Borradores de ECONOMÍA

Too-connected-to-fail Institutions and Payments System's Stability: Assessing Challenges for Financial Authorities

Por:
Carlos León, Clara Machado, Freddy Cepeda y Miguel Sarmiento

Núm. 644
2011

BANCO DE LA REPÚBLICA
COLOMBIA

Too-connected-to-fail Institutions and Payments System's Stability: Assessing Challenges for Financial Authorities[1,2]

Carlos León[3], Clara Machado[4], Freddy Cepeda[5], Miguel Sarmiento[6]
Banco de la República (Colombia)

Abstract

The most recent episode of market turmoil exposed the limitations resulting from the traditional focus on *too-big-to-fail* institutions within an increasingly systemic-crisis-prone financial system, and encouraged the appearance of the *too-connected-to-fail* (TCTF) concept. The TCTF concept conveniently broadens the base of potential destabilizing institutions beyond the traditional banking-focused approach to systemic risk, but requires methodologies capable of coping with complex, cross-dependent, context-dependent and non-linear systems.

After comprehensively introducing the rise of the TCTF concept, this paper presents a robust, parsimonious and powerful approach to identifying and assessing systemic risk within payments systems, and proposes some analytical routes for assessing financial authorities' challenges. Banco de la Republica's approach is based on a convenient mixture of network topology basics for identifying *central* institutions, and payments systems simulation techniques for quantifying the potential consequences of *central* institutions failing within Colombian large-value payments systems.

Unlike econometrics or network topology alone, results consist of a rich set of quantitative outcomes that capture the complexity, cross-dependency, context-dependency and non-linearity of payments systems, but conveniently disaggregated and dollar-denominated. These outcomes and the proposed analysis provide practical information for enhanced policy and decision-making, where the ability to measure each institution's contribution to systemic risk may assist financial authorities in their task to achieve payments system's stability.

Key words: payments systems, *too-connected-to-fail*, *too-big-to-fail*, systemic risk, network topology, simulation, central bank liquidity.

JEL codes: E58, E44, C63, G21, D85.

---

[1] Paper selected to be presented at the Second BIS Consultative Council for the Americas Conference, Ottawa, Canada, May 2011. Authors are grateful to the Board of Directors of Banco de la República, Gerardo Hernández, Hernando Vargas, José Tolosa and Dairo Estrada for their comments and suggestions to this or to a preliminary document. Technical assistance and support by Joaquín Bernal was decisive for the development of the project and this document. Work by Orlando Chipatecua and Jorge Cely in a preliminary document is also acknowledged and appreciated. Additional research assistance provided by Gabriel Angarita. As usual, the opinions and statements are the sole responsibility of the author and do not necessarily represent neither those of the Banco de la República nor of its Board of Directors.
[2] Results are intended for academic and research purposes; they may not be used to infer credit quality or any type of assessment for any financial institution. [Original version: March 2011].
[3] Research and Development Section Manager, Financial Infrastructure Oversight Department, Payment Systems and Banking Operation Division (PSBOD), Banco de la República (BR), cleonrin@banrep.gov.co/ carlosleonr@hotmail.com [corresponding author].
[4] Head of the Financial Infrastructure Oversight Department, PSBOD–BR, cmachafr@banrep.gov.co.
[5] Leader Professional, Financial Infrastructure Oversight Department, PSBOD–BR, fcepedlo@banrep.gov.co.
[6] Expert Professional, Operations and Market Development Department, BR, nsarmipa@banrep.gov.co.

Contents

Abbreviations

BF	Brokerage Firm (please refer to Table 1)
BR	Banco de la República (Colombia's central bank)
CB	Commercial Bank (please refer to Table 1)
CDS	Credit Default Swap
CF	Financial Corporation (please refer to Table 1)
CFC	Commercial Financial Corporation (please refer to Table 1)
CHAPS	Clearing House Automated Payment System
CHIPS	Clearing House Interbank Payments System
CI	Credit Intermediaries (banking institutions, please refer to Table 1)
CPSS	Committee on Payment and Settlement Systems
CUD	Colombia´s large-value payment system
DCV	BR's depositary for clearing and delivering of TES
Deceval	Private depositary for clearing and delivering stocks and TES
ECB	European Central Bank
FIFO	First-In-First-Out
FRBNY	Federal Reserve Bank of New York
IMF	International Monetary Fund
LLR	Lender-of-Last-Resort
LTCM	Long-Term Capital Management
MF	Mutual Fund (please refer to Table 1)
NCI	Non-credit Intermediaries (non-banking institutions, please refer to Table 1)
NT	Network Topology
OMO	Open Market Operations
PFM	Pension Fund Manager (please refer to Table 1)
PoQ	Payments on Queue
PS	Payments System
QRA	Queue Resolution Algorithm
RTGS	Real-Time Gross Settlement system
SEN	BR's Electronic Negotiation System (TES only)
TBTF	Too-big-to-fail
TCTF	Too-connected-to-fail
TES	Colombia's central government local bond
TLF	Transitory Liquidity Facility
VaR	Value at Risk

Introduction

The most recent episode of market turmoil exposed the limitations resulting from the traditional focus on *too-big-to-fail* (henceforth referred as TBTF) institutions within an increasingly systemic-crisis-prone financial system. It is clear now that financial stability may not only be endangered by massive banking institutions, but also by non-banking participants significantly and intricately linked within the payments system. This has encouraged the appearance of the *too-connected-to-fail* concept (henceforth referred as TCTF), and has fostered an ongoing debate on financial authorities' (i.e. central banks, regulators and supervisors) role facing systemic shocks, either during market's disruption or tranquil periods.

Acknowledging the TCTF concept broadens the base of potential destabilizing entities beyond the traditional banking-focused approach to systemic risk, but requires methodologies which cope with complex, cross-dependent, context-dependent and non-linear systems. A current trend for assessing the complexity and cross-dependency of financial and payments systems is based on network topology (hereafter NT), whilst context-dependency and non-linearity tends to be overlooked.

Hence, despite providing a comprehensive picture of systems' stability and resilience, NT is not suitable for approaching some of financial authorities' key practical concerns: If a systemic relevant institution fails, what is the intra-day and end-of-the-day dollar-value of the liquidity required by each institution within the system? Is the legal framework for customary and last-resort liquidity facilities appropriate for all the system´s participants? Is there any single institution or type of institution that conceals systemic risk? What is the market's liquidity level which may intensify dependence between institutions?

Therefore, based on a convenient mixture of NT (Becher et al., 2008; Soramäki et al., 2006) and payments systems simulation techniques (Leinonen and Soramäki, 2004), Banco de la República (BR) developed a robust, parsimonious and powerful approach for identifying and assessing systemic risk within Colombia's financial markets. First, NT basics are used to identify TCTF institutions according to the *centrality* concept. Afterwards, based on the observed transactions of an estimated payments system's typical day, the simulation procedure replicates Colombian large-value payments systems' queue resolution and multilateral settlement algorithms in order to quantify the potential consequences of the collapse of a TCTF institution.

Unlike econometrics, other customary approaches and NT alone, results consist of a remarkably rich set of quantitative outcomes which capture the complexity, cross-dependency, context-dependency and non-linearity of the payments system, but conveniently disaggregated and dollar-denominated. These outcomes and the proposed analysis provide financial authorities with practical information for enhanced policy and decision-making, where the ability to estimate each institution's contribution to systemic risk may assist financial authorities in their task to achieve payments system's stability.

This paper is divided in four sections. The first –next- section briefly covers the development of the TBTF concept for detecting and assessing systemic risk, ending with the recent appeal for the TCTF concept. The second analyzes the rationale behind the surge of connectedness as an alternative concept for detecting and assessing systemic risk. The third section is dedicated to familiarize the reader with some key features of Colombia's payments system; to present the chosen approach, and to analyze the results.

Finally, the fourth section makes some concluding remarks that may be useful for financial authorities.

1 The *too-big-to-fail* concept for systemic risk

Traditional assessment of systemic risk has focused on those market participants considered as TBTF, where that label may be granted to an institution when, due to its size, its inability to meet its obligations could result in the inability of other system participants or of financial institutions in other parts of the financial system to meet their obligations as they become due. Basically TBTF institutions are those exceeding an asset-size cutoff (Saunders et al., 2009), which is a convenient and straightforward metric readily available for any regulator or central bank, even accessible for any market participant or a fairly informed ordinary man.

Despite more complicated definitions may focus on the volume of financial services (e.g. deposits, loans) provided by an institution within the financial system (IMF et al., 2009) or other less forthright metrics, the TBTF concept for identifying systemically important institutions is rather uncomplicated, and may explain why customary tools for crisis prevention and management are designed specifically for large bank runs (e.g. lender of last resort –LLR-, deposit insurance). Moreover, because it focuses on standard accounting data (e.g. assets, investments, deposits), financial authorities have found this approach as practical. This type of supervision may be depicted as micro-prudential, since, as defined by Brunnermeier et al. (2009), it focuses on factors that affect the stability of individual institutions.

Financial history documents supervisors and central banks' reliance on the TBTF-based approach for detecting and assessing systemic risk. Quantitative evidence validates that the larger the institution, the closer the scrutiny by regulators and the less likely they are left to collapse[7] (Heffernan, 2005; Gup, 1998). In fact, as will be presented next, some of the most relevant episodes of systemic instability throughout history include the failure or near failure of a large banking or non-banking institution.

Regarding early episodes of large banking failures, it is worthwhile describing U.K. and U.S. cases in the late 19th and the wake of the 20th centuries, respectively. In 1866 England experienced the collapse of Overend Gurney and Co. Ltd., a financial institution involved in banking and bill broking, with a balance sheet ten times the size of the second largest, which precipitated the failure of a considerable number of other banking and non-banking institutions. Despite Bank of England refused to rescue Overend, which was finally declared insolvent due to losses resulting from bills of dubious quality and lending with poor collateral, Bank of England's actions during the episode[8] stated that it would intervene as LLR in situations of severe panic related to large banking institutions (Heffernan, 2005). In 1890 Baring Brothers, a large international merchant bank founded in 1762, also failed due to non-performing loans granted to Latin American countries, but

[7] Based on Gup (1998), who provides a summary of bank failures and near failures comprising 70 institutions from Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, U.K. and U.S., from 1974 to 1997, authors calculated that regarding episodes involving large banking institutions (24), 22 ended without liquidation or closure (91.7%); episodes involving medium banking institutions (8) always ended without liquidation or closure (100%); and episodes involving small institutions (38), 15 ended without liquidation or closure (39.5%).

[8] In order to face the episode the Bank of England was allowed to suspend the 1844's Bank Act (also known as Peel's Act). Under this act Bank of England's discretionary ability to issue notes was restricted to a statutory £14 million above its holdings of gold bullion (Chancellor, 2000).

was finally rescued with private funds from the Baring family. Both cases, Baring Brothers and Overend, were the result of assets' mismanagement.

In the United States, resulting from the stock market crash of October 1929, 608 banks (with $550 million of deposits) failed during November-December 1930. As in the case of Overend Gurney and Co. Ltd. in the U.K., a large banking institution, The Bank of United States, failed. According to Friedman and Schwartz (1963), because it was the largest commercial bank by volume of deposits ever to have failed up to that time in the U.S. and due to its name, the systemic consequences of the failure of The Bank of United States in December 11th 1930 were substantial. Some other large failures followed. Ultimately, the banking crises transformed a recession into the Great Depression (Krugman, 2009).

After these large bank-related failures institutions' size gradually emerged as a critical concept for supervision and regulation purposes. This was the result of a dramatic change in the character of the contractions in late 1930, when several large bank failures led to the first of what were to prove a series of liquidity crises involving runs on banks and bank failures on a scale unprecedented in U.S. history (Friedman and Schwartz, 1963).

The first case of U.S. regulators using a TBTF policy to identify, assess and contain systemic risk originating in a large financial institution came in the 1980s with the Continental Illinois bank[9] (Heffernan, 2005). Continental Illinois was the seventh largest and the largest correspondent bank in the U.S. at that time, with assets about $41.4 billion. Regulators claimed that 66 banks, with assets about $5 billion, had investments in Continental Illinois that accounted for 100% of their equity capital, whereas other 113 banks, with assets of more than $12 billion, had investments that accounted within the 50%-100% range of their equity capital. After the Comptroller of the Currency announced in congressional testimony that the government would not let any of the eleven largest banks fail (Gup, 1998), Continental Illinois was rescued in 1984, nationalized in 1989, and taken over by Bank of America Corp. in 1994. It is worth mentioning that Continental Illinois' near failure resulted from its reliance on overseas funding and on oil and gas collateralized loans –both experiencing a severe downturn by mid 1980s-, and from its direct exposure ($1 billion) to large participations in high-risk oil loans from Penn Square Bank, a bank that was allowed to fail in 1982 because it wasn't considered a major bank.

In the U.K. one of the most famous cases of a size-related policy for assessing and containing systemic risk belongs to the Bank of England's rescue of Johnson Matthey Bankers in 1984 after it had to write-off half of its loan portfolio. Johnson Matthey Bankers was a banking institution pertaining to one of the five London gold price fixers (Johnson Matthey), which was one of the largest non-banking institutions in the City. According to Heffernan (2005), this is a rare case in which the TBTF doctrine was extended to protect large non-banking arms of a financial institution. As with Baring Brothers, Overend, Penn Square Bank and Continental Illinois, Johnson Matthey Bankers case is due to mismanagement of assets (e.g. non-performing loans).

The first legendary application of the TBTF concept for non-banking institutions was the effort by the Federal Reserve Bank of New York (FRBNY) to organize a consortium of investment banks in order to avoid the failure of a massive hedge-fund in 1998: Long Term Capital Management (LTCM). LTCM is a well-known case because it is a rather

[9] According to Kaufman (2002), other U.S. banks that were extended assistance via de LLR facilities under the TBTF criteria were the Franklin National Bank [1974], the First Republic Bank [1987], MCorp [1988] and the Bank of New England [1990]. Nevertheless, Kaufman agrees with Heffernan (2005) when concluding that the only genuine TBTF case was the Continental Illinois episode.

clear example of a large non-banking institution compromising financial stability (i.e. assets and liabilities amounted to $129 billion and $124.5 billion just before its collapse, respectively, and loans and derivatives positions estimated at $1.4 trillion), and because the intervention took place despite hedge funds were not regulated by the FRBNY, and albeit fund's portfolio wasn't even located in the U.S., but in Cayman Islands. As put forward by Lhabitant (2006), controversy followed LTCM's rescue because, for the first time, despite being a privately owned fund, with no widows or orphans to protect[10], a hedge fund was deemed TBTF, a status hitherto reserved for countries and large banks. Moreover, as stated by Freixas et al. (2002), additional relevance from LTCM comes in the form of private sector's embracing the TBTF concept for rescuing the hedge fund.

Despite public funds were not used to bail-out LTCM, FRBNY's struggle to coordinate the $3.6 billion rescue of a 124.5 billion-assets hedge fund drew attention to other large non-banking institutions. Two of these large non-banking institutions that immediately concentrated attention were The Federal Home Loan Mortgage Corporation (Freddie Mac), and The Federal National Mortgage Association (Fannie Mae). As early as in 2003, taking into account that the combined balance sheet of these two institutions was about $1.5 trillion, Heffernan (2005) stressed the systemic risk posed by them under the TBTF concept, and emphasized on the incapability of the private sector for implementing a rescue analogous to the one orchestrated by the FRBNY for LTCM.

Recent developments confirmed that worries about the systemic importance of large non-banking institutions such as Freddie Mac and Fannie Mae were not unfounded. The first global financial crisis of the twenty-first century began –silently- in 2006, but became noticeable by the late spring of 2006 when housing prices began to decline (Krugman, 2009). As a consequence of a weak housing market the earliest negative announcements began to appear during 2007[11], and got worse during 2008[12]. Without any doubt, the involvement of large financial institutions characterized the severity and extent of the crisis.

Nevertheless, troubled large institutions (e.g. AIG, Bear Sterns, Lehman, Fannie Mae and Freddie Mac) appeared rather late in the crisis, and their entrance resulted from their direct or indirect exposure to the U.S. subprime-mortgage market. Moreover, the 2005-2006 U.S. housing slump was not novel in recent history, with a few sharp declines in U.S. housing prices (e.g. 1989-1993 home prices fell by over 13%), and even in other major financial markets (e.g. Japan during the 1990s); as acknowledged by Pozen (2010), prior to 2008, no housing slump in any country has ever led to a global financial crisis. As suggested by Bullard et al. (2009), a relatively small portion of the home mortgage market triggered the most severe financial crisis in the United States since the Great Depression, whilst Haldane (2009) judges the subprime crisis as a rather modest shock by global financial standards.

[10] In fact the entry terms were rather tough: $10 million minimum investment, three-year lock-up, 2% management fee and 25% performance fee (Lhabitant, 2006).

[11] HSBC Holdings announced higher delinquencies than expected –priced- in a subprime portfolio [March 5th]; New Century Financial, the second-largest subprime lender, declared bankruptcy [April 22nd]; BNP Paribas suspended calculations of three money market funds exposed to subprime debt and halted redemptions [August 9th]; Bank of England announced liquidity support and a government guarantee for Northern Rock's existing deposits [September 14th and 17th]; Freddie Mac announced 2007 Q3 losses [November 20th]; Bear Stearns announced expected 2007 Q4 write-downs [December 20th] (Acharya et al. 2009).

[12] Not only major financial institutions announced losses (Lehman Brothers, Bear Sterns, Citibank, Merrill Lynch), but also recognized valuation models' weaknesses (AIG [February 11th]); purchases and nationalizations were made public (Northern Rock by the U.K. government, Bear Sterns by JP Morgan [March 16th], Merrill Lynch by Bank of America [September 15th]); closures were decided (Indymac [July 11th]); rescues were announced (Fannie Mae and Freddie Mac, by the U.S. Treasury [July 13th], AIG by the U.S. government [September 16th]); and, finally, bankruptcy materialized (Lehman Brothers [September 15th]).

After the crisis literature has converged to declare the obsolescence of the current model of supervision and systemic risk assessment. Banks, which have been considered as the main focus of systemic risk detection and assessment because of their size (e.g. assets, deposits, loans), were not the main source of systemic risk as before (i.e. via non-performing loans, mismanagement of assets, balance mismatch). The financial system has changed dramatically since the Great Depression: though banks still play a large role, many functions that defined their traditional domain are increasingly performed by securities markets and non-bank market participants (Kambhu et al., 2007), namely unleveraged institutional investors (e.g. mutual and pension funds) and highly leveraged institutions (e.g. hedge funds); this is, non-banking participants make up the so-called "parallel banking system" or "shadow banking system" mentioned by Krugman (2009) and Acharya et al. (2009).

But the most recent global financial crisis is not the only example of the importance of the "shadow banking system". Besides its extraordinary size, LTCM episode exhibited other particularities that financial markets, central banks and supervisors were not familiar with at that time. Concerning LTCM, Brown et al. (2009) asserts that the hedge funds industry poses systemic risk because (i) hedge funds are able to be highly leveraged, which allows them for obtaining high returns, but also may end in low or negative capital when facing severe declines in their investment portfolios; (ii) they tend to follow similar investment strategies; and (iii) there is a lack of transparency in their exposures and the counterparty risk they generate.

About leverage, Chancellor (2000) documents that the effective leverage within LTCM was reported to exceed $100 of debt for every dollar of equity, which served to build a loans and derivatives position estimated at $1.4 trillion. This leverage may also explain why during May and June 1998 LTCM experienced a 16% decrease in its market value due to a widening of spreads in the mortgage-backed securities market, followed by an additional 52% decrease in August after the Russian crises exploded, which ended in its September 23rd bailout after experiencing losses about 83% in that month only (Brown et al., 2009).

Concerning the use of similar strategies within the hedge funds industry, supervisors were suspicious that if LTCM was allowed to fail, it wouldn't be the only hedge fund to do so. Despite there are several sorts of hedge funds, they all share a common feature: they provide liquidity to the aggregate of those who demand liquidity. Therefore, as Brown et al. (2009) warns, it is quite natural that hedge funds follow similar strategies because they all take the other side of the liquidity demand and so end up with returns and positions that are correlated. Such correlation may result in additional systemic risk because problems in a single non-small or several non-large hedge funds may seriously erode the market value of the whole industry's portfolios via declining market liquidity and "liquidity spirals[13]". Furthermore, because hedge funds' strategies had been highly profitable since their inception, other industries were mimicking them, extending correlation and systemic risk to other parts of the financial markets; that was the case of Salomon Brothers' $1 billion losses in analogous arbitrage positions during 1998's third quarter.

Vis-à-vis the lack of transparency in their exposures and the counterparty risk they generate, LTCM was not only large by on and off-balance positions, but it was an

[13] "Liquidity spirals" refers to the internal amplifying process whereby a falling asset leads to more sales (deleveraging), which further drives down asset prices, financial intermediaries' profit and loss statements, and balance sheets net worth (Brunnermeier et al. 2009). In the case of hedge funds, "liquidity spirals" may be particularly harsh due to the leverage they are allowed to work with, which forces hedge funds to unwind large positions when facing losses or margin calls.

important –and obscure- source of counterparty risk for global markets. As documented by Brown et al. (2009), LTCM's off-balance positions comprised $1.3 trillion notional values of derivative positions, where six banks worldwide acted as counterparties of $1 trillion approximately. According to Lhabitant (2006), LTCM's own estimate was that its 17 largest counterparties, in closing out their positions with LTCM, would have incurred in aggregated losses between $3 billion and $5 billion, with some individual institutions losing as much as $500 million. Despite this direct losses figures were non-trivial, the FRBNY's eagerness for orchestrating the rescue resulted from the potential indirect consequences of LTCM failing. As put forward by Greenspan (1998) when defending the Federal Reserve's role before the U.S. House of Representatives, "the act of unwinding LTCM's portfolio in a forced liquidation would not only have a significant distorting impact on market prices but also in the process could produce large losses, or worse, for a number of creditors and counterparties, and for other market participants who were not directly involved with LTCM."

Nevertheless, LTCM and the most recent global financial crisis are not the only cases where institutions' size is not enough to explain the episode in full. On June 26th 1974 the failure of a small German bank, Bankhaus Herstatt, almost resulted in the U.S. clearing system's collapse. Despite its size (around 50.000 customers and DM 2.0 billion in assets), its closure by the German supervisory institution and Bundesbank's cease to clear for its account, caused an overseas chain reaction that began when Chase Manhattan, its correspondent bank in the U.S., decided not to honor $620 millions in payment orders and checks drawn on behalf of Herstatt's account. As documented by Davis (1995), the immediate consequences were that the U.S. clearing system nearly collapsed, the Clearing House Interbank Payments System (CHIPS) computer was switched off and the banks had to barter checks. This episode, where a small and "outside" institution almost resulted in the collapse of the U.S. payments system, encouraged the formation of the Basel Committee on Banking Supervision (Manning et al. 2009; Alexander et al., 2006).

Consequently, evidence demonstrates that focusing exclusively on the institutions' size averts authorities from effectively detecting and assessing the systemic risk lurking beneath the nowadays highly complex and interconnected global financial system; this is, regulation and supervision were too institution-centric to see through to the systemic risk (IMF, 2009). Hence, several authors (Chan-Lau, 2010; Clark, 2010; Acharya et al., 2009; Saunders et al., 2009; Zhou, 2009; Brunnermeier et al., 2009; Trichet, 2009) recognize the inevitability of using a broader set of concepts in order to detect and assess systemic risk.

2 An increasingly systemic-crisis-prone financial system

The simplest definition –from the Merriam-Webster dictionary- of a system could be: "a regularly interacting or interdependent group of items forming a unified whole". Three main concepts comprise this definition: (i) items, (ii) interactions (interdependence) and (iii) the whole, which could be conveniently exchanged for the purpose of this paper with (i) institutions, (ii) payments[14] and (iii) the financial market. Despite being obvious that none of these concepts exists in isolation, supervision has mainly focused on the institutions only, where the best example is the reliance on the institutions' size and other accounting metrics or ratios for detecting and assessing the risk within the whole system.

[14] Some authors (Chan-Lau, 2010b) regard balance sheet claims as connections. As will be addressed in the next chapter, this document embraces payments as the primary source of connectivity.

Financial markets constitute one among many other systems exhibiting a complex organization and dynamics, where the large number of mutually interacting parts self-organize their internal structure and dynamics with novel and sometimes surprising macroscopic emergent properties (Sornette, 2003); that is, the financial system is a complex adaptive system (Haldane, 2009). Thus, the micro-prudential approach to financial markets' systemic risk, which focuses on closely analyzing the system's components (institutions), is not only insufficient, but highly unsafe; as demonstrated by recent periods of financial turmoil (i.e. LTCM, the subprime crisis), the connections between components are as important as the components themselves.

Recognizing the importance of the interdependence between participants may significantly complicate the analysis. The smaller the number of items and connections, the easier it is to understand and analyze the system. The financial system exhibits a myriad of participants, which maintain numerous connections (i.e. they engage in payments) with several other participants, whereas the characteristics of the institutions and their payments are dynamic, with episodes of extreme shifts in their individual and collective behavior. Therefore, as suggested by Landau (2009), the structure of financial systems, which is based on the interdependence between multiple actors and counterparties, is complex.

Nevertheless, despite this type of complexity makes difficult to observe, understand and analyze the financial system, it is not an undesirable feature at all. Complex systems, characterized by numerous participants and connections, may take advantage of the existence of internal self-regulatory and self-repairing processes which could make the system robust to random shocks.[15] That is, the existence of numerous participants allows for significantly different holdings and strategies across the financial system, where such heterogeneity permits a proper and efficient risk dispersion through the system.

Unfortunately, this type of advantageous complexity has been gradually fading due to a rather undesirable feature of today's financial markets: homogeneity. A complex system's robustness depends on the diversity of its participants: if all participants develop the same task, with the same tools and strategies, and with identical objectives, connectivity may not serve the purpose of risk dispersion, but amplification. Based on Haldane (2009) and Rebonato (2007), authors conclude that contemporary financial systems have experienced a sharp decrease in diversity resulting from three main reasons: (i) pursuit of returns; (ii) deregulation and disintermediation; and (iii) uniform risk assessment tools.

As documented when analyzing LTCM's case, not only hedge funds followed similar strategies within the industry, but other financial institutions, eager to achieve the extraordinary returns exhibited by hedge funds during the first half of the 1990s, imitated their strategies; that was the case of the investment bank Goldman Sachs. More recently, the decline in interest rates on U.S. Treasury bonds during the first half of the 2000s stimulated an unanimous appetite for alternative debt securities, where the exposure to high-yield subprime mortgages was extensive to all sorts of financial institutions[16]. Such lack of diversity explains why rolling averages of correlations across financial markets' sectors averaged in excess of 0.9 throughout 2004-2007 (Haldane, 2009) and why

[15] Elton's (1958) seminal work on invasions by animals and plants concluded that complex food webs –with numerous species- are likely to contain predators or parasites that control invaders, whereas simpler webs are more vulnerable to population explosions; that is, in complex systems there are always enough enemies and parasites available to turn on any species that starts being unusually numerous.

[16] Historically low interest rates set by the Fed on short-term Treasuries encouraged the growth of subprime mortgages: volume of subprime mortgages rose from $120 billion in 2001 to $600 billion in 2006; this is, from under 6% to 20% of all mortgages originated (Pozen, 2010).

unprecedented simultaneous write-downs were common among major investment banks during the subprime crisis[17]. Even central banks –particularly risk adverse agents- are reported to have increased their weight on return since the late 1990s, where their preference for asset-backed securities, especially mortgage-backed securities, has also augmented, along with the increasing use of derivatives (Borio et al., 2008).

In addition to the pursuit of returns, but inexorably related to it, is the second reason for decreasing diversity within financial markets: deregulation and disintermediation. The banking industry during the 1980s and 1990s exhibited a dynamic resulting from a broader range of activities banks were allowed to engage in, and an unprecedented level of liquidity that facilitated capital markets taking on bank's intermediation activity.

According to Rebonato (2007) disintermediation pushed banks to undertake trading activities in order to compete with non-banking institutions and, because of deregulation, they were allowed to do so for the first time since the Great Depression; these new activities took the form of bond, equity, currency, commodities, derivatives and securitized mortgages' trading. By the mid 1990s all these activities, specially high-yield complex financial instruments, had become an increasingly important source of revenue for all financial markets' participants, making institutions' strategies and holdings similar to each other.

This deregulation and disintermediation process resulted also in a key characteristic of recent episodes of systemic risk: the system has changed from bank-based to market-based systemic events, where the emphasis shifts from funding liquidity to market liquidity (Kambhu et al., 2007; Hendricks et al., 2006; Kohn, 2006), with actual tools for crisis management designed specifically for –not very likely[18]- large bank runs (e.g. LLR, deposit insurance), but insufficient to cope with new –non-banking- sources of systemic risk. This unforeseen shift from funding to market liquidity results in insufficient liquidity facilities.

Furthermore, as a consequence of the increasing importance of market-based systemic events, current liquidity risk management practices should be examined. Despite liquidity risk management is carried out by financial institutions, it is not designed for assessing and mitigating persistent (i.e. long-lasting) or systemic (i.e. non-idiosyncratic) liquidity shocks (IMF, 2009b). Therefore, financial institutions and the regulators should be aware of the existence of a defective liquidity risk management framework, and should work on its enhancement.

Regarding the existence of uniform risk assessment tools, the widespread use of rather similar methods for risk measurement poses an additional threat to financial system's diversity. As acknowledged by the IMF (2007), from a systemic perspective, it is important to ensure that there are market participants either sufficiently disparate in their holdings and strategies, or able to take large opposing positions during periods of turmoil. In this sense, the extensive use of identical risk assessment tools, such as Value at Risk (VaR) or other enhanced versions of it (e.g. Conditional VaR), promotes similar risk strategies, which result in similar "diversified" portfolios and similar "rational" decisions across different banking and non-banking institutions. Even if VaR were a perfect risk

[17] Brown et al. (2009) reports that exposures on subprime-backed assets resulted in Morgan Stanley, UBS and Merrill Lynch, losing $15, $20 and $30 billion, respectively.
[18] Kambhu et al. (2007) stress that the financial system today does not seem highly prone to contagious runs on very large banking firms.

assessment tool[19], its universal usage in the financial industry results in an undesirable self-defeating mechanism during periods of market chaos, where decreasing prices and increasing volatilities are amplified by a destabilizing positive feedback effect; this is akin to the case against "portfolio insurance" strategies, which Sornette (2003) regards as a major factor contributing to the crash of October 1987.

IMF (2007) also documents that diversity of risk management models can be a stabilizing influence. In addition to this, it is important to mention that this issue is not exclusive to risk management tools: the use of similar asset allocation techniques may also engender positive feedbacks, either during tranquil or stressful periods; accordingly, from a systemic perspective, diversity of asset allocation models may also be desirable.

Therefore, as Haldane (2009) asserts, the financial system is complex and homogeneous, with the former resulting from the participation of numerous institutions, and the latter from the lack of diversity when comparing institutions' strategies and exposures, where the sum of both features results in a *robust-yet-fragile* system. The financial system is robust because, on average, the financial system is able to absorb a random shock on behalf of the existence of numerous institutions and connections between them; but it is –at the same time- fragile, since a targeted shock (an *attack*) to a hub (a TCTF institution) may not be absorbed, but amplified.[20]

In addition to the fragility resulting from complexity and homogeneity, financial innovation has made institutions and their interrelatedness even more obscure. Complexity not only emerges from the structure or interrelations between participants. Financial innovation, regarded as a source of risk diversification and efficiency during tranquil times (e.g. structured products, credit derivatives, options), may increase the system's dimensionality and complexity during markets' unrest.[21]

Haldane (2009) highlights that financial innovations such as securitization (e.g. CDS or other structured products) resulted in participants growing in size and interconnections multiplying, where the precise source and location of underlying claims became opaque, transforming risk into uncertainty in the Knightian sense.[22] Lehman fall provides good evidence on the subject: Braithwaite (2011) documents that not only competitors were not able to know who was exposed to Lehman, but they were unable to map their own exposures with ease, particularly because Lehman was not a single institution –but about

[19] Most of VaR shortcomings for effectively assessing risk are widely know (e.g. non-normality, kurtosis, skewness) and have been partially addressed using different VaR techniques (e.g. Extreme Value Theory, jump-diffusion models, GARCH, historical simulation). Nevertheless, severe shortcomings are still poorly addressed, such as long-term scaling, measuring dependence –and diversification effects- during extreme events, capturing persistence (cumulative losses) in price changes, among others.

[20] As Haldane (2009) argues, such *robust-yet-fragile* feature is a result of the system's complexity and homogeneity, but also a consequence of the fat-tailed distribution of institution's connectivity. About the latter, on average, a shock will be aimed to a non-TCTF institution, making the system robust to random shocks; however, if the shock is non-random but consists of a shock targeted to the tail of the distribution that contains TCTF institutions, the system will be seriously affected. This issue will be addressed in the next chapter.

[21] For example, months before the crisis the IMF's Global Financial Stability Report focused on how credit derivatives helped to make the banking and overall financial system more resilient, and to mitigate and absorb shocks to the financial system (IMF, 2006); four years –and a global crisis- later, the same report focused on how credit derivatives took center stage as difficulties in financial markets intensified and on how they played a key role in counterparty risk (IMF, 2010).

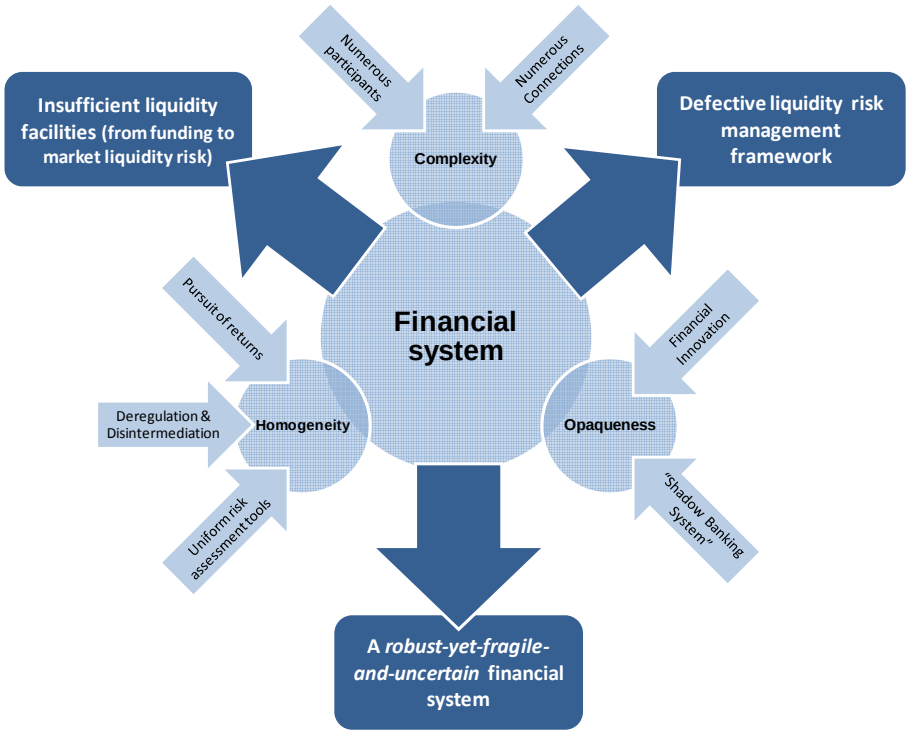
[22] According to Knight (1921), who provided an early definition of uncertainty and risk, the former corresponds to those cases in which we are unable to quantify the probabilities of various outcomes, whereas risk applies to situations where those probabilities can be known. Financial innovation, specially credit derivatives and securitization, obscured the way market participants relate to each other, resulting in counterparty risk becoming almost unknowable, thus uncertain.

10.000 institutions-, so no one could be sure what Lehman was. [23] In this sense, opaqueness in the linkages between participants make the financial system *robust-yet-fragile-and-uncertain*.

Moreover, this uncertainty, where the true counterparty exposure is difficult to define and assess, distorts asset pricing and encourages rational but –extremely- hazardous behaviors from market participants, such as herding. As a direct consequence of the opaqueness resulting from financial innovation, and due to the fact that its optimal to imitate when lacking information (Sornette, 2003), it is likely that during periods of turmoil market participants will have the "rational" incentive to imitate others' behavior, reinforcing the destabilizing positive feedback effect previously mentioned; this is, making the financial system even more fragile.

Finally, it is possible to conveniently characterize financial system's issues and challenges as follows: the sum of complexity, homogeneity and opaqueness results in a robust-yet-fragile-and-uncertain system, where the existence of a defective risk management framework and the absence of liquidity facilities able to cope with the shift towards market liquidity risk make the financial system highly prone to systemic crisis. This is summarized in Figure 1.

Figure 1
An increasingly systemic-crisis-prone financial system: issues and challenges



Source: authors´ design.

[23] Bear Sterns is also a good example. According to Acharya et al. (2009), while the market was learning about who was exposed to Bear Sterns by mid-June 2007, it was still unclear what the magnitude of this exposure was and who was at risk through counterparty failure. Kohn (2006) documents that uncertainty about counterparty risk –and market prices- was also experienced during 1987 stock market crash and the LTCM episodes, which he judges as the first two market-based (non-banking related) systemic events.