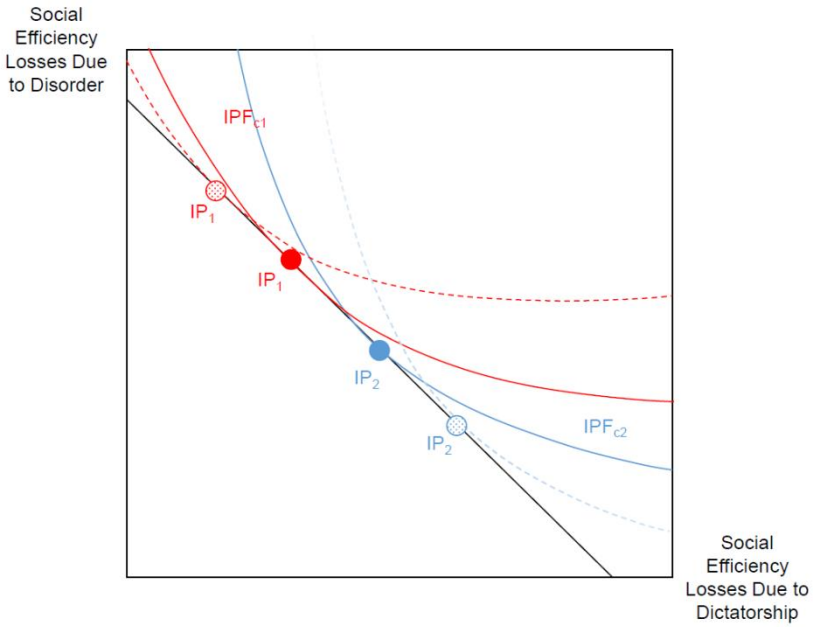

Figure 8: A subjective innovation institutional possibility frontier

If each individual perceives their own costs of a given institution, then there will indeed be a different shape and slope for every individual. This is closely linked to the ideology of the individual agent.[226] For instance, and to return to the institutions of innovation, the literature suggesting that the market failure in the discovery of basic scientific knowledge is not as clear as once thought. For instance, Kealey and Ricketts (2014), in their work on 'contribution goods' of scientific publishing and discovery, suggest that the costs of disorder may not be as high as previously expected, because these institutional solutions—through a unique combination of reputation and contributions—can lower the costs of disorder. Indeed, there has been a case built against public science by scholars such as Kealey and Nelson (1996) and by Greenberg (2001), which suggest that the perception of this curve has indeed been influenced, for instance, by rent-seeking and regulatory capture. This literature would suggest that the curve may be flatter than previously suggested, and indeed that the costs of dictatorship and disorder may be minimised using some other institutional set up.

[226] Ideology has been part of positive political economy at least since Downs (1957), and ideas—"shared mental models" of norms and custom—have been a part of institutional economics since its conception (Denzau and North 1994; North 1993). Further, Tarko (2015) recently outlined that the direction in which institutions change depends on the ideas, beliefs and values of those who change them.

Figure 8 above is a disaggregated representation of two agents (one red and one blue) possessing subjective perceptions over two different economic problems (c1 and c2) within the innovation system. The result is four different perceptions of cost minimising institutional solutions to separate dilemmas within the innovation system. This shows how the subjective political economy framework enables the analysis of the political economy process of the implementation of innovation policy. That is, by incorporating subjective costs within the IPF framework it becomes clear that the transition process between different IPF points is a political economy *process*. In a modern liberal democracy, the processes of bargaining between the different agents through some political process, where agents with different subjective costs over the relative costs of dictatorship and disorder bargain between their two cost minimising tangency points. Even when these bargaining processes occur between coalitions—including, for instance, political parties—the underlying premise remains the same: each individual has their own perceptions on the various costs of dictatorship and of disorder of which a given set of institutions will impose on society to solve a given problem. The cost minimising point itself is a perceived point, and is never objective.

The economy-wide IPF as represented in Davidson and Potts (2015) is the result of a political economy process where institutional interventions are applied. It also follows, however, that the structure of the individual subjectively determined cost curves underpinning the IPF will result in a different implementation of policies given the underlying ideology of the individuals. An aggregated society-wide innovation IPF representing the selected institutions of innovation policy is to individual subjective costs what prices are to preferences—the question is the process of getting there. An economy comprised of 'government sympathetic individuals', for instance, will see a different policy outcome to a relatively 'free market sympathetic' individuals, based on each perceived costs of dictatorship and disorder.[227] While observing and moving an IPF—in the same way as

[227] One further consequence of viewing institutional costs as an agreement between different individuals in a social is the notion of ignorance and certainty. In Djankov et al. (2003) the IPF is convex towards the origin, reflecting society's knowledge about the costs of the institutions on the curve. However, it has been observed that agents are not always well-informed about policy alternatives (Caplan 2011; Somin 2013). While in a

prices—may provide some indication of the underlying dynamics of the actors, the real detail of the analysis only emerges when the IPF is disaggregated to a lower level. Indeed, as Hayek (1945) argued, aggregate measures (and indeed any aggregate representations) ignore the fundamental underlying economic problem because all of the detail of individual movements is lost. In this same way, the future of the new comparative economics may involve disaggregating the IPF down to the level of the individuals who make up the polity. The movement of the IPF, or, more accurately the perceived movement in the IPF, can then be split into two main categories (1) a movement of the underlying subjective costs of individuals; or (2) some exogenous force which changes underlying transaction costs (i.e. civic capital). The question, then, is how we can understand the private governance of entrepreneurial discovering within this new subjective political economy framework.

7.4. Choosing private governance

Several chapters in this thesis have demonstrated that private orderings solutions to the hazards of coordinating the non-price information necessary to act entrepreneurially may minimise the dual costs of dictatorship and disorder. In the context of the IPF framework, collective action polycentric governance in the innovation commons may, on one hand, minimise the costs of dictatorship—which would hinder entrepreneurial discovery through hierarchies and path dependence—and the costs of disorder, on the other—in which opportunism, for instance, may reduce the sharing and exchange of information. This section examines the implications of this finding of the potential efficacy of private governance solutions to the innovation problem within its entangled political economy context. Three main implications are discussed. First, that that the choice-theoretic market failure perspective on the innovation problem may have systematically overweighted the disorder costs of private governance solutions to the innovation problem of proto-entrepreneurial discovery. Second, that the institutional solutions to the innovation

subjective political economy all agents are equally ignorant of 'true' or 'objective' costs, not all agents may feel they are able to produce a well-formed, well-ordered and complete ranking of institutional alternatives in the subjective IPF space relative to other agents. This is a question of the intensity of perceptions of institutional costs, where the convexity is a function of the relative certainty of costs.

problem themselves face a 'knowledge problem' (Hayek 1989) of discovering and coordinating the constellations of subjective perceptions of institutional controls. Third, examples of secession from the innovation system to privately governed innovation commons imply the need to understand the entanglement (Wagner 2016b) of public and private solutions to the innovation problem, as well as the institutional objective of robustness (Pennington 2011).

That groups of entrepreneurs have collectively developed private governance solutions to the innovation problem sits in stark contrast to the reigning conception of innovation as facing a market failure of sub-optimal investment, thereby requiring public intervention through innovation policy. Conventional perceptions of innovation policy place private ordering solutions to the innovation problem in the background of economic analysis. These two contrasting conceptions are partially reconciled through the development of subjective political economy framework for innovation policy. Davidson and Potts (2015) outlined that the perceived costs of dictatorship for innovation have been underweighted in the design of innovation policy—that is, policymakers may have underweighted the costs of intervention within the innovation system. In contrast, this dissertation has suggested that the costs of disorder, for the specific problem of proto-entrepreneurial discovery, may have been overweighted in the application of innovation policy. My findings suggest that the position of subjective innovation IPF, from the perspective of entrepreneurs making the institutional choice to engage in innovation commons, and for the specific coordination problem in the early proto-entrepreneurial stages of new technology, is flatter than that assumed within innovation policy. That the potential for groups of proto-entrepreneurs to privately come together and develop institutional solutions to the costs of dictatorship and disorder have been assumed infeasible, or at least inefficient, however, is not clear through the conventional lens of market and systems failure of the innovation problem. Put another way, the costs of disorder may have been systematically overweighted in the analysis of entrepreneurial discovery. This subjective discrepancy can perhaps be attributed to the reigning market failure view of innovation, which, since the early 1950s, has consistently

suggested private agents are unable to overcome social dilemmas in the innovation system through private orderings.

What this also demonstrates is that because the costs associated with institutional choice are subjective, they are highly influenced by academic discourse. Ideas (Leighton and López 2012), rhetoric (McCloskey 2010; 2016) and culture (Mokyr 2016) play an important role in framing subjective perceptions. When policymakers, for instance, begin their search of the institutions of innovation policy, with, for example, a starting perspective of market failure, this is tantamount to assuming that the costs of disorder are higher than those of dictatorship, and indeed will implement policies in other portions of the curve. While the benefits of innovation policies are thought to extremely high, and the costs of innovation policy (e.g. rent seeking and distortions) are rarely discussed, the subjective political economy framework suggests that the costs of the institutions of innovation are subjective, unstable and entangled. The points within the IPF space—that is, the entire suite of potential institutional solutions to economic coordination problems in the innovation system—are shrouded in fundamental uncertainty. The microstructure of costs underpinning each institutional solution is unknown, and is subjectively held within the mind of each individual.

This subjectivity or uncertainty over the institutional points within the subjective innovation IPF mean that implementing an efficient innovation system would involve discovering each of the institutions constituting the cost minimising point for each economic problem throughout an innovation trajectory. This would include each of the complementarities and substitutes between each of the curves, and take into account that this space is not stable and moving through time. Following from the propositions contained in Chapter 3, it also follows that the relevant curve for the entrepreneur would change throughout an innovation trajectory. That is, the cost-minimising interior solution to the economic problem changes as the microstructure of transaction costs change along an innovation trajectory. Disaggregating the innovation IPF by each coordination problem brings into clear view the enormous intellectual knowledge coordinating task achieving such

a feat would have to surmount (Hayek 1989). The question for a society is no longer to find the efficient institutional set up which is located of the tangency between the IPF and the cost minimising line. The policy question is one of coordinating all of the distributed bits of information over the perceptions of the location and efficiencies of the institutional possibilities. This, as especially new development economics has come to understand, is not necessarily effectively solved through top-down planning.

In this way, innovation policy itself—i.e. the mix of policy solutions that attempt to correct the innovation problem society faces—is itself an evolving *discovery process* over the cost minimising structure of each IPF. This suggests a common thread between many comparative institutional questions—that because the social costs of dictatorship and disorder are shrouded in fundamental uncertainty and thus have subjective costs the institutions implemented to mitigate these dual concerns must themselves be discovered, and will change through time as the actors perceiving them change their view. Because the eventual structure of implemented innovation policy is influenced largely by ideas of their subjective costs, academic enquiry into the collective action of entrepreneurial discovery acts to slowly shift the perceptions of the IPF over time. This dynamic process will not occur directly, but through bargaining processes as subjective perceptions of the polity are aggregated through the political process, and as various coalitions of the polity, including organised coalitions of rent-seekers, attempt to influence the subjective perceptions of the institutions of innovation for other agents within the economy. It will emerge from a bargaining process of individual perceptions; it is influenced by the reigning academic view of the costs. The search frame of institutional solutions to the innovation problem is highly influenced by academia, which thus far has been characterised by choice-theoretic market failures, thereby providing a further theoretical explanation for why the innovation commons have thus far played little role in innovation economics.

The current views of the scope and structure of innovation policy, largely through market failure and systems failure, should therefore be viewed within their historical context. Innovation policy traces back the mercantilist efforts of mid-nineteenth century

Germany to catch-up with the Industrial leader Britain. Government sponsored German engineers copied what innovative British companies were doing. Germany built the first modern research universities, and engaged in what we now call industrial policy, in developing the large chemical industry. In 1945, Vannevar Bush, head of the US Office of Scientific R&D, advocated a vast expansion of government support for science (Bush 1945). The aim was to replicate the success of government sponsorship of science during WWII (e.g. the Manhattan project) toward civilian ends. The National Science Foundation was founded. Basic science was funded by government that would then be developed by large private corporations into new consumer goods—creating the military-academic-industrial complex that is now at the heart of innovation policy. Modern innovation policy is built around the idea of a two-stage partnership between government and corporations, as well as the idea of many different institutions—that together constitute an innovation system—correct the innovation problem, stimulate innovation and propel economic growth.[228] This largely follows a similar industrial-linear model where governments lead the invention of new fundamental science and technologies that, in the second stage, will be developed for civilian consumer use by large corporations, who will release these technologies to market. From this brief history of innovation policy it is clear that governments have long sought to discover the interventions necessary to propel economic growth and development by solving the innovation problem. There is also evidence that governments haven not quite got those settings right yet, with mounting critiques of some of the major institutions of innovation policy (e.g. Boldrin and Levine 2005, 2008, 2013; Box 2009). Thus it is similarly clear that the perception of the innovation problem, and the proposed public institutional solutions to those innovation problems, have changed through time. In the context of the subjective innovation IPF, governments have been attempting to discover the cost structure of each economic problem and its corresponding solution within the innovation system.[229]

[228] See Chapter 1 on these perspectives on the innovation problem society faces.
[229] There are various caveats with this claim, the largest of which is assuming that governments are indeed seeking the cost minimising tangency point. This, however, is politics with romance. See Berg (2016).

The knowledge problem of overcoming the subjectivity of the innovation system can be viewed within the context of both entangled political economy (Smith et al. 2011; Wagner 2014, 2016b) and robust political economy (Leeson and Subrick 2006; Pennington 2011). The first perspective suggests that the polity and the economy co-dependently exist. For instance, the institutions of innovation also face complementarities in their implementation (Mohnen and Röller 2005).[230] The idea of complementarity of different IPFs is clear in the findings in Chapter 4 relating to hackerspace secession—that is, that hackers are seceding from the conventional institutions of the innovation system because they *perceive* the costs to be high—is an example of how a suite of innovation policies can shift the subjective perceptions of agents and thereby influence behaviour. It similarly holds, however, that the perceptions in these costs will change as individuals move throughout an innovation trajectory. One key upshot from this interaction between the public and private spheres is that when scholars and policymakers are conceptualising the interdependencies of the innovation policy mix they should both incorporate an understanding not only the costs they perceive are different to the people making the institutional choice (Flanagan et al. 2011), but that intervening within the process can have unintended consequences as agents shift their behaviours. That is, implemented points in the IPF space interact and change the incentives of other perceived points within the space. On a much broader level, too, the move towards secession in Chapter 6 are an entrepreneurial effort at creating a new self-contained crypto-economy because the perceived costs of dictatorship in the formal economy are too high.

Given the subjective nature of the institutions of innovation, this suggests that one objective of innovation policy should be robustness—that is, embracing complexity. The literature around robust political economy centred on an analysis of institutions taking into account human weaknesses (Pennington 2011). That is, by relaxing two assumptions which are widely held in market failure economics—that humans are omniscient, all-knowing, and

[230] Indeed, as Dourado and Tabarrok (2015, p. 149) note in the context of intellectual property "it is important to consider the ways in which nonmarket decision—both political and institutional—interact with intellectual property."

rational beings, and that humans are benevolent. The principle behind robust political economy is that institutions should only be analysed to the extent they deal with these human imperfections. Robust institutions are those which deal with the dual weaknesses of human behaviour—both in government and outside government—and thus are closely connected with the public choice perspective of innovation. Robust institutional systems "generate prosperity in the face of less than ideal conditions" (Leeson and Subrick 2006, p. 107). This suggests an important connection between a robust system and a disentangled system. Indeed, as Wagner (2016a) states in relation to entangled political economy:

> Turbulence and not placidity is the normal state of a system of entangled political economy. A system based on private ordering, however, is generally better able to calm turbulence than a system where public ordering occupies the social foreground …

This is relevant for understanding the private governance of proto-entrepreneurship in hackerspaces, where the production of novelty is a spontaneous ordering of entrepreneurs (Potts 2014). Perhaps the comparative institutional choice of hackers' interactions within the private orderings, as compared to public orderings institutions, is because the former institutions are relatively robust rather than fragile. That is, in the same way as Wagner (2006) and Leeson and Subrick (2006) note that those systems with more polycentric nodes of decision making in terms of economic organisation are more robust. A polycentric system of rules, such as those in hackerspaces, may be a more 'robust' system than centralized state-centred innovation policies because they deal better with the reality of limited human rationality and benevolence. That is, because entrepreneurs face high transaction costs relating to the discovery of knowledge and the institutions to coordinate that knowledge, having polycentric decision making, in the spontaneously-ordering sub-groups, enables trial and error institutional learning to overcome uncertainty. Such a robust polycentric decentralized system, as Mark Pennington outlines at length, enables institutional exit rather than monopoly rules.[231] How would integrating hackerspaces impact the robustness

[231] This idea of robustness is closely tied to the Austrian conceptions of the market economy in terms of time, change, and processes. That is, Austrian economics itself is the examination of robustness of various institutional systems.

of the innovation system? As we saw, hackers, at least to the extent of their own subjective perceptions of comparative institutional costs, are seceding from the conventional institutions of the innovation system (Chapter 4). Hackerspace secession can be viewed an attempt to escape the entanglement of the institutions of innovation policy. Integrating hackerspaces into the innovation system may affect their internal processes and decrease the robustness of the innovation system more broadly.

The robustness of a system of rules to facilitate entrepreneurial discovery exists at multiple levels. At the level of the entrepreneur the choice to engage in private polycentric governance through reputation mechanisms may be more robust than founding an entrepreneurial firm (because, for instance, it enables cheaper exit). On the other hand, robustness can also refer to the innovation system level, where understanding that individuals contracting in mechanisms outside the state, largely by using trust, has the capacity to increase the robustness of the system as a whole. This raises the question of what would be the consequence of reintegrating institutions of the independent innovation sector, such as hackerspaces, back into state-led innovation system? Integrating these independent autonomous innovation institutions—that is, entangling them with the political process—may have two effects: (1) impede the processes of spontaneous order on which hackerspaces are based; and (2) to decrease the robustness and adaptability of the innovation system more broadly. While state intervention through innovation policy into these spaces is not to create rules that prevent incubators and hackerspaces and co-working spaces from arising, by intervening in them and potentially adding strings attached which hackers eschew, as I have shown, the state nevertheless may undermine the ability of individual agents to polycentric structures. Or indeed, by devising state based institutions, such as intellectual property rights, that artificially raise the return and incentives of entering the state-based system, the government may too be making the innovation system more fragile. Put another way, by integrating polycentric entrepreneurial institutions within the state-led sector the innovation system may become more fragile. Because private governance structures, such as hackerspaces, are dynamic systems conducive to spontaneous ordering of entrepreneurial information and actors, caution should be

exercised when attempting to integrate these institutions within the state-led sector. Caution should be taken with state intervention here—especially that which comes with conditions or requirements attached—for this may nullify the non-price coordination and private governance mechanisms that hackerspaces have developed. More specifically, the sovereignty of hackerspaces must be maintained to induce ordering and prevent ideas being pushed towards minimum viable products. Intervening in these spaces—which is a growing phenomenon—may in fact crowd out the coordination benefits of the indeterminate, dynamic, spontaneous processes at the heart of an innovation commons.[232]

7.5. Implications and conclusion

This chapter theoretically extended the institutional possibility frontier (IPF) framework, first developed by Djankov et al. (2003) and then Shleifer (2005), to the proto-entrepreneurial innovation problem. Given that each economic problem has different cost minimising institutional solutions, the IPF should not be represented as a society-wide function, but rather down at the level of the individual economic problem. This understanding enables a focus on the specific proto-entrepreneurial innovation problem outlined in this thesis. Further, the costs of institutional choice are not objectively known. The institutional solutions to economic problems are subjectively perceived. In this view, not only does each economic problem have its own IPF, but each individual person has their own subjectively perceived IPF. Further, societies do not choose the points within the IPF space, individuals do.

Together, these extensions create a new subjective political economy analytic tool to examine the comparative institutions of the innovation problem. This new framework was applied to the specific part of the innovation problem examined in this dissertation in order to draw broader implications. This thesis goes some way to a comparative lowering of the costs of disorder relative to the costs of dictatorship by shedding light on the capacity of individuals to privately govern entrepreneurial discovery in privately governed polycentric

[232] This is similar to how government intervention distorts the structure of production in Austrian capital theory.

innovation commons. This is a shift in the cost minimising interior tangency towards private orderings such as the innovation commons, at least from the perspective of those individual entrepreneurs who see polycentric innovation commons as the cost minimising solution.

Several implications for the political economy of innovation and entrepreneurship flow from this new representation of the political economy of innovation policy and the innovation commons. First, the costs of disorder may have been systematically overweighted because of a disregard for the potential of collective action self-governance solutions. Second, given the uncertainty and instability of a subjective political economy, innovation policy itself must undergo an institutional discovery process. That is, innovation policy faces a knowledge discovery problem over the subjective perceptions of the solutions to the innovation problem. Further, this process is framed by the reigning academic orthodoxy—whether that be through a choice-theoretic or contract-theoretic lens. Third, the evidence of secession from the institutions of innovation policy speaks to the entanglement of innovation policies, and suggests the need to maintain a robust political economy. This raises questions over the complementarity and substitutability of various innovation policies and their impact on the capacity of individuals to develop private polycentric orderings to solve the economic problems they perceive they face.

Chapter 8: Summary and conclusion

8.1. Introduction

In modern economics the two main perspectives of the 'innovation problem' that society faces are market failure and systems failure. The market failure perspective of the innovation problem is that innovation outputs are public goods that will be sub-optimally produced in a competitive market due to lacking investment incentives. In this view the innovation problem is a problem of allocation of private innovation resources. This view leads to modern innovation policy, which is an attempt to correct the misaligned microeconomic incentives through state-based intervention. The second 'systems failure' perspective views the innovation problem as the complex interplay of different organisations. In a similar way to the market failure view, however, the solutions to system failure come primarily through government directing resources towards different institutional parts of the innovation system. Both of these conceptions of the innovation problem society faces are choice-theoretic analyses, emphasising the investment and the allocation of resources. Further, both of these choice-theoretic approaches to the innovation problem obscure from the process of entrepreneurial discovery of market opportunities, and in particular the governance and institutional mechanisms entrepreneurs use to coordinate the information to discover market opportunities.

This thesis has developed and applied a mainline contract-theoretic approach to the innovation problem in economics—with a foreground of analysis of uncertainty, institutions and entrepreneurship—analysed the private governance solutions to this problem, and placed these institutional choices within the context of the political economy of the institutions of innovation and innovation policy. My new contract-theoretic institutional perspective of the innovation problem does not place investment or allocation of innovation resources at the forefront of analysis, but rather begins from the perspective of the entrepreneur and their economic problem of coordinating dispersed and contextual information through comparatively effective governance structures to discover market

opportunities. This institutional perspective emphasises the institutional mechanisms that proto-entrepreneurs privately and collectively develop to economise on the transaction costs of coordinating information, and to solve their economic problem of discovering actionable market opportunities. Most generally my approach can be placed within the institutional mainline of economic thought (Boettke 2012)—in the sense that it is methodologically individualist and begins from the perspective of the entrepreneur, understands the limits of the human mind owing to bounded rationality and the subjectivity of the future, and acknowledges the potential for private ordering solutions to economic problems. Developing this new mainline approach to the innovation problem has drawn on several strands of mainline literature including Austrian and mainline theories of entrepreneurial discovery (Foss and Klein 2012; Kirzner 1978a; Knight 1921; Mises 1949), the logic and framework of transaction cost economics (Williamson 1975, 1979, 1985a), the economics of common pool resource management and the economics of collective action governance more broadly (Hess 2008; Ostrom 1990), and the new comparative economics and its focus on choice over institutional governance (Boettke et al. 2005; Djankov et al. 2003; Shleifer 2005). These distinct threads of literature were bought together to explore and analyse a new governance-centred contract-theoretic approach to the innovation problem.

This thesis has contributed not just to entrepreneurial theory, new institutional economics and the common pool resource program, but also to the economics of economic growth, and the political economy context of innovation policy that seeks to propel that growth. The applications of mainline economic thought—focusing on the hackerspace phenomenon and the development of blockchain technology—demonstrated that early stage proto-entrepreneurs do indeed develop privately governed polycentric structures to coordinate the information they require, and that, at least in their subjective perceptions, these may be transaction cost economising institutional solutions to the economic problem they perceive they face. Furthermore, these applications have implications for the political economy of innovation policy—which presently emerges from a choice-theoretic perspective—and in particular how the costs of governance solutions to the various stages

of the innovation problem are subjectively perceived by entrepreneurs, and that government intervention must acknowledge the entanglement of the costs of institutional solutions.

8.2. Contributions

Part I of the thesis was theoretical development. This began at the level of the early stage proto-entrepreneur and examined their transaction costs as they coordinated with others in groups. This enabled the development of a new transaction cost contact-theoretic definition of the innovation problem (Chapter 2). Polycentric collective action governance in the innovation commons was proposed as a potentially optimum institutional solution to the proto-entrepreneurial problem (Chapter 3). Part II applied this theoretical development to several cases. The focus was on the micro-institutional mechanisms developed by proto-entrepreneurs as they engaged in hackerspaces (Chapter 4) and in hybrid organisations coalescing around blockchain technology and blockchain entrepreneurs seek to develop the crypto-economy (Chapter 5 and Chapter 6). Part III outlined the political economy context. The institutional possibility frontier from new comparative economics was extended and applied to the proto-entrepreneurial innovation problem, drawing implications for the institutions of innovation and innovation policy (Chapter 7).

8.2.1. A new institutional approach to the innovation problem

We can now return to the three questions posed at the beginning of this dissertation. First, *what is a mainline institutional approach to the innovation problem in economics?*

Part I of this thesis developed a mainline institutional contract-theoretic approach to the innovation problem in economics. Chapter 3, focusing on the earliest stages of entrepreneurial discovery, proposed that the proto-entrepreneur must coordinate non-price information with others in order to define an actionable market opportunity, and they must do so in comparatively effective governance structures facing non-zero transaction costs. The characteristics of the knowledge necessary to define market opportunities were proposed as being both distributed and uncertain. This suggests that, given some potential

gains from trade of coordinating that proto-entrepreneurial information, the early stage proto-entrepreneur must escape innovation autarky to engage and coordinate information with others. An institutional definition of the innovation problem, therefore, focuses on the on the governance choice by the entrepreneur on how they perceive governance structures will comparatively economise on the transaction costs in their economic problem. This section also proposed the existence of an entrepreneurial fundamental transformation. That is, as a proto-entrepreneur coordinates non-price information with others about market opportunities, their microstructure of transaction costs changes, and so too does the potential range of transaction cost economising governance structures. This suggests that the earliest stages of an innovation trajectory—where proto-entrepreneurs are seeking to discover actionable market opportunities—may have a different transaction cost economising governance structure to the entrepreneurial process of acting on or exploiting those opportunities. Therefore, the economic problem of entrepreneurial discovery not only occurs with others in an institutional context, but also that the economic problem facing the entrepreneur has an intertemporal dimension—it changes throughout an innovation trajectory.

A further implication of this new approach is that the transaction cost economising institutional solutions to the innovation problem are not constrained to firms, markets and states. My approach adopted in applying the transaction cost economising framework is an institution neutral one. Following this comparative institutional analysis, as we see below, hybrid polycentric governance in the innovation commons may be the optimum institutional solution to economise on the transaction costs of the proto-entrepreneurial problem. This suggests that the private governance of entrepreneurial discovery, particularly in the earliest stages of the innovation trajectory where structural uncertainty is highest, may be more important to innovation, and therefore to economic growth, than previously thought.

The transaction cost economising governance structure in the earliest stages of the proto-entrepreneurial innovation problem may not be in firms, markets or states—but rather in privately governed polycentric hybrid governance structures such as innovation

commons. An innovation commons is defined by their underlying resource—of distributed, contextual and uncertain non-price information about market opportunities. This proposition came through application of Williamson's 'discriminating alignment hypothesis', and in particular that a hybrid structure may deal well with the dual concerns of overcoming the structural uncertainty of the proto-entrepreneurial problem as well as the threat of opportunism. This characterisation of an innovation commons was compared against previous types of commons, revealing several unique potential behavioural characteristics. An innovation commons does not necessarily emerge as a form of social provisioning, but rather as an institutional choice to realise the mutual gains from trade of coordination. An innovation commons acts to process the uncertainty about the potential of a market opportunity. Therefore, if an innovation commons is successful at whittling away the uncertainty around a market opportunity, then other governance forms will begin to outcompete the innovation commons—that is, an entrepreneurial fundamental transformation, at the level of the individual market opportunity, will shift the transaction cost economising governance structure. Finally, an innovation commons will not be society wide phenomenon, but will emerge specifically at the beginning of new technologies (especially general purpose technologies) and industries, where structural uncertainty is highest, and where there are potential gains from trade of coordinating proto-entrepreneurial information with others.

Therefore, the proposition of the innovation commons suggests that rather than new technologies being developed in the conventional organisational structures of firms, markets and states, the discovery of market opportunities may actually begin much further back in polycentric innovation commons. In this way the innovation commons may exist as institutions that precede, and indeed complement, the other institutions of innovation including firms and markets. From the perspective of the commons literature, the contemporary choice-theoretic understanding of the innovation problem in economics—ignoring the potential for collective action solutions—may be similar to the early stages of the 'tragedy of the commons' literature, where the costs of private collective action solutions were assumed to be prohibitively high.

8.2.2. The mechanisms of private governance to solve the innovation problem

We can now turn to the second question which was proposed at the beginning of this thesis: *how are entrepreneurs choosing to overcome this problem through private collective action governance?*

Part II of the thesis examined cases of proto-entrepreneurial private governance: Chapter 4 outlined the micro-institutional mechanisms developed by proto-entrepreneurs within the hackerspace phenomenon, Chapter 5 outlined the broader diversity of innovation commons emerging around a new general purpose technology, blockchain, and Chapter 6 provided a further higher order explanation for blockchain innovation commons drawing on new development economics.

Focusing on hackerspaces as a potentially analytically pure example of an innovation commons, Chapter 4 examined evidence that hackerspaces have developed mechanisms to overcome the transaction costs of the proto-entrepreneurial problem. A range of secondary data sources revealed that proto-entrepreneurs have developed a range of mechanisms that can be interpreted as attempts to economise on the transaction costs they face in discovering opportunities. Hackerspaces have forms of graduated social ostracism and exclusion based on the local contextual knowledge of the reputation of other hackers, mechanisms of costly signalling (such as teaching classes and volunteering) which may act both as a form of signalling to order complementary information and to reveal contributors, processes of collective action rule formation based on voting, and several tiers of nested hierarchies of rules that range from broad constitutional rules down to polycentric sub-group rules where proto-entrepreneurs form their own rules to govern exchange.

Focusing on a new potential general purpose technology, blockchain, Chapter 5 examined a range of diverse hybrid innovation commons as potential institutional solutions to the proto-entrepreneurial problem. Several secondary case studies explored the diversity of hybrid blockchain innovation commons coalescing around blockchain technology to discover its valuable uses. My analytical focus was on self-definitions in a range of blockchain innovation commons including workshops and conferences, hack-a-thons,

centres and online forums and message boards. Chapter 6 extended the potential explanations of blockchain innovation commons by stepping away from the assumption that blockchain technology was applied within a given territorial institutional environment. That is, rather than assuming that blockchain technology can only be entrepreneurially integrated within existing institutions, such as firms within the existing territorial institutions, this chapter emphasises the core functional role of blockchain technology as a tool for political exit or secession. From this perspective the core functional role of blockchain is to institutionally secede and create the new decentralised frontier society, the crypto-economy. This entrepreneurial problem requires a process of complementary institutional entrepreneurship and discovery. As such, using the new development economics literature, the economic problem facing blockchain entrepreneurs is to discover the complementarities of 'protective-tier' institutional technologies to form the institutional structure of the crypto-economy. Rather than in a territorial developing nation, where 'planners' (i.e. governments) may coordinate this discovery process, the lack of sovereign state in the crypto-economy suggests this process must be privately governed by 'searchers' (i.e. entrepreneurs). The implication of this is to provide a higher order explanation for the existence of privately governed blockchain innovation commons outlined in Chapter 5—that is, as a form of private economic development.

The implications of these contributions, taken together, are that the private governance of the proto-entrepreneurial problem around new technologies is indeed possible, and it may be optimal in the sense of solving the proto-entrepreneurial problem that entrepreneurs perceive they face. The institutional ecosystem within which entrepreneurial discovery occurs—particularly at the beginning of new technologies, including general purposes technologies—may be in privately governed polycentric innovation commons. These innovation commons may be more central to the discovery and development of new technologies than previously assumed, and may have been ignored in the literature due to their transient and temporary properties.

8.2.3. The subjective political economy of the innovation commons

The final question this thesis asks is: *given this new mainline understanding of the innovation problem and its private governance solutions, what are the political economy implications for innovation policy?*

What form of economic organisation a proto-entrepreneur engages in is a question of comparative institutional choice within an entangled political economy ranging from purely private to purely public governance. Part III outlines some of the political economy implications of the private governance of entrepreneurship within an innovation commons. The aim of this contribution was not to draw specific policy implications, but to examine how successful private governance in the innovation commons can be squared within the political economy of innovation policy using the institutional possibility frontier (IPF) from new comparative economics (Djankov et al. 2003).

The first contribution, together with Chris Berg, was to extend the IPF framework to incorporate the Austrian notion of subjective costs. The IPF is based on a trade-off between the costs of disorder and dictatorship in institutional choice. However, these costs are subjectively perceived by individuals because they are based on the opportunity costs of institutions. Given that each individual economic activity has a different cost minimising institutional solution, the IPF should not be represented at the level of a society, but rather must be disaggregated downwards to the level of the individual economic problem. The second contribution was to apply this subjective political economy framework to understand how the private governance of proto-entrepreneurship is squared with the institutions of innovation policy. In this view, each of the institutions of innovation, including each of the institutions of innovation policy, can be placed as points within the IPF space. This enabled an examination of the economic problem of proto-entrepreneurial discovery. The potential of collective action governance of entrepreneurial discovery within the innovation commons represents a flattening of the subjective IPF, which from the perspective of the proto-entrepreneur shifts in the cost minimising interior tangency towards private orderings such as the innovation commons.

Several implications for this new subjective political economy framework for understanding the mainline approach to the innovation problem were outlined. The costs of polycentric organisation within the innovation commons may have been subjectively and systematically underweighted in the application of innovation policy. That is, that the costs of disorder of developing private solutions to the innovation problem may have been assumed to be prohibitively high. This discrepancy also has implications for the understanding of the design and development of policies to stimulate innovation. In particular, the process of innovation policy itself is a discovery process. Governments must discover the entire constellation of subjective costs of institutions within the IPF space, and for each individual economic problem throughout the innovation process. This discovery process itself is an economic problem, which must be solved within the context of an entangled political economy where they are interdependencies between the social losses of the different innovation policies.

8.3. Limitations of study

This thesis has focused on the specific economic problem facing proto-entrepreneurs as they seek to coordinate information to discover actionable market opportunities. In contrast to the conventional choice-theoretic perspectives, this economic problem was viewed through the contract-theoretic lens of mainline economic thought, and then applied and contextualised within the framework of political economy. In this way, the aim of the thesis was not to develop a detailed institutional analysis of a single solution to the innovation problem. My analytical approach was a broad enquiry into entrepreneurial institutional choice over a wide range of potentially comparatively economising solutions. Connecting such seemingly disparate bodies of work within the mainline of economics—from transaction cost economics to new development economics—into a single coherent thesis, and with a constrained length, has some limitations. Some of those limitations are noted here, while others have been covered at various parts throughout the dissertation.

This thesis has not examined the entire suite of collaborative hybrid governance structures within which entrepreneurs engage, or indeed the literatures on hybrid

institutions within the innovation process. Rather, this thesis has developed the foundations of a contract-theoretic institutional approach to the collaboration between entrepreneurs within mainline institutional analysis. This leaves open the question of how the framework and contributions made here can be applied to understand some of the other examples of collaborative entrepreneurship and innovation activities elsewhere.

My study of existing innovation commons was through mixed methods over secondary data of contemporary innovation commons, and has not examined the specific motivations of entrepreneurs who are choosing to enter an innovation commons, or in particular whether those motivations are to later exploit those opportunities within firms and markets. The norms and values of the proto-entrepreneurs who choose to coordinate in innovation commons, such as hackerspaces, will influence the comparative efficacy of different forms of economic governance. Indeed, norms are an input into the subjective perceptions of institutional choice. In this same way I have not formally modelled the entrepreneurial choice of the comparative transaction cost economising properties of the various institutions of innovation. Such an approach would need to take into account the subjective perceptions of the proto-entrepreneur and their institutional choice.

Each of these limitations, however, presents opportunity for further examination. These future research opportunities sit variously on the boundary of institutional economics, entrepreneurial theory, and private governance, some of which are outlined below.

8.4. Further study

This new mainline institutional approach to the innovation problem opens up lines of economic enquiry in two directions. First, to the sources of economic growth and prosperity. This thesis began with a brief discussion of the drivers of modern economic growth since the Industrial Revolution, emphasising the structure of institutions and the process of entrepreneurial discovery. The theory of the innovation commons raises questions over how the culture or the values preceding this take-off in global prosperity shaped the formation of polycentric groups of proto-entrepreneurs. Can innovation

commons be observed in history? How did proto-entrepreneurs organise themselves when they embraced a culture of growth following the Scottish Enlightenment?

Second, to the dynamics of political economy. The subjective political economy framework developed within this thesis helps to expand the domain of new comparative economics. When taken into an intertemporal dimension, the subjective political economy framework helps inform the dynamics of coordination of subjective perceptions over institutional choice. How are institutional costs discovered through bargaining and through politics? Does the intensity of subjective perceptions of institutional costs alter the path of institutional change? How does this process of institutional choice play out as new technologies, such as blockchain, expand the suite of institutional possibilities? What does the potential for political exit and crypto-secession mean for institutional choice?

More generally this thesis presents scope for further case studies into the micro-institutional mechanisms of innovation commons. These studies could be undertaken within a modified version of the Institutional Analysis and Development (IAD) Framework, and be combined into a broader database of innovation commons, as has been the case with the study of natural resource commons. These case studies need not be constrained to modern technology-centred innovation commons, but could include a broader range of innovation commons throughout history, such as craft guilds or scientific societies, shedding light on the intertemporal proposition of an entrepreneurial fundamental transformation.

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Appendices

Appendix A: Blockchain conferences		
Conference Name	location	Website
Hackers Congress	Prague, Czech Republic	http://www.hcpp.cz/eng/
d10e	A series of events.	http://www.d10e.org/#san-francisco-2016
Coinfest	Many locations worldwide	http://www.coinfest.org/coinfest-2016/
Consensus 2016	New York	http://www.coindesk.com/events/consensus-2016/
The Bitcoin Conference	Lithuania	http://thebitcoinconference.com/
Bitcoin Conference Russia	Moscow	http://bitcoinconf.moscow/en
North American Bitcoin Conference	Miami	http://btcmiami.com/
Blockchain Conference	San Francisco	http://www.theblockchainconference.com/
Blockchain Conference New York	New York	http://www.blockchain-newyork.com/
London Blockchain Conference 2016	London	https://blockchainlondon.com/
Blockchain 2016	London	http://www.incoda.org/blockchain-2016/
Blockchain Congress 2016	London	http://europeanblockchain.com/
Blockchain Summit	London	http://www.marketforce.eu.com/events/financial-services/blockchain-summit
Blockchain Summit	Australia	http://www.blockchainsummit.com.au/

Blockchain Summit	Nekker Island	http://www.blockchainsummit.io/
The Business Blockchain Conference 2016	New York	http://thebusinessblockchain.com/
DC Blockchain Summit	Washington DC	http://digitalchamber.org/dcsummit.html
Blockchain Week	Barcelona	http://blockchainweek.co/
The Blockchain and Bitcoin Africa Conference 2016	Johannesburg	http://bitcoinconference.co.za/
The Blockchain Event 2017	Fort Lauderdale	http://www.theblockchainevent.com/east/
The Blockchain Conference	San Francisco, New York, Austin	http://www.theblockchainconference.com/
Blockchain World Expo	Toronto	http://www.blockchainworldexpo.com/
BLOCKCON	Singapore	http://blockcon.co/
DEVCON2	Shanghai	https://ethereumfoundation.org/devcon/
APAC Blockchain Conference 2017	Sydney	http://www.questevents.com.au/apac-blockchain-conference-2017

Appendix B: Bitcoin Embassies			
Name	Location	Website	Self-identification
emBassy Global Network	Worldwide	http://www.bitcoinembassy.io/	"Global locations where fellow likeminded cryptocurrency enthusiasts, and also members of the general public, can come together to learn more about Bitcoin and cryptocurrencies." "While extensive networking and business opportunities can be explored and discussed at such a location, the actual Embassies operate as a non-for-profit community organisation so entry is free." "All locations operate autonomously and independently."

Tel-Aviv Bitcoin Embassy	Tel Aviv, Israel	http://www.bitembassy.org/	"Here you can ask, share and talk about the new decentralized cryptocurrency." "It is a physical venue for all things Bitcoin. A place, for all walks of local and global community: inquirers, users, developers, investors, entrepreneurs, media etc. Everyone is invited, information is free." "The 'architecture' of the emBassy reflects the base concept of decentralized currency, by functioning as an open social code." "It is not a 'for profit' organization, yet it serves as a facilitator/platform for many bitcoin initiatives. The emBassy model strives to achieve sustainability by the support of the projects it incubates."
Bitcoin Embassy Amsterdam	Amsterdam, Netherlands	http://bitcoinembassyamsterdam.nl/	"At the Embassy you will find comprehensive and dependable knowledge relating to Bitcoin and the entire crypto-currency ecosystem. A place, for all walks of local and global community: inquirers, users, developers, start ups, investors, entrepreneurs, media etc." "By encouraging dialogue between businesses, banks, the media, and regulators, The Bitcoin Embassy aims to provide guidelines about compliance with Dutch and European laws when dealing with cryptocurrencies."
Bitcoin emBassy Stockholm	Stockholm, Sweden	http://www.bitcoinambassaden.se/	"Introductory lectures on Bitcoin for beginners and hosts more advanced lectures about crypto currencies and blockchain technology."
Embajada Bitcoin Espania	Madrid, Spain	https://www.territoriobitcoin.com/embajada-bitcoin/	"We help and advise on the process of adapting your business using Bitcoin." "The Embassy will try to become a meeting point, information, training and referral, about the exciting world of Bitcoin in Spain."

Ambasada Bitcoin Warszawa	Warszawa, Poland	http://www.ambasadabitcoin.pl/	“Bitcoin Embassy is a place where Bitcoin becomes tangible. It's also a place of meetings, training events, and the source of information on the Bitcoin world.”
Bitcoin Embassy Czech Republic	Prague, Czech Republic	http://bitcoinfoundation.cz/	“Our aim is to enable people to exchange resources and ideas freely.”
Bitcoin Embassy Ukraine	Kiev, Ukraine	http://www.bitcoinua.org/	“We are a civic organization that formed around an interest in blockchain technology and other distribution protocols, sees the common good in their use, and aims to become an information center for dissemination in Ukraine.” “Cryptocurrency legal framework in dealing with banks and legal entities Ukraine.”
Bitcoin Embassy Russia	Moscow, Russia	http://bitcoinembassy.ru/	“We understand how important it is to have full information about the processes taking place right now in 2015.” “Our mission - to promote education and a smooth transition of Russia to a new level in the FinTech segment. And right now in times of crisis, sanctions and the rapid depreciation of the currency Bitcoin will allow Russia not only to survive, but also to strengthen our economy, create reserves of Russia.” “We are happy to help you choose the correct position, and also will render all necessary assistance in drafting legislation.” “Among us there are employees with extensive experience in both Russian and foreign banks. We understand the importance of compliance with the RF legislation.”

Bitcoin Embassy Tokyo	Tokyo, Japan	http://bitcoinembassy.tokyo/	"Provides you the opportunity expert from beginner, start-up or investors to interact and share ideas and business."
Bitcoin Embassy Seoul	Seoul, South Korea	http://www.bitcoinembassy.kr/	"Where enthusiasts of cryptocurrencies can coexist and talk freely. Anyone who loves Bitcoin can participate freely, as it is a space of free communication among users. Bitcoin Embassy Seoul aims to help Bitcoin education, propagation, and communication."
Perth Bitcoin Embassy	Perth, Australia	http://www.bitcoinembassy.com.au/	"Our team can assist individuals and businesses with the tools and expertise to manage Bitcoin by providing all the equipment and expertise necessary."
Melbourne Bitcoin Technology Centre	Melbourne, Australia	http://bitcoincenter.co/	"The Bitcoin ecosystem is in its infancy and is fertile for innovation and experimentation. There are emerging spaces for focused businesses and projects to further drive the uptake and availability of access to technologies leveraging the blockchain. We aim to foster and support this activity through the creation of a community of driven and passionate advocates for Bitcoin and the opportunities it affords into the future." "Our commitment is to be true to the core values of the blockchain."
Montreal Bitcoin Embassy	Montreal, Canada	http://bitcoinembassy.ca/	"Educates and assists individuals and merchants on the use of Bitcoin and related crypto-technologies." "We act as an incubator for disruptive startups and financial services providers in the blockchain technology industry." "The Bitcoin Embassy is the first physical space in the world dedicated to blockchain technology and cryptocurrency."

Houston Bitcoin Embassy	Houston, United States.	http://texascoinitiative.com/	Bitcoin co-working space and also home to the Texas Coininitiative.

Appendix C: Bitcoin Centres			
Name	Location	Website	Self-identification
New York Bitcoin Center	New York, United States	http://bitcoincenternyc.com/	"dedicated to promoting Bitcoin, educating the public, and hosting the local Bitcoin community." "The Center holds events with well-known or relevant speakers and is a part of the bitcoin industry in a support role that no other group holds." "The Bitcoin Center aims to be a place where developers can really take their software developments to town, now focusing more on its developers than its public – first things first, as the industry can't take off properly until there are better ways for consumers to use the technology."
Toronto Bitcoin Decentral	Toronto, Canada	http://decentral.ca/	"A home to tech start-ups and innovative entrepreneurs that focus on disruptive and decentralized technologies."
Decentral Vancouver	Vancouver, Canada	http://decentralvancouver.com/	"We are not just another shared workspace, we are truly a niche community of likeminded individuals, friends, and peers. Our drive is to steer P2P and Blockchain Technology in a positive way that empowers the individual, and improves society – locally and globally."
Chicago Bitcoin Center	Chicago, United States	http://www.chicagobitcoin.com/	"Located in Chicago's 1871 (www.1871.com) incubator—an entrepreneurial centre home to 325 early-stage digital startups—Chicago's Bitcoin Center will provide a co-working space, mentorship, public relations and government affairs services to blockchain-focused startups."

Espacio Bitcoin Buenos Aires	Buenos Aires, Argentina.	http://espaciobitcoin.com/	"Meeting space for the Bitcoin community and technology in general, together with an ideal environment for entrepreneurs coworking." "The Seedcoin Coworking Space has daily, weekly and monthly plans (one, two and three times a week). And the conference and meeting rooms can be rented per day, half-day option also available. Special discounts for use of bitcoin."
La Maison Du Bitcoin	Paris, France.	http://www.lamaisondubitcoin.fr/	"The House of Bitcoin is the space dedicated to Bitcoin in Paris. Individuals, come there to buy your first bitcoins. Companies, you can train to the challenges of Bitcoin."
Bitcoin Center Berlin	Berlin, Germany.	http://www.bitcoincenterberlin.com/	"Berlin has a great Bitcoin community. Between events at the GTEC, regular meetups, film nights, and a host of other events public and private, the community is alive and well." "The co-working space is on pause right now. May be resumed again in the future."
Bitcoin Center Korea	Seoul, South Korea.	http://bitcoincenterkorea.org/	"We provide educational classes, collaborative workshops, networking and other exciting events related to Bitcoin, FinTech or open source projects. In addition, we provide business development and incubation services."

Appendix D: Hackerspaces and others			
Name	Location	Website	Self-identification
Paralelní Polis	Prague, Czech Republic.	http://www.paralelnipolis.cz/en/	"The aim of the Institute Cryptoanarchy is to make available tools for unlimited dissemination of information on the Internet and encouraging a parallel decentralised economy, crypto currencies and other conditions for the development of a free society in the 21st century."

			“With a fast internet connection, reliable anonymity and decentralised currency, you preserve freedom which we have been loosing as a society.”
CoinSpace	New York, United States.	http://coinspace.io/	“Coinspace is a blockchain powered collective open to anyone working with bitcoin, ethereum, blockchain and beyond. We're an organization practicing radical transparency, with public financials and fair and open decision making. We keep track of the workspace needs and member input, and reward contributors in our own crypto-token riding on the bitcoin blockchain (colored-coins).” “We're using BoardRoom's ethereum-based governance app to manage membership, responsibilities and voting of the collective. As the technology allows for it, Coinspace will run as a Distributed Collaborative Organization.”
CoinApex	New York, United States	http://www.coinapex.com/	“As a team with diverse backgrounds, we all agree on one thing: Think big, work hard, and be flexible.” “Coin Apex has the structure in place to bring forth value in areas from giving guidance on regulatory compliance to building out specific programming projects.” “At Coin Apex, we help shape, develop and facilitate innovative ideas into full-on reality through the process of bringing technology companies, products and services to market. We aim to encourage the forward motion of the fintech ecosystem and help build the infrastructure needed to ensure sustainability of the emerging sectors of which we operate in.”