DISS. ETH NO. 22583

Liquidity Creation and Financial Instability

A thesis submitted to attain the degree of

DOCTOR OF SCIENCES of ETH ZURICH

(Dr. sc. ETH Zurich)

presented by

SUSANNE VON DER BECKE

M.Sc., London School of Economics and Political Science

Born on 22 July 1977

Citizen of Germany

accepted on the recommendation of

Prof. Dr. Didier Sornette, examiner

Prof. Dr. Perry Mehrling, co-examiner

2015

Short biography

Susanne von der Becke is a PhD student under the supervision of Prof. Didier Sornette at the Chair of Entrepreneurial Risks at ETH Zurich. Her work at ETH Zurich was presented at several academic and public conferences.

She graduated with a Master of Science in Management from the London School of Economics and is alumna of the GMP executive program at Harvard Business School.

Susanne draws on over 10 years of professional experience in the finance industry. Before joining ETH Zurich, she was a Director at Lehman Brothers in London, specialized in structured credit and asset-backed securities. She later held the position as a Vice President at LGT Capital Partners, leading a sales team dedicated to hedge fund and private equity investments.

Acknowledgements

I would like to express my deepest gratitude to my supervisor Prof. Didier Sornette for his guidance during my PhD studies and in writing this thesis. I have very much enjoyed all of our discussions, the frequent exchange of ideas, and the challenge to derive a deeper understanding of the topics under investigation. His immense knowledge, positive thinking and passion for work are truly an inspiration.

I also thank Prof. Perry Mehrling for accepting to be the co-examiner. His teachings on "Money and Banking", rooted in a profound understanding of economic theory as well as of present and historical money market operations, have strongly influenced this thesis. Moreover, I thank Prof. Florian von Wangenheim for chairing my doctoral examination.

My gratitude also goes to my husband Reto, for his encouragement and support in writing this thesis. His loving heart, generous soul and sharp mind are second to none. I could not wish for a better partner in life.

This thesis has benefited tremendously from comments and discussions with others. Specifically, I would like to thank Prof. Alistair Milne, Dr. Claudio Borio, Prof. Yuri Biondi, Dr. Peter Cauwels, Dr. Vladimir Filimonov and Dr. Fulvio Corsi for providing very helpful comments on various parts. I also thank the discussants of the SFI Brown Bag Lunch Seminar at University of Zurich.

Last but not least, I would like to thank the current and former members of the Chair of Entrepreneurial Risks. My special thanks goes to Prof. Yannick Maleverne for his work on quantifying our credit creation framework, Dr. Zalán Forró for trying out various ideas and running data, Dr. Qunzhi Zhang for helpful observations from the FCO, Amro Elsarafy and Florian Niclause for providing research assistance, Heidi Demuth and Isabella Bieri for helpful administrative support, and Tatyana Kovalenko for being such a pleasant office sharer. I also enjoyed enriching discussions with Hyun-U Sohn, Maroussia Favre, Dr. Monika Gisler, Dr. Dorsa Sanadgol, Dr. George Harras, Dr. Andreas Hüsler, Dr. Ryan Woodard and many others in the team.

Abstract

This cumulative thesis investigates how liquidity creation within the financial system can lead to financial crises.

In the first article, we develop a conceptual asset-based framework of credit creation based on three leading variables: (i) the amount of assets acceptable as collateral, (ii) the level of leverage and (iii) the level of trust and confidence. As credit expands along these dimensions in a non-linear dynamic, the financial system becomes more liquid. At the same time, it becomes more prone to endogenous feedbacks and vulnerable to internally generated instabilities manifested as booms and busts. Applying this framework to the global financial crisis, we show that the subprime crisis was both a signature and only one possible trigger in an increasingly unstable financial system. Using historical data, we demonstrate a significant shift in the components of US bank balance sheets and a decoupling of bank assets from deposits since the mid-1980s, marking the rise of "securitized-fractional reserve banking". The subsequent decades were a period of growing leverage, with debt-securities assuming money-like functions and serving as collateral for further credit creation. As trust began to recede, so did leverage and the amount of assets acceptable as collateral, leading to a contraction in credit and to liquidity spirals. Finally, we discuss the potential general applicability of this framework of credit creation and define extensions for future research.

In the second article, we extend the concept of a "hierarchy of money" to our current monetary and financial system based on fiat money, with monetary policy that is conducted through the sale and purchase of securities and credit intermediation by non-bank financial intermediaries. This exposes a feedback loop between the upper and lower level of the hierarchy, which allows for more than full use of otherwise dormant capital but that also increases inherent instabilities manifested in asset booms and busts. We find that, from the perspective of hierarchical money, the call to ban banks from creating money neglects the significant role of securities-based financing in the global financial market at the lower level as well as the money creation capacity of central banks at the higher level of the hierarchy. Moreover, the inherently expansive nature of the hierarchy of money contradicts the long-term feasibility of full-reserve banking.

The third article presents a partial review of the potential for bubbles and crashes associated with high frequency trading (HFT). Our analysis complements still inconclusive academic literature on this topic by drawing upon both conceptual frameworks and indicative evidence observed in the markets. A generic classification in terms of Barenblatt's theory of similarity is proposed which suggests, given the available empirical evidence, that HFT has profound consequences for the organization and time dynamics of market prices. Provided one accepts the evidence that financial stock returns exhibit multifractal properties, it is likely that HFT time scales and the associated structures and dynamics do significantly affect the overall organization of markets. A significant scenario in Barenblatt's classification is called "non-renormalizable", which corresponds to HFT functioning essentially as an accelerator to previous market dynamics such as bubbles and crashes. New features can also be expected to occur, truly innovative properties that were not present before. This scenario is particularly important to investigate for risk management purposes. This report thus suggests a largely positive answer to the question: "Can high frequency trading lead to crashes?"

Kurzfassung

Mit der vorliegenden Sammeldissertation wird untersucht, wie die Schaffung von Liquidität im Finanzsystem zu Finanzkrisen führen kann.

Im ersten Artikel wird ein konzeptioneller Rahmen für die auf Vermögenswerte gegründete Kreditschöpfung mit drei Leitvariablen entwickelt: (i) die Menge von als Sicherheit in Frage kommenden Vermögenswerten, (ii) der Fremdfinanzierungsgrad und (iii) der Grad an Vertrauen und Zuversicht. In dem Maße, wie sich die Kreditmenge entlang dieser Dimensionen in einer nichtlinearen Dynamik ausweitet, entsteht im Finanzsystem Liquidität. Zugleich werden in ihm interne Rückkopplungen wahrscheinlicher und es wird anfälliger für selbst erzeugte Instabilität, die sich als Auf- und Abschwünge darstellt. Mit der Anwendung dieses Rahmens auf die globale Finanzkrise wird gezeigt, dass die Subprime-Krise sowohl ein Vorzeichen als auch nur ein möglicher Auslöser in einem zusehends instabileren Finanzsystem war. Aufgrund historischer Daten wird eine klare Verschiebung der Bestandteile der Bilanzen von US-Banken und eine Entkopplung von Bankvermögen und Einlagen seit Mitte der 1980er dargelegt, welche die Hinwendung zum „Securitized fractional reserve banking“ markiert. In den folgenden Jahrzehnten wuchs der Hebeleffekt aus Fremdfinanzierung in der Art, dass auch Schuldtitel geldgleiche Funktionen übernahmen und bei der weiteren Kreditschöpfung als Sicherheit gestellt werden konnten. Mit dem Rückgang von Vertrauen schwächte sich dieser Hebeleffekt ab und die als Sicherheiten in Frage kommenden Vermögenswerte wurden weniger, was zu Kreditschrumpfung und Liquiditätsspiralen führte. Abschließend wird die potenziell allgemeingültige Anwendbarkeit dieses Kreditschöpfungsrahmens diskutiert und Weiterentwicklungen für künftige Forschungen definiert.

Im zweiten Artikel wird das Konzept der „Hierarchie des Geldes“ auf unser derzeitiges Geld- und Finanzsystem ausgedehnt, welches auf Fiatgeld beruht und dessen Geldpolitik durch Veräußerung und Erwerb von Wertpapieren betrieben wird. Hier ergibt sich eine Rückkopplungsschleife zwischen der oberen und der unteren Stufe der Hierarchie, welche die mehr als vollständige Ausnutzung sonst toter Kapitalien erlaubt, jedoch ebenso die inhärente Instabilität vergrößert, was sich als Auf- und Abschwung

am Vermögensmarkt zeigt. Es zeigt sich, dass aus Sicht des hierarchisch aufgefassten Geldes die Forderung, Geschäftsbanken von der Geldschöpfung auszuschließen, die sowohl auf der unteren Stufe also auch auf der oberen Stufe bedeutsame Rolle der auf Wertpapieren beruhenden Geld- und Kreditschöpfung ausblendet. Zudem steht das inhärent expansive Wesen der Hierarchie des Geldes der langfristigen Machbarkeit eines Vollreservesystems entgegen.

Im dritten Artikel wird eine Besprechung der Möglichkeit des Entstehens von Börsenabstürzen im Zusammenhang mit Hochfrequenzhandel (*high frequency trading*, HFT) präsentiert. Die Auswertung ergänzt die zurzeit unvollständige wissenschaftliche Literatur zum Thema durch den Rückgriff sowohl auf konzeptionelle Rahmen als auch auf Hinweise aus Marktbeobachtung als Belege. Eine generische Klassifikation gemäß der Ähnlichkeitstheorie nach Barenblatt wird vorgeschlagen und deutet unter Berücksichtigung der verfügbaren empirischen Belege an, dass HFT tiefgreifende Konsequenzen für die Organisation und die Dynamik von Marktpreisen hat. Die Annahme, dass Renditen auf Finanzwerte mehrfach fraktale Eigenschaften aufweisen, als belegt vorausgesetzt, ist es wahrscheinlich, dass HFT-Zeitschienen und die mit ihnen verbundenen Strukturen und Dynamiken die Organisation von Märkten nachhaltig beeinflussen. Ein wesentliches Szenario der Barenblatt-Klassifikation heißt „nicht renormalisierbar“ und entspricht einem HFT, der wesentlich als Beschleuniger vorgängiger Marktdynamiken, z.B. „Booms“ oder „Crashes“, wirkt. Das Auftauchen neuer Merkmale lässt sich ebenfalls erwarten, also tatsächlich neuartiger Eigenschaften, die zuvor nicht vorhanden waren. Dieses Szenario lohnt die Untersuchung im Rahmen des Risikomanagements besonders. Der Bericht gibt insofern eine im großen und ganzen bejahende Antwort auf die Frage: „Kann Hochfrequenzhandel zu Börsenabstürzen führen?“

Author contribution and funding sources

All articles in this thesis have been co-authored by Prof. Didier Sornette and Susanne von der Becke. The research question was formulated jointly. The articles were also written jointly. Susanne von der Becke provided data analysis and literature reviews.

The two papers “An asset-based model of credit creation” and “Should banks be banned from creating money?” were partially funded by the Swiss National Science Foundation. Both articles are currently in submission / re-submission.

The paper “Crashes and high frequency trading” was commissioned and funded by the UK Government. It was blindly peer-reviewed and subsequently published as one of the driver reviews in the Foresight project on the “Future of computer trading”.

https://www.gov.uk/government/collections/future-of-computer-trading#driver-reviews

LIQUIDITY CREATION AND FINANCIAL INSTABILITY

Table of Contents

PART II: MARKET LIQUIDITY

List of tables

List of figures

1. Introduction

This thesis was motivated by the desire to better understand two extraordinary events: the global financial crisis that started with the US subprime crisis in 2007 and the "Flash Crash" that occurred on May 6th, 2010. The global financial crisis led to the "Great Recession", with large repercussions for the real economy and monetary policy responses that in their scale are unprecedented in the history of central banking. The Flash Crash led US equity indices to fall by 10 percent in just a few minutes and saw individual shares suddenly trading at multiples or fractions of their previous price. On the one hand, my interest in these events is simple intellectual curiosity, particularly because the familiar models of efficient markets, rational agents, and equilibrium states did not leave much room for explanations. On the other hand, this quest has a personal dimension. How was it possible that some of the bonds that I sold during my time at Lehman Brothers were apparently worth close to nothing? How could a reputable investment bank suddenly go bankrupt? And was it really feasible that high frequency algorithmic trading could have caused the flash crash?

What both these events have in common is that they have been described as a "liquidity crisis" (Brunnermeier 2009; Easley, Lopez de Prado and O'Hara 2011). The general concern with liquidity crises is a contraction or sudden "evaporation" of liquidity. This is interesting, because it neglects the fact that prior to financial crises, liquidity is often particularly high. Trading volume, which is often mistaken as an indictor of market liquidity, was exceptionally high just before the Flash Crash. Moreover, several studies identify credit as a key driver of financial crises (e.g. Reinhart and Rogoff 2009; Mendoza and Terrones 2012; Schularick and Taylor 2012) and its growth as one of the best predictors of financial crises (Berger and Bouwman 2012; Jorda et. al. 2011). Only a few economists have suggested that, rather than a lack of liquidity, the problem of our current financial system is in fact its excess liquidity (e.g. Biondi 2013; Fantacci 2013; Borio 2014).

Liquidity is created through financial intermediaries. Market liquidity generally refers to the ease with which an asset can be exchanged for cash without impacting its price. Funding liquidity has been defined as the ease of obtaining financing in order to

settle obligations with immediacy (Drehmann and Nikolaou 2010). Brunnermeier and Pedersen (2009) showed that market and funding liquidity are essentially intertwined: traders provide market liquidity, which depends on their ability to obtain funding. At the same time, their ability to obtain funding is influenced by the market liquidity of their assets. As a consequence, borrowers can be caught in liquidity spirals, where an initial liquidity problem can swiftly turn into a matter of solvency. Traditionally, central banks could alleviate such liquidity crises by acting as a lender of last resort to banks. Within an increasingly market-based financial system, however, this has become ineffective and has led central banks to become essentially "dealers of last resort" (Mehrling 2011).

Financial intermediaries have been absent in the macroeconomic models, which influenced policy makers' decisions prior to the global financial crisis. Recently, there have been a number of attempts to rectify this and to include financial frictions in dynamic stochastic equilibrium models. Beck, Colciago, and Pfajfar (2014) provide a recent literature survey and discussion of theoretical and empirical findings on the role of financial intermediaries in the transmission of monetary policy. One strand of the literature models credit constraints faced by households and firms due to information asymmetries and collateral constraints, largely building on Bernanke and Gertler (1989) and Kiyotaki and More (1997). These models only consider market-based credit transactions and ignore bank-based funding. Another strand of the literature includes banks and models the macroeconomic impact of liquidity constraints within the financial sector. Interestingly, both strands of literature generally apply shocks to the financial system, which then amplify through mechanisms similar to the "financial accelerator" (Bernanke, Gertler, and Gilchrist 1999). The shock is an exogenous event that appears to be happening to the financial system, rather than being a result of its own behavior. This stands in contrast to Hyman Minsky (1986, 1992) and others who emphasized the inherent instability of the financial system. Moreover, it views the financial system primarily as a transmission mechanism of monetary policy. This neglects the fact that monetary policy itself is a direct response to the current and expected state of the economy and financial markets (Zhou and Sornette 2004).

In this context, the aim of this thesis is to connect different strands of literature in order to clarify and link important threads that can explain the underlying

mechanisms linking liquidity and financial instability. Methodologically, this thesis draws on theoretical and empirical findings within complex systems, finance and economics.

The remainder of this thesis is structured as follows. The first part of the thesis contains two articles concerned with the creation of funding liquidity. In our first article we develop "*An asset-based framework of credit creation*", which is consequently applied to the global financial crisis. This provides an alternative perspective to credit creation, which has been argued to arise either through the transfer of "prior deposits" or "out of nothing". Using historical flow of funds data, we analyze the components of US bank balance sheets and describe the rise of what we term "securitized-fractional reserve banking". We subsequently discuss the potential broader applicability of this asset-based understanding of credit creation.

In our second article, we apply a hierarchical perspective of money to our current financial and monetary system and use it as basis for answering the question: "*Should banks be banned from creating money?"*. This question goes back at least as far as the 1930's, when Irving Fisher (1936) and other economists proposed a monetary reform that envisioned to remove all private money creation by banks. The global financial crisis has reopened this debate and stimulated new advocates seeking to prohibit banks from creating money (e.g. Benes and Kumhof 2012; Chamley, Kotlikoff, and Polemarchakis 2012; Wolf 2014).

In our third article, we turn to the creation of market liquidity. In the presence of increasingly electronic and fragmented markets, high frequency traders have been described as the "new market makers" (Menkveld 2013). The paper *"Crashes and high frequency trading"* analyzes whether high-speed algorithmic trading could lead to market crashes. At the time of its publication, just over one year after the Flash Crash, academic literature using high frequency data was quite limited. We hence provide an *"Afterthought on HFT, liquidity and instability"*, which gives an overview of the current state of the literature and specifically addresses the role of high frequency traders as market makers.

Finally, we summarize our main findings and conclusion and provide supplementary material in the annex. Our asset-based-framework of credit creation is

partially the result of an initial contrasting of contradictory theories of credit creation among different schools of economic thought. We provide this as a background under the section *"Demystifying credit creation out of nothing"*. The annex also contains *"A comment on complexity",* which was published in Nature as a response to Haldane and May (2011) and others who argued that in order to understand the complex dynamics of the financial and economic system, one should invest in sophisticated models, combining system theory, various branches of the natural sciences, network analysis, and out-of-equilibrium agent- based models with traditional economics.

2. An asset-based framework of credit creation

An Asset-Based Framework of Credit Creation
(applied to the Global Financial Crisis)

Susanne von der Becke* and Didier Sornette
ETH Zurich, D-MTEC - Chair of Entrepreneurial Risks
Scheuchzerstrasse 7, 8092 Zurich, Switzerland
svonderbecke@ethz.ch and dsornette@ethz.ch
Working Paper – revised 27 January 2015

Abstract: We develop a conceptual asset-based framework of credit creation based on three leading variables: (i) the amount of assets acceptable as collateral, (ii) the level of leverage and (iii) the level of trust and confidence. As credit expands along these dimensions in a non-linear dynamic, the financial system becomes more liquid. At the same time, it becomes more prone to endogenous feedbacks and vulnerable to internally generated instabilities manifested as booms and busts. Applying this framework to the global financial crisis, we show that the subprime crisis was both a signature and only one possible trigger in an increasingly unstable financial system. Using historical data, we demonstrate a significant shift in the components of US bank balance sheets and a decoupling of bank assets from deposits since the mid-1980s, marking the rise of "securitized-fractional reserve banking". The subsequent decades were a period of growing leverage, with debt-securities assuming money-like functions and serving as collateral for further credit creation. As trust began to recede, so did leverage and the amount of assets acceptable as collateral, leading to a contraction in credit and to liquidity spirals. We discuss the potential general applicability of this framework of credit creation and define extensions in future research.

Keywords: Credit creation, Financial crises, Leverage, Liquidity, Confidence
JEL: B53, E12, E13, E51, G01

* Corresponding author.

2.1 Introduction

"It's obvious that many commenters don't get the distinction between the proposition that banks create money — which every economics textbook, mine included, says they do (that's what the money multiplier is all about) — and the proposition that their ability to create money is not constrained by the monetary base. Sigh. .... Bank loan officers can't just issue checks out of thin air; like employees of any financial intermediary, they must buy assets with funds they have on hand."

Paul Krugman, March 30, 2012[1]

"Based on how monetary policy has been conducted for several decades, banks have always had the ability to expand credit whenever they like. They don't need a pile of "dry tinder" in the form of excess reserves to do so."

William C. Dudley, July 29, 2009[2]

Although credit existed prior to money (Graeber, 2011) and research identifies it as a key driver in the history of financial crises (Reinhart & Rogoff 2009; Schularick & Taylor 2012), contradicting explanations persist on how credit is created, how it can be influenced and how it impacts the economy. In mainstream economics textbooks, credit creation by banks is generally understood to arise from their function as intermediaries between savers and borrowers within the fractional reserve banking system. As banks lend fractions of the money that savers deposit with the bank, they create loans and multiply the amount of money available to the economy. It follows that the amount of multiplication and lending is constrained by the availability of deposits and reserves.[3] This view is contradicted by scholars and practitioners arguing that banks do not need prior deposits but can create credit and money ex nihilo. The idea can be traced back at least as far as Schumpeter, who emphasized that banks' ability to create credit arises not from the transfer of existing purchasing power but through "the creation of new purchasing power out of nothing" ([1912] 1934, p. 73).

[1] http://krugman.blogs.nytimes.com/2012/03/30/banking-mysticism-continued/.
[2] http://www.newyorkfed.org/newsevents/speeches/2009/dud090729.html.
[3] The classic textbook example demonstrates how an initial deposit of 1,000 dollars can multiply to create 9,000 dollars in loans, consequently creating a total of 10,000 deposits and 1,000 dollars in reserves (Krugman & Wells, 2009, p. 393).

The role of money and credit in determining economic growth differs within various economic schools and with it its emphasis throughout the history of economic thought. For Fisher (1936), the chief cause of the Great Depression was a one-third reduction in the stock of bank money between 1929 and 1939. Like Schumpeter, he stressed that banks create money by "pen and ink" (p. 16). In his view, booms and depressions could be greatly reduced through a banking reform that would require banks to hold 100 percent in reserves and that would consequentially mitigate inflations and deflations. Since then, the mainstream consensus is that of long run neutrality of money and short-term non-neutrality (for a review and reconciliation of the mainstream consensus since Fisher and Wicksell, see Blanchard, 2000). Credit in relation to its impact on the economy has received attention mainly as a transmission mechanism of monetary policy either through interest rates or bank lending (e.g., Bernanke & Gertler, 1995). Credit is perceived from a monetary perspective: somebody's liability is someone else's asset and even though exchange may take place on credit, final settlement must be in money, hence only money matters. Consistent with the view of intermediation, banks as such have been absent in the dynamic stochastic general equilibrium (DSGE) models that were used by central banks to inform their monetary policy in the run up to the global financial crisis that started in 2007. Since the crisis, there have been several research efforts to incorporate the financial sector into DSGE models (e.g., Gerali et al., 2010; Gertler & Kiyotaki, 2011). Financial crises have generally been treated as exogenous shocks to the demand or supply side, albeit with some exceptions that incorporate endogenous feedbacks through credit and leverage (Kiyotaki & Moore, 1997; Bernanke, Gertler, & Gilchrist, 1999; Battiston et al., 2012b; Fostel & Geanakoplos, 2008).

At the same time, credit and financial intermediaries have always played a role in some schools of thought. For example, credit creation was at the heart of the Austrian business cycle theory (von Mises, [1912] 1953; von Hayek, 1933 and others). It viewed business fluctuations as a result of monetary imbalance due to credit creation within fractional reserve banking and/or expansionary central bank policy, a theme that remains central to contemporary Austrian economics (Horwitz, 2000; Huerta de Soto, 2009; Boettke, 2010; Holcombe, 2014). Credit creation within the banking system also plays a principal role in Post-Keynesian economics. From its

perspective, the money "supply" is demand driven and created not from prior savings but endogenously through the demand for credit (e.g. Lavoie, 1984; 2009; Godley 1999; Rochon & Rossi 2013). Minsky (1986; 1992) demonstrated the inherently unstable nature of credit due to the pro-cyclical behavior of financial intermediaries and borrowers.

A study by Bezemer (2011) shows that economists who anticipated the recent financial crisis had the following in common: a focus on credit flows and the differentiation between financial wealth and real assets. Interestingly, these economists came from a variety of schools of thought and only two out of twelve relied on mathematical models (Keen, 2013). Given the clear evidence of the importance of credit to understanding financial crises, and the contradictory views on how credit is created, this paper aims to discuss an alternative complementary perspective of credit creation. We propose an asset-based framework of credit creation according to which credit creation expands and contracts along three variables: (i) the amount of assets acceptable as collateral, (ii) the level of leverage, and (iii) the level of trust and confidence.

The remaining article is structured in three parts. The first part introduces the framework, its three key variables and the associated dynamics. In the second part, we apply the framework to the recent global financial crisis. Using historical flow-of-funds data, we document the rise of "securitized fractional reserve banking". We contrast traditional and securitized fractional reserve banking and argue that credit creation took place increasingly not through traditional banks but within this market-based system. Finally, we discuss the potential broader applicability of an asset-based-framework, its challenges and avenues for future research.

2.2 An asset-based model of credit creation

2.2.1 The dynamics: non-linear positive feedbacks

We propose an asset-based framework of credit creation based on three fundamental variables: (i) the amount of acceptable collateral assets, (ii) the level of leverage and (iii) the level of trust and confidence. These three variables of credit creation are not,

in general, independent. In the dynamics of a given economic and credit expansion, they interact and often mutually self-reinforce each other. We suggest that as credit expands along these variables, the financial system becomes more liquid and the money supply increases.

The key mechanisms of expansion and contraction are positive feedbacks (related to "procyclicality"), which result from the interaction between agents within the financial and economic system. This interaction is driven, for example, by our human tendency for cognitive biases, imitation and herding. In economics, these behavioral tendencies are perhaps best known as "animal spirits" (Keynes, 1936; Akerlof & Shiller, 2009). Positive feedbacks create instabilities that arise endogenously within the system and manifest in boom-bust dynamics, as previously described by Minsky (1986; 1992) and others. Indeed, laboratory experiments have demonstrated that bubbles can form in the absence of credit creation and asymmetric information and just on the basis of interactions between agents (Heemeijer et al., 2009; Hüsler, Sornette, & Hommes, 2012). The interaction of agents eventually leads to a critical stage, a bifurcation, at which the behavior or the system no longer follows its past trajectory but changes into a different state. At this "critical point", there are multiple possible triggers (often small in amplitude compared with their consequences), which can prompt the system to change regime. The eventual trigger is not the cause of instability but the result of endogenous processes leading to a build-up of instability (Scheffer, 2009). While risk transformations make the financial system more liquid and more complete, they can develop endogenous instabilities due to feedback between asset prices and trading strategies.[4] What seems to be more

[4] Following Kyle's (1985) model of the feedback of trading practices on market prices, several recent empirical and theoretical results show that such feedback effects can cause dynamic instabilities because of portfolio optimization, which increases cross-correlations between assets (Marsili, Raffaelli, & Ponsot, 2009) or can increase volatility because of heterogeneous beliefs (Zapatero 1998) or options trading (Bhamra & Uppal, 2009; Ni, Person, & Poteshman, 2005; Sircar & Papanicolaou, 1998). Brock, Hommes and Wagener (2009) demonstrate a mechanism in which the proliferation of financial instruments, in a model with heterogeneous agents, is found to lead to market instability. They show that the introduction of hedging instruments – which is supposed to make the market more complete and hence more stable – may destabilize it in the presence of traders who have heterogeneous expectations and adapt their behavior according to experience-based reinforcement learning. Caccioli and Marsili (2010), Caccioli, Marsili, and Vivo (2009) and Marsili, Raffaelli, and Ponsot, (2009) show that the market becomes more unstable, as additional Arrow securities are introduced, and approaches the ideal situation of completeness. The intuition is that as the market becomes more complete, the

efficient on an individual level can increase the risk for the system as a whole. For example, in an analysis of credit networks, Battiston et al. (2012a; 2012b) find that while increased connectivity reduces individual risk because of risk sharing, it increases the fragility of the system and systemic risk as a whole. Consequently, we suggest that as credit creation expands, financial markets approach a point of "criticality" at which even tiny perturbations can trigger a significant change in regime (Sornette, 2003).[5]

2.2.2. First variable: the amount of acceptable collateral assets

We stipulate that potential credit creation depends on the availability of assets qualifying as collaterals for loans. From a finance perspective, an asset can be defined as "anything having a commercial or exchange value that is owned by a business, institution, or individual" (Downes & Goodman, 2003). What makes an asset valuable is the expectation or confidence that this asset can be converted into cash at some point in the future. From a legal perspective, it has been defined as "real or personal property, whether tangible or intangible, that has financial value and can be used for the payment of its owner's debts" (Lehman, 2004). This definition exposes a direct link between assets and credit. Within our framework, any loan is given explicitly or implicitly against an asset posted as collateral. These can be tangible, such as property, or intangible, such as the talent (human capital) of an entrepreneur, or of the future professional income resulting from the investment in education in the context of a student loan. The asset-backed view is obvious when considering secured loans. However, it also applies to so-called "unsecured" loans: in consumer financing, for example, credit is given to people only with a high credit score. Their ability to generate future income from a job and their history of meeting previous credit

possibility of replicating the same cash flows using different portfolios increases leverage and enhances price fluctuations.

[5] We like to give the example of balancing a pen on top of one's fingertip. We will manage to balance it for a while until the pen falls perhaps because we jerked our hand or perhaps the wind blew it over. The immediate trigger is irrelevant; the ultimate cause was the fundamentally unstable position in the first place.

obligations serve as implicit collateral to the loan[6]. In the most extreme and too often trodden examples of history, borrowers themselves, or members of their family, have served as collaterals for a loan by serving as slaves (Graeber, 2011). An asset, defined in this broad sense, is hence dependent on the creditor's risk perception of the debtor's ability to fulfill his side of the exchange in the future (e.g., in goods, services or money). From this perspective, credit is never created "out of nothing" but always takes place in the presence of existing assets and confidence in future cash flows. The expression of "out of nothing" just reflects a lack of accounting for the not directly observable assets that are in reality present as collateral in one form or another.

2.2.3 Second variable: the level of leverage

On the one hand, the level of leverage refers to the level of debt obtained against some kind of asset. For example, how much a retail customer can borrow against his or her house, how much an entrepreneur can borrow against his or her shares or how much a financial intermediary can borrow against its securities. To the extent that securities can be borrowed and rehypothecated, the same set of securities (collateral assets) can be leveraged multiple times. We have defined assets as deriving their value from the creditor's risk perception of the debtor's ability to fulfill his or her side of the exchange in the future. Consequently, on the other hand, the level of leverage must also measure the ability to meet cash flow obligations with the income that is generated from various assets. This was key to Minsky's (1992) inherent instability hypothesis, which defined different stages of leverage as either hedged, speculative, or Ponzi finance.[7] From this income-debt perspective, entities without

[6] Note that the infamous subprime NINJA ("no income, no job and no assets") loans, extended in the build-up of the subprime crisis, were possible precisely because of the over-confidence placed in the future worth of the underlying collateral (the property). Other mechanisms also contributed, such as the lowering of the professional standards and the securitization-distribution model that relieved the issuers from default risks leading to moral hazard. Explicitly posted collateral reduces the necessity of confidence in the borrower as a counterparty and transfers the confidence to the expected worth of the collateral.

[7] Hedge financing being defined as economic units that can fulfill all their contractual payment obligations (principal and interest) through its cash flows. In contrast, speculative finance units are only able to meet their ongoing interest payment obligations and must roll over the debt in order to meet principal payments. Finally, Ponzi units are unable to cover their payment obligations from their

any equity constraints, such as for example a mutual fund or a national government, can become insolvent simply through liquidity shortfalls and in the absence of changing asset values. Minsky defined his three stages of finance as a progression towards increasing instability, fuelled by ever lower perceptions of risk (our third variable discussed below) during boom phases. This neglects the fact that it may be natural and necessary for economic units to be in either speculative or Ponzi state at some point in time. Biondi (2013) hence suggested that Minsky's stages of finance should not be understood in a normative sense but rather as morphological conditions that expose the factual interdependent states between the economy and finance. Moreover, he argued that, in this interdependent context, Minsky's analysis may be better served by an entity rather than by an ownership approach. The perspective would shift from that of ownership of capital to that of creditor-debtor relationships. It would consequently require a dynamic rather than a static view of accounting. A dynamic understanding of leverage, which takes into consideration its development over time and space from the perspective of economic entities, is therefore consistent with our dynamic framework of credit creation.

2.2.4 Third variable: the level of trust and confidence

In this asset-based framework, trust and confidence[8] are where the expansion and contraction of credit creation start. They are prerequisites for the expansion of assets accepted as collaterals (first variable) and the leveraging of assets (second variable). Financial prices and economic values are based fundamentally on trust (Bachmann & Zaheer, 2006). They are not based on fancy mathematical formulas or on subtle, self-consistent, efficient economic equilibriums. Rather, they are built on

operating cash flows and must hence rely on the sale of assets even to meet its interest payments (1992, p. 7)

[8] Trust and confidence have many similarities, involving both positive expectations about future events. However, trust is broader, whereas confidence is more specific (Adams, 2005). Trust involves a general measure of positive belief concerning the entire pattern of the behavior of the counterparty. By contrast, the term "confidence" is more appropriate for a belief in the competence in some dimensions of the other. As a consequence, a failure of confidence may be cured more easily and quickly than a failure of trust. Because the economic and financial literature uses both terms almost interchangeably, we also refer to these terms equally.

trust in the future, trust in economic growth, trust in the ability of debtors to face their liabilities, trust in financial institutions to play their role as multipliers of economic growth and trust that your money in a bank account can be redeemed at any time you choose. Akerlof and Shiller (2009) argued that confidence cannot be predicted rationally and is "the first and most crucial" of animal spirits (p.14). Spikes in risk perception can take place in the absence of significant changes in fundamentals and can lead to "self-fulfilling shifts in risk" due to feedbacks between the current asset price and risk about the future asset price (Bacchetta, Tille, & Wincoop, 2010). Bansal and Shaliastovich (2010) showed that uncertainty about expected economic growth affects investor beliefs and consequently influences asset prices and risk premiums. They found that the "confidence risk channel" is able to explain large negative price moves in the absence of fundamental changes in macroeconomic variables. In a similar spirit, Borio and Zhu (2012) highlighted the mutually reinforcing perception and value of risk and the increasing importance of the "risk taking channel" in the transmission of monetary policy.[9]

Financial stability, in general, and credit creation, in particular, requires trust and confidence. This is evident in our history of monetary regimes, which have shifted between commodity money and credit money. The former was associated with periods of war and low levels of trust, as it could be more easily used to settle with strangers and pay travelling soldiers. The latter generally involved repeating interactions within a community, and therefore required higher levels of trust and was present primarily in peaceful times (Graeber, 2011). Trust and confidence can be facilitated by transparency or by guarantees from trusted institutions perceived to have the necessary resources. One example is the effective elimination of traditional bank-runs through the introduction of deposit insurance. Another example is evidence that suggests that repo margins in the tri-party market, i.e., using a clearing bank,

[9] "The measurement, management and pricing of risk have moved from the periphery to the core of financial activity. The link between valuations and risk perceptions has tightened. The mutually reinforcing feedback between perceptions of value and risk, on the one hand, and financing constraints and "liquidity", on the other, has arguably become more prominent. Under some circumstances, it may therefore also contribute to amplifying business fluctuations more than in the past" (Borio & Zhu, 2012, p. 248).

were much more stable than those in the bilateral market (Copeland, Martin, & Walker, 2014).

2.3 Application to the global financial crisis

2.3.1 The Great Leveraging: a maturation towards instability

The decades preceding the global financial crisis were characterized by an increasingly large and more connected banking sector and by a build-up in debt in most advanced economies. The extent of this build-up is unprecedented in the history of more than a century and has thus been coined "The Great Leveraging" (Taylor, 2012).

Historical data show that the number of US banks steadily increased under the free banking and national banking era (from under 800 banks to over 25,000 between 1834 and 1913) and plateaued at around 15,000 banks after the introduction of deposit insurance. Since the mid-1980s, the number of US banks has been declining steadily.

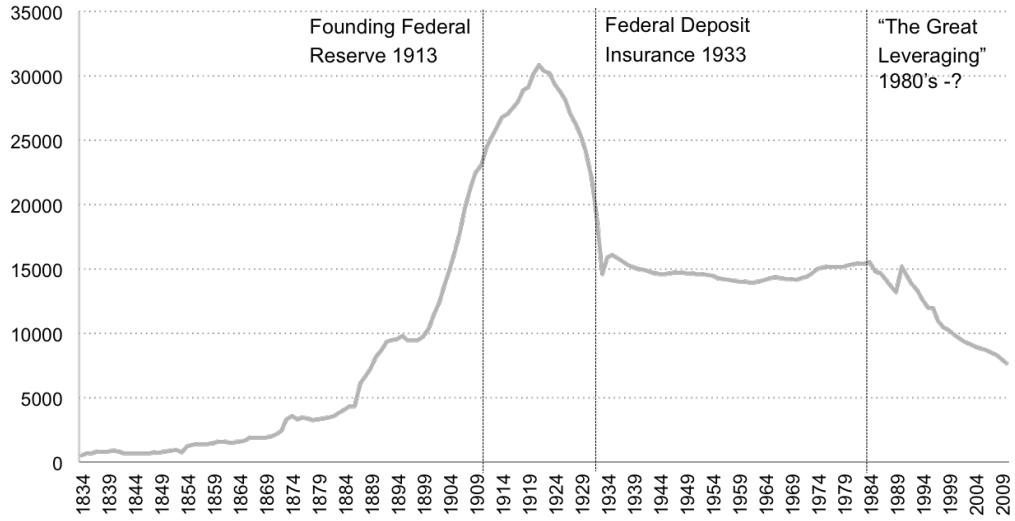


Figure 1:Number of US Banks from 1934 to 2011.
The number of US banks increased steadily and peaked in 1921 with over 30,800 banks. Between the founding of the Federal Reserve in 1913 and the Federal Deposit Insurance Corporation in 1933, the number of banks dropped by more than 50 percent. In the decades associated with the "The Great Leveraging" (mid-1980s to ?), the number of banks declined to levels last seen at the end of the nineteenth century.
Data: United States Census Bureau.

This decline in the number of banks, however, has been accompanied by a strong increase in bank assets. For example, a study by the Federal Reserve of St Louis shows that between 1984 and 2011, the number of US commercial banks halved, while average inflation-adjusted assets held increased from US$ 167 million to US$ 839 million. The concentration is even more evident at the top, as in 2011 "the five largest banks held 48 percent of total system assets. Four banks had total assets in excess of $1 trillion each, and the largest commercial bank—JPMorgan Chase Bank—had $1.8 trillion of assets, equal to 14 percent of the total assets of all U.S. commercial banks" (Wheelock, 2012). Commercial banks in the United States and Britain held about 5 percent equity against their assets. Interestingly, these levels have persisted since post-WWII, reaching this level at the end of a steady downward trend developing in the nineteenth century prior to the rise of securitized banking (the US asset-to-equity ratio around 1870 was 35 percent and this has steadily declined since).[10]

Moreover, the decades preceding the financial crisis of 2008 were characterized by globally increasing debt levels in the private and public sectors, which grew fastest in the advanced economies. For example, in the United Kingdom, the compounded annual growth rate of debt to GDP was 3.3 percent between 1990 and 2000, accelerating to 5.2 percent between 2000 and 2008, a total increase of 157 percent over the entire period. In the US, the percentage of household debt to disposable income has been steadily rising and grew particularly fast after 2000, from a level of approximately 90 percent to 130 percent before 2008 (Roxburgh et al., 2010; Roxburgh et al., 2012). In the run up to the financial crisis, private sector nonfinancial debt in Western countries rose by an average of 43 percent between the beginning of 2004 and the beginning of 2009.[11] Considering these figures, credit evidently financed much of the economic growth over recent decades.

It is important to stress that the same decades were accompanied by lower variability in prices and output, low unemployment and low inflation, generally referred to as "The Great Moderation". This calm period gave policymakers

[10] *The Economist*, "Free exchange: Strength in numbers", 10 November 2012.
[11] *The Economist*, "Global Debt Guide", 19 Sept 2012. Data excludes Germany.

confidence in their ability to steer the economy; risk perception was low and financial crises thought to be a thing of the past. The rise in leverage described above was hence also accompanied by an increase in confidence and trust. It shows that during the process of expansion, we tend to be oblivious to the internal risks building up, especially if credit and banks are excluded from our macroeconomic thinking. It is consequently not surprising that policymakers initially failed to grasp the wider global implications of what started as a relatively small local subprime crisis.[12]

Finally, these decades have also been characterized by an increasing finacialization of assets. In the United States, the growth in financial assets grew approximately at the same rate as GDP until the 1980s, when it accelerated at a much faster rate. According to some estimates, global financial stock increased from 54 to 212 trillion US$ between 1990 and 2010. This corresponds to a financial depth (global financial stock over GDP) of 263 percent and 356 percent, respectively.[13] Another study estimates the value of global financial assets in 2010 at about US$ 600 trillion (including those on financial intermediaries' balance sheets) compared with US$ 210 trillion of nonfinancial assets[14]. Of course, not all of these financial assets are by far eligible as collateral. However, the availability of assets has increased substantially with deeper financialization and wealth held in liquid financial assets, such as in debt instruments and derivatives thereof, which have become acceptable collateral for credit creation.

In summary, prior to the financial crisis, we could observe (1) an increase in eligible collateral for credit creation through the financialization of assets, (2) increasingly leveraged economies in most advanced countries, and (3) a sustained

[12] "All that said, given the fundamental factors in place that should support the demand for housing, we believe the effect of the troubles in the subprime sector on the broader housing market will likely be limited, and we do not expect significant spillovers from the subprime market to the rest of the economy or to the financial system. The vast majority of mortgages, including even subprime mortgages, continue to perform well. Past gains in house prices have left most homeowners with significant amounts of home equity, and growth in jobs and incomes should help keep the financial obligations of most households manageable" (Bernanke, 2007).

[13] Figures from the McKinsey Global Institute (Roxburgh et al., 2011).

[14] Figures from "A World Awash in Money" by Bain & Company (2012). "Financial assets" include the financial holdings of direct owners (e.g., households, corporations, governments) as well as financial assets controlled by and held on the balance sheets of banks and financial intermediaries. "Nonfinancial assets" include everything that might appear as a nonfinancial asset on a balance sheet, such as factories, farms, infrastructure and intellectual property.

period of trust seemingly validated by "The Great Moderation". These trends, which have been mostly present since the mid-1980s, have been accompanied by an unprecedentedly large and globally connected financial sector. Borio (2006) found that financial liberalization has "greatly facilitated the access to credit. It has therefore also increased the scope for perceptions of wealth and risk to drive the economy, more easily supported by external funding. More than just metaphorically, we have shifted from a cash flow-constrained to an *asset-backed global economy"* (p. 4, emphasis original).[15] Instrumental to this development has been the rise of what we call "securitized fractional reserve banking".

2.3.2 The rise of Securitized Fractional Reserve Banking

With "securitized fractional reserve banking", we refer to market-based credit creation, where credit is financed not from bank deposits but from short-term loans among primarily institutional investors, including non-bank financial intermediaries. Our terminology builds on the work of Gorton and Metrick (2010; 2012) who likened the financial crisis of 2007/2008 to a bank run not on deposits in the traditional banking sector but to a "run on repo" in "securitized banking". Whereas traditional banks create money (deposits) through granting loans, the securitized banking system creates securities that can function like money (for example, they can be used as a means of payment in mergers or they may be held as a substitute for bank deposits).[16] Both systems are inherently fractional and consequently prone to bank runs. In traditional banking, deposits can be converted into currency, and there are always more deposits outstanding than there is currency. In securitized fractional reserve banking, dealers convert deposits into securities, and there are always more money-like securities outstanding than there are deposits. The system is consequently prone to runs in times of crisis, when investors convert their securities back into deposits.

[15] Borio's emphasis is a reference to Calverley (2004), who may have first used the term "asset-backed economy".
[16] In this sense, we use the term "securitized" not just as a description of the bundling and tranching of loans, i.e. asset-backed securities, but as the financialization of assets through the creation of securities.

Consistent with the increasing financialization of assets since the 1980s, we can observe significant shifts in commercial banks' balance sheets. For example, bank assets and deposits had historically moved together, but data show a decoupling from the mid-1980s onwards as assets grew more than deposits. Comparing the liability side of US commercial banks in 1950 and 2007 demonstrates the decreasing importance of deposits for funding investments; in 1950, deposits made up 97 percent of liabilities compared with 66 percent in 2007. Most notable is the decrease in checkable deposits (against which reserve requirements are imposed) from 70 percent to 7 percent and the appearance of short-term financing including repos from almost nil to 13 percent. (After the crisis of 2007/2008, short-term financing decreased to 5 percent four years later.) Between 1945 and 2010, the asset composition of commercial banks changed markedly, from mostly treasuries to mortgages and consumer credit, both used extensively in securitizations and key instruments for bank funding.

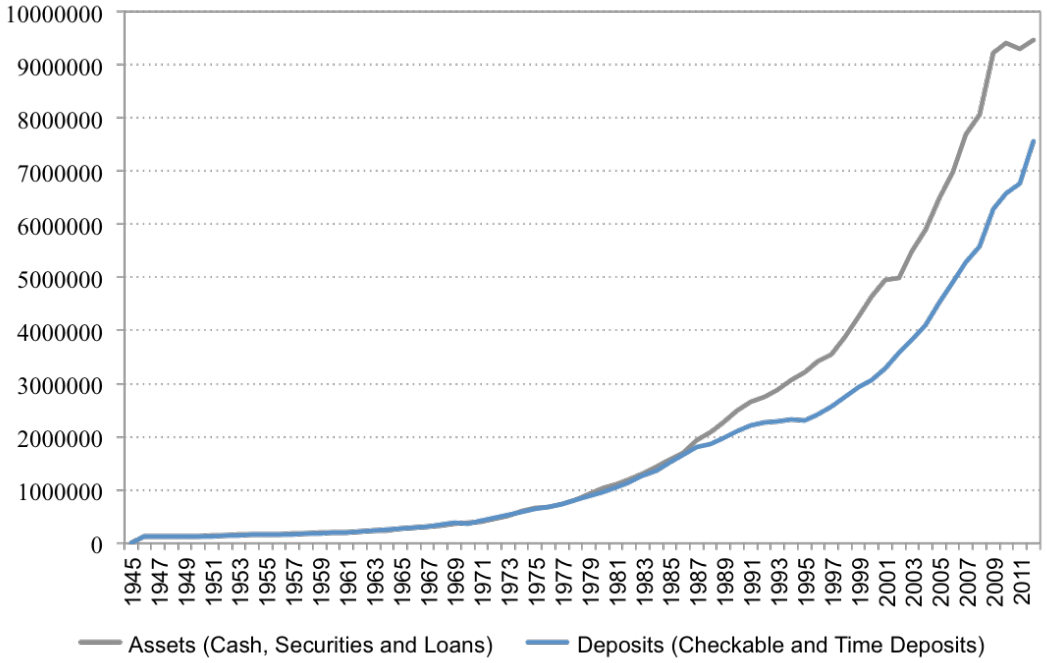


Figure 2: Assets and Deposits of US Commercial Banks from 1945 to 2011.
Assets and deposits move together until the mid-1980s, suggesting deposits mostly funded assets. Assets consecutively decouple, coinciding with the rise of shadow banking and increasing credit creation within the securitized fractional reserve banking system.
Data: Federal Reserve Flow of Funds.

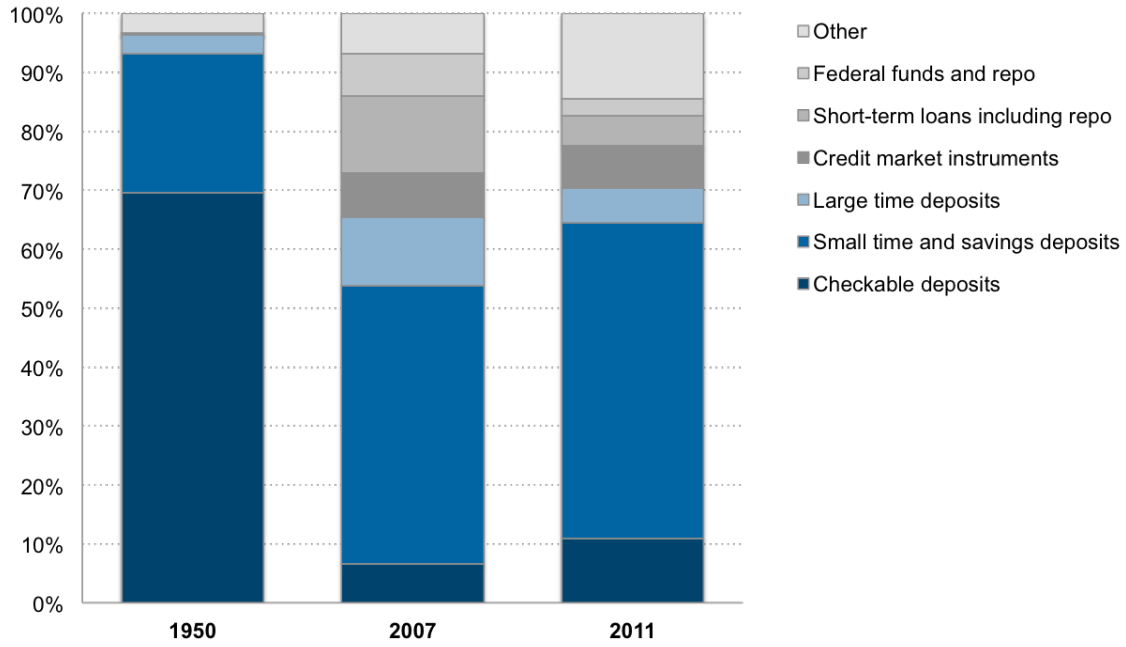


Figure 3: Composition of US Commercial Banks' liabilities in 1950, 2007, 2011.
The changing liability structure demonstrates a shift away from deposit-based funding toward short-term loans. After the crisis of 2007/2008, this trend slightly reversed.
Data: Federal Reserve Flow of Funds.

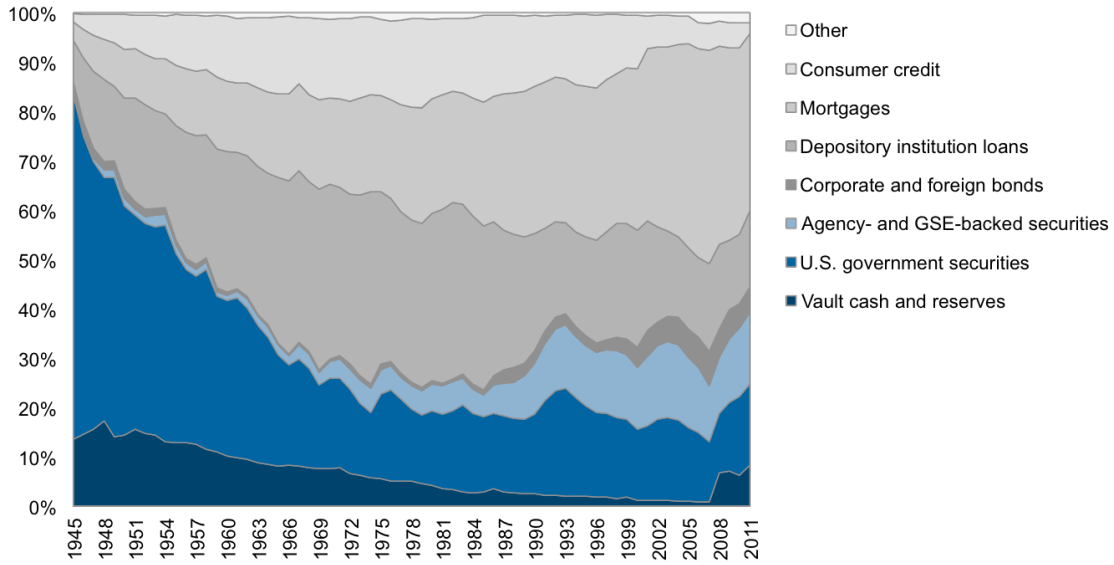


Figure 4: Composition of US Commercial Banks' assets from 1945 to 2011.
The changing asset structure demonstrates a transition from mostly US government securities toward mortgages and consumer credit as well as the decreasing percentage holdings of reserves until the Federal Reserve's balance sheet expansion in response to the crisis of 2007/2008.
Data: Federal Reserve Flow of Funds.

Repos and other short-term loans give financial institutions access to "deposit"-like funding, where they pledge securities to the lender, generally institutional investors, such as asset managers and nonfinancial corporates. King (2008) estimated that, by September 2008, just before the collapse of Lehman Brothers, about 50 percent of brokers' assets were financed by repos.[17] The securitization of loans (e.g., mortgages, credit card receivables, student loans) increased the amount of assets against which banks could obtain funding.[18] Additionally, "rehypothecation" and "securities lending" enable banks to obtain and provide funding from borrowed securities. Hedge funds, for example, often allow brokers to use their securities in return for funding and lower brokerage fees. The securities are not part of the bank's assets as they belong to the hedge fund, but they can be used by the bank as collateral to acquire funding. In the UK, the amount of customer securities that can be rehypothecated is unlimited and may even be used for proprietary trading by the prime broker. The US restricts this use and limits rehypothecation to 140 percent of the client's indebtedness to the broker (Singh & Aitken, 2010; FSB, 2012). In securities lending, institutions with custodial responsibility for asset managers lend their clients' securities against cash (or other securities), thereby increasing the amount of securities available against which credit can be granted[19].

[17] Note that banks' balance sheets do not reflect the full extent of short-term financing, as instruments can be both an asset and a liability and are netted across multiple assets and counterparties. It is possible to follow the use of gross repo financing in the footnotes from the 10-Q forms required of listed companies by the Securities and Exchange Commission (see King, 2008).

[18] Interestingly, repos and securitizations per se are not "new" innovations. In the US, repos have been used since 1918 as the main tool of the Federal Reserve, and they only started being used more broadly by investment banks from the mid-1980s onwards (Choudry, 2010). Similarly, the use of mortgage-backed securities goes as far back as the 18th century but it also became more widely used during the 1980s. Milne (2009) attributed the shift from "retail" toward "whole sale" funding of banks to international capital flows (p. 39). The countries that rely least on wholesale funding are major exporters of goods and natural resources with current account surpluses such as Germany, Japan, and Canada.

[19] The three largest custodians are Bank of New York Mellon with US$ 26 trillion in assets under custody (as of June 2013), and JPMorgan and State Street each with about US$ 18 trillion US in assets under custody (as of December 2012). From http://www.globalcustody.net/us/custody_assets_worldwide/.

While credit creation in securitized fractional reserve banking takes place in what is considered to be the shadow banking system.[20] it is important to stress the tight and re-enforcing links between shadow banking and traditional banking. For example, commercial banks were the largest group of sponsors of off-balance sheet SIVs and conduits that issued asset-backed commercial paper and invested in longer-term AAA asset-backed securities (Acharya et al., 2013). Moreover, with the advent of universal banking, large financial firms can be commercial in addition to investment banks and prime brokers and asset managers, all under one group.[21] The size of the US shadow banking system grew from approximately US$ 3 trillion in 1990 to its peak of US$ 21 trillion of gross liabilities by mid-2008 and since the crisis it has retracted to approximately the same size as the traditional US banking sector with US$ 15 trillion in liabilities in 2011 (Pozsar et al., 2012). The size of the repo market is difficult to estimate because of the lack of official statistics and issues of double counting. Gorton and Metrick (2012) estimated it to be around US$ 10 trillion (,p. 433), although Copeland, Martin, and Walker (2014), in another recent report, put the figure much lower at around US$ 3 trillion.

Under traditional banking, banks transform illiquid assets into liquid liabilities (Diamond & Dybvig 1983) and perform a crucial role in the lubrication of the real economy. Today, liquidity is increasingly created outside the traditional banking sector. For example, Singh & Stella (2012) emphasized the importance of "leverage-like elements" that stem from the pledged collateral market to the overall financial lubrication of the monetary world (p.14). "Ultimate liquidity" should include "money-like assets", which are defined as central bank deposits (reserves) plus good

[20] Described as financial credit intermediation outside the light of regulators and without "public enhancement" such as liquidity from the Federal Reserve or deposit insurance. Pozsar et al. (2012) separated shadow banking into three subsystems: "The government-sponsored shadow banking sub-system refers to credit intermediation activities funded through the sale of Agency debt and MBS [mortgage-backed securities], which mainly includes conforming residential and commercial mortgages. The "internal" shadow banking subsystem refers to the credit intermediation process of a global network of banks, finance companies, broker-dealers and asset managers and their on- and off-balance sheet activities—all under the umbrella of financial holding companies. Finally, the "external" shadow banking sub-system refers to the credit intermediation process of diversified broker-dealers (DBDs), and a global network of independent, non-bank financial specialists that include captive and standalone finance companies, limited purpose finance companies and asset managers" (p. 26).

[21] Although US holding companies are forbidden from transferring cash from a sister company to the prime-broker arm, a "left-over" from the Glass –Steagall Act (King 2008).

collateral that can be converted into central bank deposits at no haircut. Their calculations show that, in the United States, the "ultimate liquidity leverage", defined as the ratio of "total financial intermediaries' liabilities" to "ultimate liquidity", rose exponentially prior to the subprime crisis (from 4 at the end of 1951 to 673 at the end of 2006).[22] Adrian and Shin (2010) find that broker-dealers increase (decrease) leverage in line with larger balance sheets given higher (lower) mark-to-market valuations of their assets and increased net worth (in contrast to households, where leverage tends to be high when balance sheets are small). The authors argued that, in the context of secured lending, "liquidity" is best understood as the growth of intermediaries' balance sheets. "When liquidity dries up, it disappears altogether rather than being allocated elsewhere. When haircuts rise, all balance sheets shrink in unison, resulting in a generalized decline in the willingness to lend" (Adrian & Shin, 2009, p. 603). Consistent with the rise of securitized fractional reserve banking, they argue that monetary aggregates such as M2 are good indicators of the aggregate size of leveraged institutions "in a hypothetical world where deposit-taking banks are the only intermediaries." Instead, they suggested "market-based liabilities such as repos and commercial paper as better indicators of credit conditions that influence the economy" (2009, p. 604). In this market-based system, financial intermediaries engage in maturity transformations as well as "reverse" maturity transformations (Pozsar & Singh, 2011).

It is generally accepted that highly liquid financial markets benefit the real economy by reducing transaction costs and improving access to credit. Credit creation is essential for entrepreneurs and growth, as perhaps most famously argued by Schumpeter (1934). Following Schumpeter, Biondi (2013) argued that Minsky's "hedge finance" can be attributed to a stationary circular flow economy, which prevents entrepreneurial activity and economic development from arising. He concludes that fractional reserve banking (or currency issuance) is required in order to "introduce a dynamic leverage on that hedged flow bound to ownership and wealth" (p. 157). Consequently, traditional fractional reserve banking is a leveraging of existing assets (ownership and wealth). Banks create liquidity through maturity

[22] This leverage ratio has since fallen back to levels last seen at the beginning of the 1980s (around 30).

transformation and the issuance of deposits by granting loans. This benefit is perceived to outweigh the risk of a bank run, which can be mitigated by deposit insurance and a "lender of last resort". In the present context of credit creation in securitized fractional reserve banking, the Federal Reserve has additionally assumed the function of "dealer of last resort" (Mehrling, 2011), providing market liquidity by bidding for risky assets that serve as collateral. The central bank thereby insures "not the payments that the debtor had promised to make but rather the market value of the promise itself" (Mehrling, 2011, p. 134).[23] The caveat is that this can support the value of collateral securities, but it also reduces their availability.

Table 1: Stylized features of traditional and securitized fractional reserve banking.

	Traditional Banking	**Securitized Banking**
Entity	Commercial Banks	Investment Banks, Broker-Dealers, Asset Managers, Custodians, Other Financial Intermediaries
Allocation mechanism	Bank-based	Market-based
Money creation	Deposits	Short-term debt securities (e.g., repurchase agreements, commercial paper, Treasury bills)
Credit creation	Loans	Debt securities
Liquidity creation	Maturity transformation	Maturity and reverse maturity transformation
Type of liquidity	Funding liquidity	Funding liquidity and market liquidity
Source of bank runs	Deposits > Currency	Securities > Deposits
Function of central bank	Lender of last resort	Dealer of last resort

[23] Mehrling (2012b) argued that, in a market-based credit system, monetary policy must focus on asset markets rather than on banking institutions and on market liquidity rather than funding liquidity and that the central bank must become the "dealer of last resort" rather than the lender of last resort. Bagehot's (1906) rule to "lend freely but at a high price" during a crisis should be adapted to buy and sell securities freely, albeit at a wide spread. Rather than supporting a subset of too-big-to-fail banks, the central bank should focus on the liquidity support of a subset of good securities, honoring Bagehot's principle to lend only "against all good banking securities."

If, as argued above, credit creation in traditional banking allows for the introduction of dynamic leverage of wealth, securitized banking allows for an even higher degree of leverage. Dealers provide market liquidity, which in turn facilitates funding liquidity as the most liquid securities qualify, in general, as collateral for credit creation. The securitization of assets, and more generally the ability to create tradable instruments from otherwise illiquid assets, has been key in developing deep and liquid financial markets. Although it appeared to merely distribute risk throughout the financial system, securitization effectively transformed the nature of risk from credit risk to liquidity risk (Amato & Fantacci, 2012). Echoing our description of securitized fractional reserve banking, Fantacci (2013) argued that the current structure of monetary and financial institutions has made money and credit tradable through ever more liquid financial markets (p. 344). Moreover, rehypothecation increases liquidity by allowing for the multiple uses of collateral assets. Securitized fractional reserve banking thus increases credit creation and liquidity by (i) increasing the amount of collateral through the creation of financial assets, (ii) leveraging those assets multiple times through rehypothecation and securities lending, and (iii) shifting trust from the ability to repay to the ability to refinance.

Table 2: The three variables within traditional and securitized banking.

Key variable	**Traditional Banking**	**Securitized Banking**
(1) Availability of acceptable collateral assets	Depends on the creation and perceived value/risk of primarily real assets	Depends on the creation and perceived value/risk of primarily financial assets
(2) Level of Leverage	Leverage of relatively illiquid, often non-transferable collateral assets	Multiple leverage of relatively liquid, transferable collateral assets through securitization and re-hypothecation
(3) Level of Trust	Trust in ability to repay	Trust in ability to refinance

2.3.3 A local perturbation with global repercussions

When Lehman Brothers collapsed in 2008, it triggered a systemic banking crisis and significant drawdowns in stocks and other asset classes. What was originally perceived as just a local US subprime crisis, developed into a global financial crisis and the "Great Recession". From the perspective of our asset-based framework, we can observe a contraction of the three variables both at the institutional as well as at the macro level.

For example, Lehman Brothers' largest clearing agent JPMorgan required Lehman to post approximately UD$ 5 billion of securities in June 2008. When reports surfaced that negotiations with the Korea Development Bank failed on 9 September 2008, JPMorgan requested an additional US$ 5 billion in collateral the same day. It also demanded an extension of its master agreements to include its relationships with all Lehman entities (not just LBI), significantly extending JPMorgan's rights to request and retain collateral. On September 11, JPMorgan raised increasing concerns about the quality and valuation of the collateral posted by Lehman and requested another US$ 5 billion in collateral (Valukas, 2010, pp. 1068–1071). On September 15, Lehman Brothers filed for bankruptcy and triggered the worst financial crisis in recent history. This sequence of events shows the unfolding of a crisis at the company level when credit contracts across the three variables reflected in decreasing assets accepted as collateral, higher margins (i.e. lower leverage), and deteriorating levels of trust and confidence. This is echoed in the conclusion that "Lehman failed because it was unable to retain the confidence of its lenders and counterparties and because it did not have sufficient liquidity to meet its current obligations" (Valukas, 2010, p. 16).

As the subprime crisis of 2007 unfolded, the demand for higher margins and a decrease in acceptable collateral assets was observable also in the markets. Haircuts on subprime-related collateral increased from previously zero to 100 percent by the end of 2008, meaning that subprime assets were no longer accepted as repo collateral. After an initially gradual increase in margins toward 20 percent by mid-2008, consecutive shifts occurred suddenly to over 50 percent and 100 percent (Gorton & Metrick, 2010, p. 513), resembling regime shifts in confidence. As counterparties

needed to raise cash to meet higher margins or to close repos, they were forced to deleverage and sell assets. The sell-off in assets decreased the value of the collateral, inducing further haircuts and more asset sales. Consequentially, funding liquidity and market liquidity became mutually reinforcing within a liquidity spiral (Brunnermeier & Pedersen, 2009). The subprime crisis subsequently spread across other asset classes despite sound collateral and to other financial institutions in a global system-wide contraction along the three variables of credit creation. The contagion took place primarily through liquidity and risk premium channels (Longstaff, 2010). The resulting flight to quality reduced the amount of eligible collateral for repo financing (asset-backed or corporate collateral was no longer accepted). Singh (2012) estimated the shortage of collateral to have reduced liquidity by US$ 4–5 trillion. Moreover, as trust receded, the availability of repo financing was reduced to ever-shorter maturities, such as days and weeks (Hördahl & King, 2008). As more financial firms started to have liquidity problems, they became caught in a spiral and were forced to sell assets in order to raise liquidity, which in turn decreased collateral prices and further increased selling pressure.

The fact that not only subprime-related securities but also asset-backed securities in general were affected by increased haircuts and lower prices suggests that a lack of trust rather than changing fundamentals was the driver of changes in those asset values. In a similar vein, Milne (2009) argued that the unfolding banking crisis was not so much a consequence of over-lending and bad assets, but one of a lack of trust and confidence, as the consequence of increasingly risky maturity transformation by banks borrowing short and lending long. The mechanisms he proposed to restore this trust are large-scale government insurance guarantees against credit losses and the unorthodox monetary policy of asset purchases [24]. In fact, central banks and governments attempted to re-instill trust and confidence by increasing liquidity or by broadening insurances. Promises, such as Mario Draghi's (the president of the European Central Bank) to do "whatever it takes" to support the euro

[24] Rather than this being understood as a bailout of banks (giving them money), this should be understood as investment to obtain a return. "Governments should do this because private investors are scared and will not provide funds. But government should not hesitate because they, alone, have the deep pockets that will allow them to make good returns from these investments and stabilize the financial and economic system to boot" (Milne, 2009, p. 326).

and to buy sovereign debt in potentially unlimited amounts, were largely successful in calming the markets and reducing the interest rates of troubled European states. Another example is the almost unison extension of government guarantees of deposits in order to avoid the bank run on securitized banking to spread into the traditional retail banking sector.[25]

In summary, prior to the burst of the subprime mortgage bubble, financial markets were "highly liquid" and "highly leveraged". Liquid financial markets are generally seen as facilitating economic growth by efficiently directing capital to the real economy (e.g., Demirgüç-Kunt & Levine, 2001). However, Berger and Bouwman (2012) measured bank liquidity creation and found that high liquidity creation (relative to trend) helps predict future financial crises. Contrary to having been a liquidity crisis, it appears to have been a crisis caused by too much liquidity (Biondi, 2010; Fantacci, 2013). In similar spirit, Borio (2014) argued that the current international monetary and financial system amplifies the key weakness of national monetary and financial systems, namely to produce "excess financial elasticity", which leads to credit and asset booms and busts, systemic banking crises and macroeconomic dislocations.[26]

The presence of a highly liquid financial system is consistent with our asset-based framework of credit creation, where increasing liquidity leads to the build-up of internal instabilities, translating into a maturation of the whole system towards "criticality". When the system reaches its critical point, a small perturbation is enough to initiate a regime change and a multitude of events can trigger a change of regime. The relatively local event of the US subprime crisis of 2007 and the much larger global financial crisis is an example of such an occurrence. The unfolding events suggest that at the heart of the contraction in credit (or liquidity) is diminishing

[25] For example, the United States increased its deposit insurance from US$ 100,000 to US$ 250,000, effective October 2008; the states of the European Union extended their insurance to 50,000 euros in June 2009 and 100,000 in December 2010; in the UK, deposit insurance was raised from 35,000 to 50,000 pounds in October 2008. In several cases, these extended insurances were coupled with political (not legally binding) statements from government officials to provide unlimited support.

[26] Nevertheless, the general response by central banks has been to provide whatever liquidity necessary to prevent the system from collapsing and to provide impulses for new credit creation for the real economy. Unprecedented large-scale asset purchases by the Federal Reserve, Bank of England, Bank of Japan and the Swiss National Bank illustrate their transition from "lenders of last resort" to "dealers of last resort".

trust and confidence. This can be triggered by fundamental losses, but it can consequently be amplified through feedbacks between asset prices, fire sales and safety margins as described above. Consequently, we can observe a mutually reinforcing retraction along the suggested three key variables of credit creation, both observable at the individual institutional level and in the wider financial system. Credit creation in securitized fractional reserve banking is particularly prone to the build-up of endogenous instabilities because of the positive feedbacks between the value of collaterals and liquidity (Corsi & Sornette, 2014). In contrast to the equilibrium view of demand and supply, where demand for a good reduces as its price increases, demand for financial assets often increases as their prices rise, thus fueling the expectation that their prices will rise further. This makes the leveraging of financial assets particularly procyclical and financial markets prone to speculative bubbles.[27]

2.4 Toward a universal framework of credit creation

2.4.1 Centuries of credit- driven booms and busts

In his study of 5000 years of human societies, Graeber (2011) found that debt, as a key component of societies and a driving force of development, has everywhere and in all times grown to unstable proportions, the ends of the spiraling debt cycles being characterized by "jubilees", i.e., some kind of global debt pardon occurring every one or two generations. Moreover, he found that credit systems existed prior to physical money. If credit has expanded and eventually collapsed throughout history, is it not necessary to derive an understanding of credit creation that is independent of the prevailing monetary and financial system? In their analysis of eight centuries of financial crises, Reinhart and Rogoff (2009) found that "we have been here before. *The instruments of financial gain and loss have varied over the ages*, as have the types of institutions that have expanded mightily only to fail massively. But financial

[27] Yan, Woodard, and Sornette (2012) found that, preceding the market crash of 2008, the repo market exhibited all the features of bubble behavior preceding the burst.

crises follow a rhythm of boom and bust through the ages. *Countries, institutions, and financial instruments change across time, but human nature does not*" (xxvii, our emphasis).

We demonstrated above that securitized fractional reserve banking was a crucial development prior to the global financial crises and argued that it is particularly prone to positive feedbacks and consequentially to asset booms and busts. Moreover, we argued that, just like traditional banking creates deposits, this system creates money on the form of securities. Biondi (2010) argued that, in the current financial and economic system, money is best understood "as a socio-economic medium without intrinsic content" (p. 35) and that accounting should be dynamically capturing the economic and monetary process generated over time. "The ownership of invested money is irrelevant in the case of money interest, because the bank system's collective action creates money *endogenously,* without connection to an existing base of capital, money or gold" (p.48). We suggest that there is always an existing base, that of tangible and intangible asset serving explicitly or implicitly as collateral. Perhaps our current financial system is not as unique as we think. Some financial instruments, like credit default swaps and later synthetic collateralized debt obligations, were indeed new inventions developed during the rise of securitized banking. However, the use of financial innovation in order to facilitate credit is far from new. For example, Baptist (2012) found that financial innovation in the 1820s and 1830s, specifically the developments of new debt instruments and the securitization and mortgaging of slaves, was crucial to the development of the international boom in the cotton industry.[28] Just as increasing speculation in real estate preceded the global financial crisis, speculation in slave labor fuelled the financial and economic boom of the 1830s, which ultimately led to the Panic of 1837 (Rothman, 2011). The ability to use private property (land, housing, slaves) as collateral for loans gave farmers access to credit. The general ability to use private

[28] The importance of slavery in the US economy at that time is made clear in Piketty's (2014) book in which he writes: "the total market value of slaves represented nearly a year and a half of US national income in the late eighteenth century and the first half of the nineteenth century, which is roughly equal to the total value of farmland" (pp. 143-144).

assets as collateral for credit creation has been attributed with explaining the extraordinary success of capitalism in modern Western economies (de Soto, 2001).

It is also not a new phenomenon that credit creation preceding a financial crisis was financed by nonbank lenders. For example, the mortgaging of slaves in the nineteenth century was financed primarily through informal credit networks, which operated alongside rather than through the emerging banking system (Martin, 2010). Another example is the seventeenth century tulip mania that, according to Kindleberger (1978), was fuelled by credits not from banks but from sellers of the bulbs (p.64). The point is that, throughout history, credit creation preceded asset booms, independent of whether credit was extended through merchants, commercial banks or shadow banks. From our perspective, an "asset-based" understanding of credit creation could capture the essential underlying dynamics, independent of the existing institutional frameworks. It presents an alternative complementary understanding to credit creation "from deposits" and credit creation "out of nothing". To borrow an analogy from physics, credit (like matter) is not created out of nothing; assets (like energy) overwhelmingly pre-exist any transaction and process. From this perspective, the history of finance and money can be interpreted as a chain of innovations to make use of the enormous but otherwise dormant universe of assets that are held explicitly or implicitly as collaterals in lending and in all sorts of financial transactions.

However, this asset-based framework of credit creation is subject to several important limitations and criticisms. Below we provide a brief discussion of what we believe to be the most important challenges and present avenues for future research.

2.4.2 Challenges, limitations and further research

The first pressing challenge is the quantification of our framework within a dynamic and non-linear model. One can envision several metrics for the three variables, with the caveat that they are strongly intertwined: acceptable assets depend on the level of trust, which in turn also influences the level of leverage. The three variables are mutually re-enforcing, which is different from mere correlation.

The level of trust could be measured, for example, by a combination of consumer, business and investor confidence indices, spreads on credit default swaps, the VIX volatility index, and rating up- or downgrades. It may be useful to combine these metrics into an aggregate variable. The level of leverage could be captured by loan to value ratios, collateral margins, and debt-to-income ratios. Finally, the amount of assets acceptable as collateral could be estimated through the amount of highly rated and liquid securities outstanding, number of new businesses, new patents or new housing. It could be a function of turnover in those assets, a type of "velocity" through the selling, lending, and rehypothecating of existing assets. As argued before, the acceptability of assets is largely a function of the prevailing risk perception and expectations about the future.

Apart from issues related to the availability and quality of data, aggregation may pose a particularly difficult challenge. Total credit creation at the macro-level cannot simply be added across different entities as, of course, someone's liability is always someone else's asset. Consequently, it could be helpful to distinguish between different levels of credit creation through a hierarchical understanding of money and credit. According to this perspective, what is money at one institutional level is merely credit for the entities one level above (Foley, 1987; Bell, 2001; Mehrling, 2012a). Moreover, it may prove useful to distinguish between financial and real assets, the former being essentially derivatives of the latter. In practice, however, this distinction may be difficult because real assets can essentially become financial assets through speculation (consider for instance real estate or even tulips). As always, the challenge in developing a good model, conceptual or quantitative, is to find the right level of simplicity and abstraction within a system that is essentially complex and emergent in nature.

The second important challenge relates to the determination of "the right amount of credit creation". Can we develop guidelines towards this end? The presented framework offers an alternative understanding to how credit is created and why it is inherently unstable. Determining the "right amount of credit" is difficult, not least because the growth of the economy is not a stable process because of exogenous factors as well as the endogenous fluctuations of innovations (Gabaix, 2011). Even if it were possible to establish the optimal level of credit within an economy, the choice

is more likely to be one of a range or a bandwidth of economic fluctuations between booms and busts that society is willing to accept in return for a desired growth rate. One option society may pursue is the design of controls such that financial bubbles burst much earlier, just like regularly and intentionally conducted wood-fires engineered in order to avoid much larger destruction (Minnich, 1983; Minnich & Chou, 1997). The consequence may be that these much shorter boom periods result in less aggregate wealth growth (Louzoun et al., 2003). Financial bubbles can also constitute an important mechanism in the formation of innovation. This idea was central to Keynes' "animal spirits", without which there would be insufficient investment. He argued that animal spirits, rather than mathematical calculations, were the key drivers of entrepreneurial action (Keynes, 1936). Janeway (2012) shows that the innovation economy begins with discovery and culminates in speculation, with continuous positive feedback loops between them. Over some 250 years, economic growth has been driven by successive processes of trial and error, with upstream explorations in research and inventions and downstream experiments in exploiting the new economic space opened by innovation. In this context, asset bubbles can be beneficial in the long-term by developing a social climate that pushes investors to take risks that they would never have taken otherwise by using a rational cost-benefit analysis (Gisler & Sornette, 2009; 2010). Examples abound, from the railway boom of 1840 in the UK to the ICT bubble bursting in 2000.

Ultimately, to be sustainable, the economic surplus to pay for the cost of credit (interest) has to be generated in the real economy. Profits from capital gains on financial assets may increase GDP through a wealth effect but these are not sustainable, as the positive feedback between demand and asset prices leads to asset bubbles that can no longer be justified by the fundamental growth in the economy. In this scenario, asset prices rise faster than real GDP. Sornette and Cauwels (2014) documented a sequence of financial bubbles and an underlying trend away from productivity-based growth toward gains based on debt and finance since the 1980s. The belief that value can be extracted "out of nothing", namely from financial profits and debt rather than productivity and innovation, has been described as the "illusion of the perpetual money machine" (Sornette & Cauwels, 2014). The use of credit may be relevant with respect to financial stability and real economic growth. For example,

Werner (2005) argued for the need to distinguish between “credit for production”, which increases GDP in the long-term, “credit for speculation”, which merely drives up asset prices, and “credit for consumption”, which increases GDP in the short-term and tends to drive inflation up. The difficulty is that these categories are not always easy to determine and nor to distinguish.

The final avenue for future research that we would like to address is the need to develop a deeper understanding of credit creation within different institutional frameworks. We have argued that market-based securitized fractional reserve banking is particularly prone to the development of assets. However, as mentioned before, asset bubbles can develop in the absence of credit, with bank-issued credit and with nonbank-issued credit. What exactly are the tradeoffs between credit creation in different banking regimes with respect to economic growth and financial stability? Our analysis focused primarily on US data, where finance has historically been more market- than bank-based. Mettenheim (2013) correctly pointed out that banks in market-centered finance capitalism are paradoxically both paradigm and outliers. Even though much research has focused on market-based finance, most European banking systems are not only more bank-centered, they also continue to rely on savings and cooperative banks in addition to private banks. However, his praise for traditional deposit- and loan-based banking for better smoothing economic shocks may be premature. Although banks have been found to cushion business cycle fluctuations better than markets, a recent study suggests that, when recessions coincide with financial crises, the impact on GDP is three times as severe as in market-based economies (Gambacorta, Yang, & Tsatsaronis, 2014). Moreover, despite being more bank-based, the share of commercial banks in the aggregate total assets of the financial sector in the euro area has decreased from 58.1 percent in 1999 to 50.9 percent in 2013. In the meantime, the share of other financial intermediaries increased from 41.9 percent to 49.1 percent respectively. During the same period, total assets of all financial intermediaries grew in both the United States as well as the euro area relative to GDP. By 2013, US financial intermediaries held assets worth 423 percent of GDP compared to 565 percent of GDP in the euro area (Deutsche Bundesbank, 2014). One can thus ask the question: Is there a trend towards securitized fractional reserve banking, even in historically bank-centered economies?

2.5 Conclusion

This article introduced a conceptual framework of credit creation that depends on the amount of eligible collateral assets, the level of leverage and the level of trust and confidence in future cash flows. The associated dynamics are non-linear and subject to positive feedbacks, which give rise to endogenously generated instabilities. By building on the works of previous authors that underlined instabilities associated with credit, we proposed that, as credit expands along these variables, the financial system becomes more liquid and vulnerable to internally generated instabilities manifested as booms and busts.

Consequently, we applied this framework to the global financial crisis. We showed that the decades preceding the crisis were characterized by strong growth in financial assets, increasing leverage relative to GDP and a false sense of security as evident in the concept of a "Great Moderation". Using US flow of funds data, we demonstrated a shift in the components of US banks' balance sheets and a decoupling of bank assets from deposits since the mid-1980s. We described this as "the rise of securitized fractional reserve banking", where credit creation takes place not within traditional commercial banking but within the global financial markets. Whereas traditional banks create deposit-money through granting loans, market-based securitized banking creates money-like securities. Both systems are fractional and subject to bank-runs. As a result, central banks transitioned from being lender of last resort to being dealers of last resort, as characterized by unprecedentedly large asset purchasing programs. We argued that, over the past century, collateral assets became increasingly financial in nature. As assets were increasingly leveraged, the financial system became more efficient and more liquid, performing maturity transformations across different asset classes and timescales. However, it also became increasingly pro-cyclical due to positive feedbacks between asset prices and their demand. We argued that, as financial markets become more complete through credit creation, inherent instabilities build up and even a small external perturbation can have large repercussions on financial stability, transmitting from the financial markets to the real economy. From this perspective, the subprime crisis was only one possible trigger in an increasingly unstable financial system. As trust receded, so did the amount of assets acceptable as collaterals as well as the level of leverage and liquidity.

Subsequent measures by policymakers can be interpreted as attempts to avoid further contraction along the three dimensions of acceptable assets, leverage and trust.

Finally, we discussed the possibility of a universal asset-based understanding of credit creation. Within this framework, credit is never "out of nothing" as it is implicitly or explicitly always backed by collateral assets. We suggested that this perspective may reconcile the fact that credit has been a key driver of booms and busts over centuries (independent of the prevailing financial and monetary system) and that credit existed before money. We pointed out challenges associated with this framework and proposed avenues for future research.

2.6 References

Acharya, V. V., Schnabl, P., & Suarez, G. (2013). Securitization without risk transfer. *Journal of Financial Economics*, *107*(3), 515–536. doi:10.1016/j.jfineco.2012.09.004

Adams, B. (2005). Trust vs. Confidence. *Department of National Defence: Defence Research and Development Canada - Toronto*, 1–24.

Adrian, T., & Shin, H. S. (2009). Money, Liquidity and Monetary Policy. *American Economic Review*, *99*(2), 600–605. doi:10.1257/aer

Adrian, T., & Shin, H. S. (2010). Liquidity and leverage. *Journal of Financial Intermediation*, *19*(3), 418–437. doi:10.1016/j.jfi.2008.12.002

Akerlof, G. A., & Shiller, R. J. (2009). *Animal Spirits*. Princeton, New Jersey: Princeton University Press.

Amato, M., & Fantacci, L. (2012). *The end of finance*. Cambridge: Polity.

Bacchetta, P., Tille, C., & Wincoop, E. V. (2012). Self-Fulfilling Risk Panics. *American Economic Review*, *102*(7), 3674–3700. doi:10.1257/aer.102.7.3674

Bachmann, R., & Zaheer, A. (Eds.). (2006). *Handbook Of Trust Research*. Cheltenham: Edward Elgar Publishing Limited.

Bagehot, W. (1906). *Lombard Street: a Description of the Money Market*. New York: Charles Scribner's Sons.

Bain & Company. (2012). *A World Awash in Money* (pp. 1–32). Macro Trends Group. Retrieved from http://www.bain.com/Images/BAIN_REPORT_A_world_awash_in_money.pdf

Bansal, R., & Shaliastovich, I. (2010). Confidence Risk and Asset Prices. *American Economic Review: Papers & Proceedings*, *100*(2), 537–541. doi:10.1257/aer.100.2.537

Baptist, E. E. (2012). *Toxic Debt, Liar Loans, Collateralized and Securitized Human Beings, and the Panic of 1837*. (M. Zakim & G. J. Kornblith). Chicago: The University of Chicago Press.

Battiston, S., Gatti, D. D., Gallegati, M., Greenwald, B., & Stiglitz, J. E. (2012a). Default cascades: When does risk diversification increase stability? *Journal of Financial Stability*, *8*(3), 138–149. doi:10.1016/j.jfs.2012.01.002

Battiston, S., Gatti, D. D., Gallegati, M., Greenwald, B., & Stiglitz, J. E. (2012b). Liaisons dangereuses: Increasing connectivity, risk sharing, and systemic risk. *Journal of Economic Dynamics and Control*, *36*(8), 1121–1141. doi:10.1016/j.jedc.2012.04.001

Bell, S. (2001). The role of the state and the hierarchy of money. *Cambridge Journal of Economics*, *25*, 149–163.

Berger, A. N., & Bouwman, C. H. S. (2012). Bank Liquidity Creation, Monetary Policy, and Financial Crises, 1–48. Retrieved from http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1952728

Bernanke, B. S. (2007, May 17). The Subprime Mortgage Market. *The Federal Reserve*. Retrieved January 11, 2015, from http://www.federalreserve.gov/newsevents/speech/bernanke20070517a.htm

Bernanke, B. S., & Gertler, M. (1995). Inside the Black Box: The Credit Channel of the Monetary Policy Transmission. *Journal of Economic Perspectives*, *9*, 27–48.

Bernanke, B. S., Gertler, M., & Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In J. Taylor & M. Woodford, (Vol. 1, pp.

1341–1393). Handbook of Macroeconomics.
Bezemer, D. J. (2011). The Credit Crisis and Recession as a Paradigm Test. *Journal of Economic Issues*, *45*(1), 1–18. doi:10.2753/JEI0021-3624450101
Bhamra, H. S., & Uppal, R. (2009). The Effect of Introducing a Non-Redundant Derivative on the Volatility of Stock-Market Returns When Agents Differ in Risk Aversion. *Review of Financial Studies*, *22*(6), 2303–2330. doi:10.1093/rfs/hhm076
Biondi, Y. (2010). Money without value, accounting without measure: how economic theory can better fit the economic and monetary system we live in. In M. Amato, L. Doria, & L. Fantacci, *Money and Calculation: Economic and sociological perspectives* (pp. 34–62). London: Palgrave.
Biondi, Y. (2013). Hyman Minsky's Financial Instability Hypothesis and the Accounting Structure of Economy. *Accounting, Economics and Law: a Convivium*, *3*(3), 141–166. doi:10.1515/ael-2013-0045
Blanchard, O. (2000). What do we know about macroeconomics that Fisher and Wicksell did not? *Quarterly Journal of Economics*, *115*(4), 1375–1410.
Boettke, P. J. (Ed.). (2010). *Handbook on Contemporary Austrian Economics*. Northampton, Massachusetts: Edward Elgar Publishing, Inc.
Borio, C. (2006). Monetary and prudential policies at a crossroads? New challenges in the new century. *BIS Working Papers*, 1–34.
Borio, C. (2014). The international monetary and financial system: its Achilles heel and what to do about it. *BIS Working Papers*, 1–33.
Borio, C., & Zhu, H. (2012). Capital regulation, risk-taking and monetary policy: A missing link in the transmission mechanism? *Journal of Financial Stability*, *8*(4), 236–251. doi:10.1016/j.jfs.2011.12.003
Brock, W. A., Hommes, C. H., & Wagener, F. O. O. (2009). More hedging instruments may destabilize markets. *Journal of Economic Dynamics and Control*, *33*(11), 1912–1928. doi:10.1016/j.jedc.2009.05.004
Brunnermeier, M. K., & Pedersen, L. H. (2009). Market Liquidity and Funding Liquidity. *Review of Financial Studies*, *22*(6), 2201–2238. doi:10.1093/rfs/hhn098
Caccioli, F., & Marsili, M. (2010). Information Efficiency and Financial Stability. *Economics: the Open-Access, Open-Assessment E-Journal*, *4*(2010-20), 1. doi:10.5018/economics-ejournal.ja.2010-20
Caccioli, F., Marsili, M., & Vivo, P. (2009). Eroding market stability by proliferation of financial instruments. *The European Physical Journal B*, *71*(4), 467–479. doi:10.1140/epjb/e2009-00316-y
Calverley, J. P. (2004). *Bubble$ and how to survive them*. London: American Express Bank Ltd.
Choudry, M. (2010). *The Repo Handbook*. Elsevier Ltd.
Copeland, A., Martin, A., & Walker, M. (2014). Repo Runs: Evidence from the Tri-Party Repo Market. *The Journal of Finance*, *69*(6), 2342–2380.
Corsi, F. & Sornette D. (2014). Follow the Money: the Monetary Roots of Bubbles and Crashes. *International Review of Financial Analysi*s, 32, 47–59.
de Soto, H. (2001). The Mystery of Capital. *Finance and Development, Quarterly Magazine of the IMF*, *38*, 1–9. Retrieved from https://www.imf.org/external/pubs/ft/fandd/2001/03/desoto.htm
Demirgüc-Kunt, A., & Levine, R. (Eds.). (2001). *Financial Structure and Economic Growth*. Cambridge, Massachusetts: The MIT Press.

Deutsche Bundesbank. (2014). *The shadow banking system in the euro area: overview and monetary policy implications*. *Monthly Report* (pp. 13–34). Retrieved from http://www.bundesbank.de/Redaktion/EN/Downloads/Publications/Monthly_Report_Articles/2014/2014_03_shadow.pdf?__blob=publicationFile

Diamond, D. W., & Dybvig, P. H. (1983). Bank Runs, Deposit Insurance, and Liquidity. *The Journal of Political Economy*, *91*, 401–419.

Downes, J., & Goodman, J. E. (2003). *Dictionary of Finance and Investment Terms* (Sixth edition.). Hauppauge: Barron's Educational Series, Inc.

Dudley, W. C. (2009, July). The Economic Outlook and the Fed's Balance Sheet: The Issue of "How" versus 'When'. *Federal Reserve Bank of New York*. Retrieved January 27, 2015, from http://www.newyorkfed.org/newsevents/speeches/2009/dud090729.html

Fantacci, L. (2013). Why Banks Do What They Do. How the Monetary System Affects Banking Activity. *Accounting, Economics and Law: a Convivium*, *3*(3), 333–356. doi:10.1515/ael-2013-0017

Foley, D. K. (1989). Money in Economic Activity. In J. Eatwell, M. Milgate, & P. Newman, *Money* (2nd ed., pp. 248–262). New York and London: The New Palgrave.

Fostel, A., & Geanakoplos, J. (2008). Leverage Cycles and the Anxious Economy. *American Economic Review*, *98*(4), 1211–1244. doi:10.1257/aer.98.4.1211

FSB. (2012). *Securities Lending and Repos: Market Overview and Financial Stability Issues* (pp. 1–45). Financial Stability Board.

Gabaix, X. (2011). The Granular Origins of Aggregate Fluctuations. *Econometrica*, *79*(3), 733–772. doi:10.3982/ECTA8769

Gambacorta, L., Yang, J., & Tsatsaronis, K. (2014). Financial structure and growth. *BIS Quarterly Review*, 1–15.

Gerali, A., Neri, S., Sessa, L., & Signoretti, F. M. (2010). Credit and banking in a DSGE model of the euro area. *Temi Di Discussione*, 1–62.

Gertler, M., & Kiyotaki, N. (2011). *Financial Intermediation and Credit Policy in Business Cycle Analysis*. *Handbook of Monetary Economics* (Vol. 3, pp. 547–599). Elsevier Ltd. doi:10.1016/B978-0-444-53238-1.00011-9

Gisler, M., & Sornette, D. (2009). Exuberant Innovations: The Apollo Program. *Society*, *46*(1), 55–68.

Gisler, M., & Sornette, D. (2010). Bubbles Everywhere in Human Affairs. In L. Kajfez-Bogataj, K. H. Müller, I. Svetlik, & N. Tos, *Modern RISK-Societies, Towards a New Framework for Societal Evolution* (pp. 117–134). Vienna: Edition Echoraum.

Godley, W. (1999). Money and credit in a Keynesian model of income determination. *Cambridge Journal of Economics*, *23*, 393–411.

Gorton, G., & Metrick, A. (2010). Haircuts. *Federal Reserve Bank of St. Louis REVIEW*, 1–14.

Gorton, G., & Metrick, A. (2012). Journal of Financial Economics. *Journal of Financial Economics*, *104*(3), 425–451. doi:10.1016/j.jfineco.2011.03.016

Graeber, D. (2011). *Debt: The First 5000 Years* (pp. 1–699). New York: Melville House Publishing.

Heemeijer, P., Hommes, C., Sonnemans, J., & Tuinstra, J. (2009). Price stability and volatility in markets with positive and negative expectations feedback: An experimental investigation. *Journal of Economic Dynamics and Control*, *33*(5),

1052–1072. doi:10.1016/j.jedc.2008.09.009
Holcombe, R. G. (2014). *Advanced Introduction to The Austrian School of Economics*. Northampton, Massachusetts: Edward Elgar Publishing, Inc.
Horwitz, S. (2000). *Microfoundations and Macroeconomics: An Austrian Perspective*. New York, NY: Routledge.
Hördahl, P., & King, M. R. (2008). Developments in repo markets during the financial turmoil. *BIS Quarterly Review*, 1–17.
Huerta de Soto, J. (2009). *Money, Bank Credit and Economic Cycles* (Second English edition. pp. 1–938). Ludwig von Mises Institute, Auburn, Alabama.
Hüsler, A., Sornette, D., & Hommes, C. H. (2013). Super-exponential bubbles in lab experiments: Evidence for anchoring over-optimistic expectations on price. *Journal of Economic Behavior and Organization*, *92*, 304–316. doi:10.1016/j.jebo.2013.06.005
Janeway, W. H. (2012). *Doing Capitalism in the Innovation Economy: Markets, Speculation and the State*. Cambridge: Cambridge University Press.
Keen, S. (2013). Predicting the "Global Financial Crisis": Post-Keynesian Macroeconomics. *Economic Record*, *89*(285), 228–254. doi:10.1111/1475-4932.12016
Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*. London: Macmillan.
Kindleberger, C. P. (1978). *Manias, Panics, and Crashes*. Hoboken, New Jersey: John Wiley & Sons.
King, M. (2008). *Are the brokers broken?* European Quantitative Credit. Strategy & Analysis. Citigroup Global Markets Ltd.
Kiyotaki, N., & Moore, J. (1997). Credit Cycles. *The Journal of Political Economy*, *105*(2), 211–248. doi:10.1086/262072
Krugman, P. (2012, May 30). The Conscience of a Liberal. *The New York Times*. Retrieved October 22, 2013, from http://krugman.blogs.nytimes.com/2012/03/30/banking-mysticism-continued/?_r=0
Krugman, P., & Wells, R. (2009). *Macroeconomics* (Second.). New York: Worth Publishers.
Kyle, A. S. (1985). Continuous Auctions and Insider Trading. *Econometrica*, *53*, 1315–1335. Retrieved from http://www.jstor.org/stable/1913210
Lavoie, M. (1984). The endogenous flow of credit. *Journal of Economic Issues*, 1–27.
Lavoie, M. (2009). *Introduction to Post-Keynesian Economics* (2nd ed.). Basingstoke: Palgrave Macmillan.
Lehman, Jeffrey, & Phelps, S. (2004). *West's Encyclopedia of American Law* (2nd ed.). Thomson Gale. Retrieved from http://legal-dictionary.thefreedictionary.com/asset
Longstaff, F. A. (2010). The subprime credit crisis and contagion in financial markets. *Journal of Financial Economics*, *97*(3), 436–450. doi:10.1016/j.jfineco.2010.01.002
Louzoun, Y., Solomon, S., Goldenberg, J., & Mazursky, D. (2003). World-Size Global Markets Lead to Economic Instability. *Artificial Life*, *9*(4), 357–370.
Marsili, M., Raffaelli, G., & Ponsot, B. (2009). Dynamic instability in generic model of multi-assets markets. *Journal of Economic Dynamics and Control*, *33*(5), 1170–1181. doi:10.1016/j.jedc.2008.12.005
Martin, B. (2010). Slavery's Invisible Engine: Mortgaging Human Property. *The*

Journal of Southern History, *76*(4), 817–866.
Mehrling, P. (2011). *The New Lombard Street: How the Fed Became the Dealer of Last Resort*. New Jersey: Princeton University Press.
Mehrling, P. (2012a). The Inherent Hierarchy of Money (pp. 1–21). Prepared for Duncan Foley festschrift volume, and conference April 20-21, 2012.
Mehrling, P. (2012b). Three Principles for Market-Based Credit Regulation. *American Economic Review*, *102*(3), 107–112. doi:10.1257/aer.102.3.107
Mettenheim, K. (2013). Back to Basics in Banking Theory and Varieties of Finance Capitalism. *Accounting, Economics and Law: a Convivium*, *3*(3), 357–405. doi:10.1515/ael-2013-0008
Milne, A. (2009). *The Fall of the House of Credit*. Cambridge, New York: Cambridge University Press.
Minnich, R. A. (1983). Fire Mosaics in Southern California and Northern Baja California. *Science*, *219*, 1287–1294.
Minnich, R. A., & Chou, Y. H. (1997). Wildland Fire Patch Dynamics in the Chaparral of Southern California and Northern Baja California. *International Journal of Wildland Fire*, *7*(3), 221–248. doi:10.1071/WF9970221
Minsky, H. P. (1986). *Stabilizing an Unstable Economy*. New Haven and London: Yale University Press.
Minsky, H. P. (1992). The financial instability hypothesis. *Levi Economics Institute, Working Paper*, 1–10.
Ni, S. X., Pearson, N. D., & Poteshman, A. (2005). Stock price clustering on option expiration dates. *Journal of Financial Economics*, *78*(1), 49–87. doi:10.1016/j.jfineco.2004.08.005
Piketty, T. (2014). *Capital in the twenty-first century*. Cambridge, Massachusetts; London, England: The Belknap Press of Harvard University Press.
Pozsar, Z., & Singh, M. (2011). The Nonbank-Bank Nexus and the Shadow Banking System. *IMF Working Paper*, 1–19.
Pozsar, Z., Adrian, T., Ashcraft, A., & Boesky, H. (2012). Shadow Banking. *Federal Reserve of New York Staff Reports*, 1–38.
Reinhart, C. M., & Rogoff, K. S. (2009). *This time is different*. Princeton and Oxford: Princeton University Press.
Rochon, L.-P., & Rossi, S. (2013). Endogenous money: the evolutionary versus revolutionary views. *Review of Keynesian Economics*, *1*(2), 210–229.
Rothman, J. D. (2011). The Contours of Cotton Capitalism: Slavery, Speculation, and Economic Panic in Mississippi, 1832-1841. In S. Rockmann & S. Beckert. Presented at the Slavery's Capitalism: A New History of American Economic Development, Providence, Rhode Island / Cambridge, Massachusetts: University of Pensylvania Press. Retrieved from http://hsozkult.geschichte.hu-berlin.de/index.asp?id=3665&view=pdf&pn=tagungsberichte
Roxburgh, C., Lund, S., & Piotrowski, J. (2011). Mapping global capital markets 2011. *McKinsey Global Institute*, 1–38.
Roxburgh, C., Lund, S., Daruvala, T., Manyika, J., Dobbs, R., Forn, R., & Croxson, K. (2012). Debt and deleveraging: Uneven progress on the path to growth. *McKinsey Global Institute*, 1–64.
Roxburgh, C., Lund, S., Wimmer, T., Amar, E., Atkins, C., Kwek, J.-H., et al. (2010). Debt and deleveraging: The global credit bubble and its economic consequences. *McKinsey Global Institute*, 1–94.
Scheffer, M. (2009). *Critical Transitions in Nature and Society*. Princeton: Princeton

University Press.
Schumpeter, J. (1912, 1934). *Theorie der wirtschaftlichen Entwicklung: Eine Untersuchung über Unternehmergewinn, Kapital, Kredit, Zins und den Konjunkturzyklus* (4 ed.). Leipzig: Duncker & Humblot.
Singh, M. (2012). The (Other) Deleveraging. *IMF Working Paper*, 1–22.
Singh, M., & Aitken, J. (2010). The (sizable) Role of Rehypothecation in the Shadow Banking System. *IMF Working Paper*, 1–16.
Singh, M., & Stella, P. (2012). Money and Collateral. *IMF Working Paper*, 1–21.
Sircar, R. K., & Papanicolaou, G. (1998). General Black-Scholes models accounting for increased market volatility from hedging strategies. *Applied Mathematical Finance*, *5*, 45–82.
Sornette, D. (2003). *Why Stock Markets Crash: Critical Events in Complex Financial Systems*. Princeton, New Jersey: Princeton University Press.
Sornette, D., & Cauwels, P. (2014). 1980–2008: The Illusion of the Perpetual Money Machine and What It Bodes for the Future. *Risks*, *2*(2), 103–131. doi:10.3390/risks2020103
Taylor, A. (2012). The Great Leveraging. *Bank for International Settlements*, 1–38.
The Economist. (2012a, August 19). Global debt guide: The debtor's merry-go-round. *The Economist*. Retrieved from http://www.economist.com/blogs/graphicdetail/2012/09/global-debt-guide
The Economist. (2012b, November 10). Free exchange: Strength in numbers. *The Economist*. Retrieved from http://www.economist.com/news/finance-and-economics/21565937-how-much-capital-did-banks-opt-hold-when-they-had-choice-strength
Valukas, A. R. (2010). *Lehman Brothers Holdings Inc. Chapter 11 Proceedings Examiner Report*. Jenner & Block LLP. Retrieved from http://jenner.com/lehman/
von Hayek, F. A. (1933). *Monetary Theory and the Trade Cycle* (pp. 1–242). New York, N. Y. : Sentry Press.
von Mises, L. (1912,1953). *The Theory of Money and Credit* (pp. 1–500). New Haven: Yale University Press.
Werner, R. A. (2005). *New Paradigm in Macroeconomics*. Basingstoke: Palgrave Macmillan.
Wheelock, D. C. (2012, October 3). Too Big To Fail: The Pros and Cons of Breaking Up Big Banks. *The Regional Economist, Federal Reserve of Bank St. Louis*, 1–2.
Yan, W., Woodard, R., & Sornette, D. (2012). Leverage bubble. *Physica A*, *391*(1-2), 180–186. doi:10.1016/j.physa.2011.07.013
Zapatero, F. (1998). Effects of financial innovation on market volatility when beliefs are heterogeneous. *Journal of Economic Dynamics and Control*, *22*, 597–626.

3. Should banks be banned from creating money?

Should banks be banned from creating money? An analysis from the perspective of hierarchical money

Susanne von der Becke* and Prof. Didier Sornette
ETH Zurich, D-MTEC – Chair of Entrepreneurial Risks
Scheuchzerstrasse 7, 8092 Zurich, Switzerland
svonderbecke@ethz.ch and dsornette@ethz.ch

27 January 2015

Abstract

We extend the concept of "hierarchy of money" to our current monetary and financial system based on fiat money, with monetary policy that is conducted through the sale and purchase of securities and credit intermediation by non-bank financial intermediaries. This exposes a feedback loop between the upper and lower level of the hierarchy, which allows for more than full use of otherwise dormant capital but that also increases inherent instabilities manifested in asset booms and busts. We find that, from the perspective of hierarchical money, the call to ban banks from creating money neglects the significant role of securities-based financing in the global financial market at the lower level as well as the money creation capacity of central banks at the higher level of the hierarchy. Moreover, the inherently expansive nature of the hierarchy of money contradicts the long-term feasibility of full-reserve banking.

Keywords: credit creation, full-reserve banking, asset bubbles, financial stability

JEL: E42, E44, E51, G21, G23

* Corresponding author.

3.1 Introduction

The magnitude of the global financial crisis and its economic consequences has renewed interest in the role of financial intermediaries as facilitators of money and credit. Their potential role in the amplification of asset booms and busts and their consequences for macroeconomic instability have been recently discussed, for example by Adrian, Moench, and Shin (2010) and Brunnermeier and Sannikov (2014). In particular, the debate on full-reserve banking, which has also reappeared, can be traced back at least as far as the early 1930s to economists supporting the Chicago Plan in 1933, such as Henry Simons and Frank Knight, to Frederick Soddy (1934), Irving Fisher (1936) and later Milton Friedman (1960). While the details of different proposals vary, full-reserve banking generally requires a separation of the deposit-taking and lending operations of banks. Moreover, full-reserve banking means that deposits have to be 100 percent backed by reserves. For Fisher (1936), the chief cause of the depression was a one third reduction in the stock of bank money between 1929 and 1939. He emphasized that banks create money by "pen and ink" when granting a loan. Full-reserve banking, or "100 percent money" as he called it, would greatly reduce booms and depressions because inflations and deflations would be mitigated. In his view, the total supply of money was to be controlled by an independent commission with the power to create debt-free money in line with the needs of the economy. Benes and Kumhof (2012) reconstruct Fisher's proposal in a DSGE model of the US economy and find that it would significantly decrease public and private debt levels, eliminate bank runs and allow for the reduction of business cycle fluctuations. Using a theoretical four-sector model (firms, commercial banks, household and the central bank), Chiarella et al. (2012) compare the macroeconomic impact of the present broad banking system to a 100 percent reserve ratio narrow banking system. They find the latter system provides greater systemic stability through the elimination of bank runs while guaranteeing sufficient loan supply. Krainer (2013) reviews Milton Friedman's "Proposal for Monetary Stability" in light of our present financial system and argues for the adoption of a 100 percent reserve banking system in order to moderate the amplifying effect of fractional banking on the real economy, i.e. to dampen expansions and recessions.

It is probably fair to state that advocates of full-reserve banking have failed in general to convince other scholars and political authorities for almost a century. We

argue that this could be because its proclaimed benefits rest on a limited and linear understanding of money and credit creation whereas reality is more complex. In this article, we apply the concept of "hierarchical money" to the question of whether banks should be banned from creating money. From the perspective of the hierarchy of money, what counts as merely money at one level of the hierarchy is credit for the institution above. We extend the concept to our current monetary and financial system, where base money is no longer backed by a commodity but by securities, and credit is created by commercial banks as well as other financial intermediaries in the global capital markets. Consequently, the hierarchy of money closes into a circle, thereby exposing a feedback loop between the upper and lower level of the hierarchy. Within this hierarchy, potentially any asset can be and is generally used as a form of money as well as the collateral for credit. The use of assets, securities, and even derivatives, to create credit and liquidity is the channel through which capital is used (rather than stored idle) for future innovations and growth.

Our article is structured as follows. We first apply the "inherent hierarchy of money" to the present financial and monetary context. This perspective can explain what we believe to be at the heart of much confusion between money and credit. Second, we explore the lower level of the hierarchy more deeply and find that it was crucial to the endogenous build-up of instabilities and the unfolding of the global financial crisis. Thirdly, we discuss the asset bubbles in relation to the hierarchy of money. Positive feedback is a key mechanism that gives rise to boom and bust dynamics and is present between different levels of the hierarchy of money as well as across them. A focus on just the money creation capabilities of commercial banks fails to understand money creation in its full hierarchical context and neglects the potential for instabilities, as well as opportunities, arising at the lower and higher level of the hierarchy. We conclude that the problems are not in the existence of credit creation "out of nothing" or the fact that money is created by bank loans. The problem is, as always, a question of measure and excesses: "The dose makes the poison" as first expressed by Paracelsus. When in excess, credit creation, which fuels innovation and entrepreneurship at the right dose, becomes the cause of bubbles and subsequent distress. Banning banks from creating money is not necessarily the right means to address this challenge, in the same way that banning bread is not the solution to obesity.

Finally, the inherently expansive nature of the hierarchy leads us to question the long-term feasibility of enforcing full-reserve banking even if it were a desirable policy.

3.2 Understanding money in terms of hierarchies

Commercial banks create money through the process of credit creation by issuing liabilities that are used as final means of settlement by deposit holders. The process of "loans creating deposits", as recently explained by the Bank of England (McLeay, Radia, and Thomas 2014), has been treated as a vindication for those arguing against the loanable funds view of banks intermediating between savers and borrowers. By matter of accounting, the creation of a loan requires the creation of a deposit. Banks do not need prior deposits in order to lend as long as they can obtain financing later. However, this does not mean that banks can create money "out of nothing". First, a loan is implicitly or explicitly always given against an asset (this could be as tangible as a house for a mortgage or as intangible as a university degree for a student loan). Second, it does not mean that individual banks can create their own financing indefinitely. The moment the proceeds of the loan are transferred to another bank, the loan needs to be funded by a new liability, ideally in the form of a new deposit or otherwise by borrowing in the money markets. But where is the cash in the money markets coming from if not from a prior deposit? Even though central banks have historically followed an accommodative policy on reserves (Goodfriend and Hargraves 1983; Gray 2011), this does not mean that individual banks can always get funding later.[1]

The debate of whether "loans create deposits" or "deposits create loans" becomes irrelevant once we stop thinking about these flows of money and credit in a linear fashion, isolating a single operation. Credit creation and money creation takes place often simultaneously across a multitude of financial institutions, instruments and timescales. Commercial banks are special in their ability to issue liabilities that are "a final medium of settlement" for the general public. They cannot, however, create their own medium of settlement, which is reserves and not deposits. Understanding money

[1] This is most evident in the number of bank failures: see for example http://www.fdic.gov/bank/individual/failed/banklist.html

and banking in terms of hierarchies reveals that what is money at one level is merely credit for the level above (Foley 1987; Bell 2001; Mehrling 2012). At any timescale, the pyramid of money and credit is continuously expanding and contracting. The hierarchy is inherently fractional at all levels as money (the means of final settlement) is generally scarcer than credit (promises to pay money). It follows that bank runs can occur at each level of the hierarchy when funding is withdrawn and credit converted into money, i.e. when convertibility and liquidity of what was previously credit is required on short notice to demonstrate that it can act as money (means of payment and storage of value). During boom times, the pyramid flattens/widens and credit becomes more "money-like" until the qualitative difference between money and credit reasserts itself in times of crisis. The hierarchy of money is intertwined with a hierarchy of institutions, where institutions at the top of the hierarchy are generally able to create what is money for institutions below.

Building on Mehrling's "Inherent Hierarchy of Money" (2012), let us explain what is at the heart of much of the confusion between money and credit:

(1) At the first level, gold or other types of accepted storage of value is the basis of value for the creation of an IOU ["I owe you"] certificate in the form of "currency". On the other hand, gold can be directly exchanged between partners against other goods thus functioning as money. This is most obvious under nineteenth-century banking. In current times, the IOU is no longer convertible into anything other than itself. From the balance sheet perspective of the central bank, it is backed by securities.

(2) At the second level, the IOU certificate can be exchanged as money against goods, thus functioning in its standard role of facilitator of exchanges. But it is a credit with respect to the first level, in the sense that the holder of an IOU certificate is entitled to get, if he/she wishes, the equivalent value in gold or other storage of value associated with the certificate. Nowadays, the value of this IOU certificate/currency is no longer defined by its conversion into a pre-established quantity of gold but is relative to the value of conversion into other national currencies.

(3) At the third level, deposits of IOU certificates in banks are liabilities of the banks to the depositors, i.e., they function as effective credit extended by depositors to

banks. But deposits are also a medium of exchange between accounts, banks and firms, functioning in that sense as money.

(4) Securities are storage of value, representing fractions of firms. They can be exchanged between partners, for instance in mergers and acquisitions. They thus act as money at this fourth level in the hierarchy. On the other hand, they are IOU certificates to their holders who own in principle the right for the corresponding asset of the firm. Securities are obtained in particular in exchange for deposits.

This fourth level creates a remarkable phenomenon, namely the closing of the hierarchy by the creation of a loop in which securities are both (i) part of the fourth level of money, (ii) are credit of the third level, but (iii) can also be used again for money creation at the first level by serving as collateral in the place of gold or of the other accepted storages of value of the first level. This combined process of money and credit creation can continue in principle many times, creating securities of securities. It is this ability to use private assets as collateral for credit creation that has been attributed with explaining the extraordinary success of capitalism in modern Western economies (de Soto 2001). Indeed, on the positive side, the use of securities as money of the first level provides the engine for full (and more than full) use of capital that would be otherwise unutilized. On the negative side, however, this loop creates intrinsically the recurrent danger of instabilities and excessive credit.

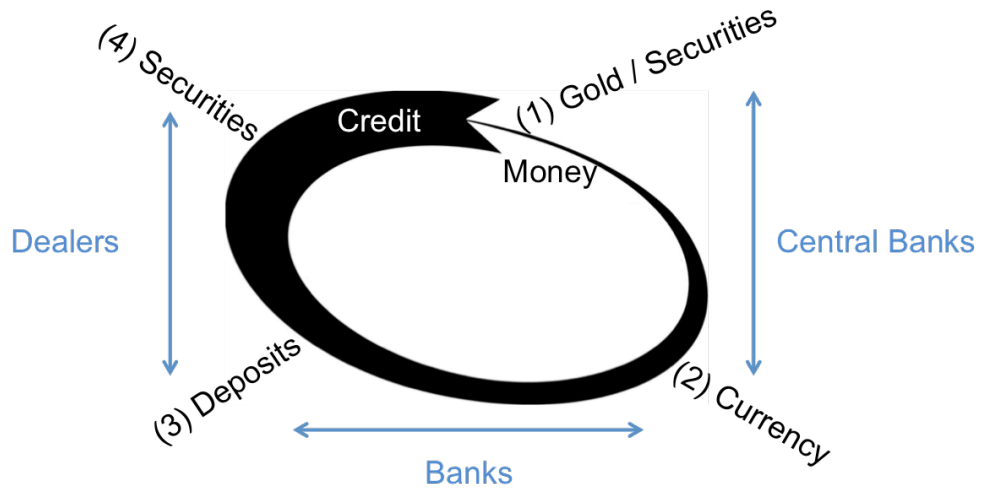


Figure 5: The "Inherent Hierarchy of Money" and its feedback loop.
What is money at one level is credit at the previous level. Central banks manage the conversion of currency to gold or securities, banks manage the conversion of deposits to currency and dealers the conversion of securities into deposits. The Ouroboros- like shape stresses the fact that "securities" behaving as credit at the bottom of the hierarchy become the basis for money creation at the top of the hierarchy to account for the fact that the assets backing the currency are no longer gold but securities. This exposes the feedback loop between money and credit creation, and in a wider sense also the feedback loop between economic productivity and finance.
Source: Mehrling (2012) and our own extension within the Ouroboros representation.

Mehrling (2012) notes that money is *inherently* hierarchical "to emphasize that the hierarchical character of the system, and its dynamic character over time, are both deep features of the system that emerge organically from the logic of its normal functioning. That is to say, the hierarchy is not something simply imposed from the outside, e.g. by the power of government, or the force of law. Rather, monetary systems are inevitably hierarchical, from the inside, by the logic of their internal operations" (9). The expansive nature of money seems to be supported even when it is tied to a more inelastic anchor like gold. The abandoning of the Gold Standard and the eventual breakup of Bretton Woods in 1971 are just two examples that show when push comes to shove conversion constraints will be abandoned. Even when currency was physically tied to gold, the money supply was never completely fixed but expanded due to imports from other countries or from reducing the gold content in coins. The real economy is non-stationary and its growth is driven endogenously by innovations (Romer 1994), which in turn are strongly catalyzed by access to credit and long-term investments in the various forms of productive capital, foremost human capital in modern societies. Consequently, there is an intrinsic tendency for credit to expand and contract, even if

money at the level above is fixed. “Near monies” are likely to develop and to expand the money supply until a conversion into money forces its contraction.

3.3 The important role of market-based securitized finance

The call to prevent banks from creating money in order to prevent future financial crises neglects the increasingly important role of money and credit creation at the fourth level of the hierarchy. Debts to GDP ratios in most developed markets are presently at record levels. Much of this debt was not generated by deposit-creating bank loans but financed by transferred purchasing power in the global financial markets. The public debt of 16 trillion US$ owed by the U.S. Government was not financed by bank loans but the issuance of securities. Lehman Brothers, a non-deposit-taking investment bank, was one of the largest originators of subprime loans through its ownership of BNC Mortgages. Of the 13.3 trillion US$ in mortgage debts outstanding in Q3 2013, only 3.6 trillion US$ were held by commercial banks.[2]

The point is, commercial banks may be creators of deposit money but credit creation takes place in a much wider system of financial intermediaries, such as dealers and asset managers, including what has been described as the shadow banking system. Loans are converted into securities, which in turn can be used as collateral for further credit creation. Short-term securities have become money-like instruments, as large institutional investors prefer not to hold cash in bank deposits but rather instruments such as repurchase agreements or commercial paper. Liquidity is provided through maturity and reverse maturity transformations (Pozsar and Singh 2011) and short-term debt instruments have become much better indicators of liquidity and credit conditions than traditional measures based on reserves and deposits (Adrian and Shin 2009; Singh and Stella 2012). Money-like securities are being created, which serve as collateral for more credit creation through the hierarchical money loop. We can best summarize the situation by emphasizing that most money creation is done by apparent non-money

[2] http://research.stlouisfed.org/fred2/graph/?g=EaU

issuance of securities of all types, which acts as money and as the basis for the next level of credit creation as explained above.

In a study of 14 developed countries, Schularick and Taylor (2012) finds that, between 1870 and 1939, money and credit "maintained a roughly stable relationship to each other, and to the size of the economy", the only exception being the Great Depression, when money and credit aggregates collapsed. After its recovery post-1945, money and credit decoupled from the 1970s onwards, when credit grew rapidly "via a combination of increased leverage and augmented funding via the non-monetary liabilities of banks" (1031). Data from Roxburgh et al. (2009) shows that, for over a century, U.S. deposits have grown roughly in line with GDP (approximately 50 percent of U.S. GDP). What grew much faster, particularly over the last three decades, was "money" in the form of securities. The growth of debt and equity securities accelerated from the 1980s onwards, culminating in total U.S. financial assets worth 442 percent of U.S. GDP just before the crisis of 2008.

It is this hidden creation of money and credit that controls the dynamics of unsustainable bubble-like regimes leading to financial and economic instabilities. Just as the traditional banking system, this securitized market-based system is also inherently fractional, because there are more securities outstanding than there are deposits and because the same securities can collateralize multiple loans, as evident by the practice of re-hypothecation (Singh and Aitken 2010).

In times of crisis, institutional investors withdraw their funding and securities are converted back into cash, putting downward pressure on asset prices, which accelerates the positive feedback where funding liquidity and market liquidity become mutually reinforcing within a liquidity spiral (Brunnermeier and Pedersen 2009). The banking crisis of 2008 was not a traditional bank run on deposits, it was primarily a run on short-term securities (Gorton and Metrick 2012). Consequently, the role of the central banks has evolved from that of the traditional "lender of last resort" to that of "dealer of last resort", providing market liquidity by bidding for risky assets that serve as collateral (Mehrling 2011).

Full-reserve banking would prevent bank runs on commercial banks but it would not be able to prevent a run on other financial intermediaries. It would also not prevent

the creation of other money-like liabilities.[3] It should be noted, however, that the distinction between "traditional commercial banking" and "shadow banking" is rather academic. In practice, the two are very much intertwined, just one example being that traditional banks were major sponsors of bank conduits that invested in asset-backed securities, which eventually had to be taken back on balance sheet. Full-reserve banking could draw a clearer line between traditional and non-traditional banking but it would most likely shift even more lending to the latter. As traditional banks deleverage, financing solutions for households and for small and medium enterprises are already coming increasingly from shadow banks (Braithwaite, Arnold and Alloway 2014).

[3] Chamley, Kotlikoff and Polemarchakis (2012) address the issue and propose that all limited liability financial institutions, whether they are commercial banks, investment banks, insurance companies or hedge funds, should operate as mutual fund-holding companies and be 100 percent equity financed. However, they also state, "shadow banks will be those without limited liability. They will be permitted to take leverage." (116). In this context, their definition of shadow banking is not entirely clear to us nor is the envisaged role of the central bank.

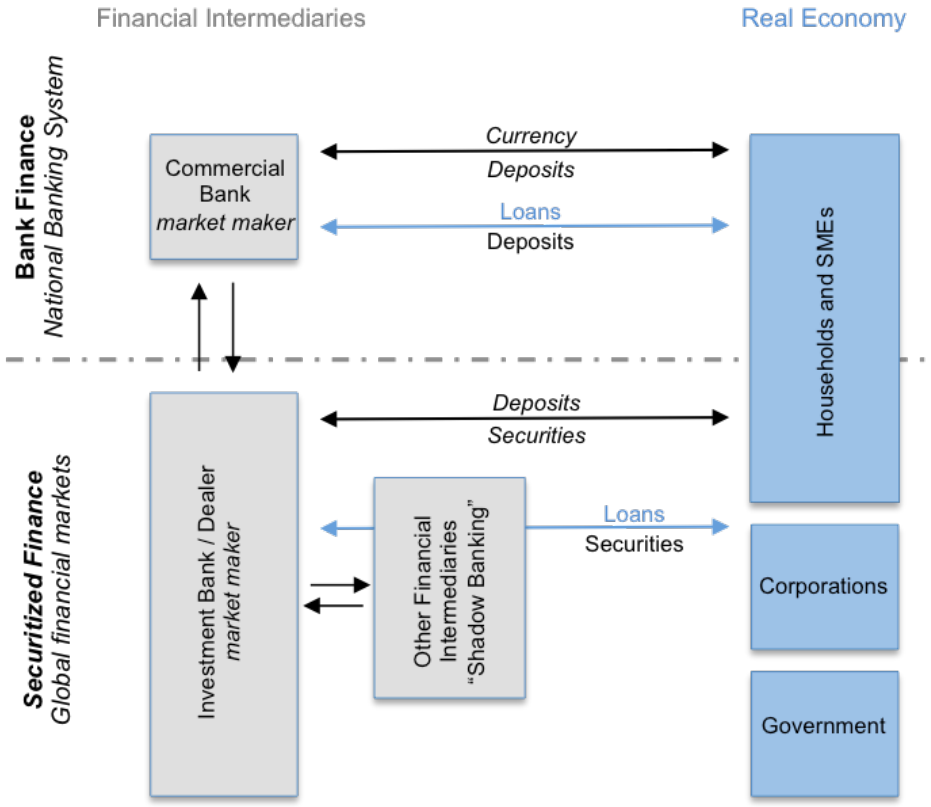


Figure 6: Bank credit creation vs. securitized credit creation.
Under traditional bank finance, banks create loans funded primarily by deposits. They act as market makers between deposits and currency and create liquidity by taking on conversion risk. Under securitized finance, financial intermediaries create loans that are funded by short-term debt, often collateralized with securities. Dealers act as market makers between securities and deposits and create liquidity by taking on inventory. Households and SMEs generally depend on access to bank finance although they increasingly receive credit also from other financial intermediaries. Large corporations and governments generally finance themselves in the global capital markets.
Source: own illustration

3.4 Money creation and asset bubbles

Credit creation is of vital importance for entrepreneurs and growth, as perhaps most famously argued by Schumpeter. However, it is also a liability on future growth and a key precursor to financial crises (e.g. Reinhart and Rogoff 2009; Schularick and Taylor 2012). Money creation matters because it affects the prices of assets (real or financial assets, depending on the type of money creation) and because it constrains and controls the creation of credit through the hierarchy of money explained above. We have stressed that credit is always backed implicitly or explicitly by some kind of asset. When financial assets serve as collateral, there is a positive feedback between credit creation and the value of the asset: a larger asset price equates to a larger collateral

value and thus allows for larger credit creation; a larger credit creation provides larger purchasing power of the pool of assets, therefore pushing their price higher; and so on. The larger the pool of money chasing one particular type of asset and the scarcer the asset, the stronger the positive feedback on its price. Paired with human herding behavior, this can give rise to asset bubbles (Corsi and Sornette 2014).

The rise of an increasingly securitized monetary and financial system has been accompanied by a succession of financial bubbles developing jointly and feeding on each other, as documented by Sornette and Cauwels (2014).[4] A key mechanism that gives rise to financial booms and crashes is positive feedback, which arises from the interactions within the system (Sornette 2003; Sornette and Cauwels 2015). The inherent hierarchy of money exhibits both positive feedback between individual levels of the hierarchy and, as we have shown above, across the hierarchy through the extraordinary role of securities.

On the positive, financial bubbles can be catalysts of innovation, as witnessed in historical examples of "new technology" bubbles. They can encourage investments in areas that would otherwise not bring the technological advances if projects had been evaluated rationally using standard cost-benefit analyses (Gisler and Sornette 2010). Moreover, asset booms can change regime without having a large impact on the economy.

On the negative, they can also be indicators of an increasingly unstable system that, when stressed by a relatively small local perturbation (such as the US subprime crisis), can trigger a large response in the global system (the Global Financial Crisis). The current international monetary and financial system has been argued to amplify the key weakness of national monetary and financial systems as producing "excess financial elasticity", which leads to credit and asset booms and busts and consequently systemic banking crises and macroeconomic dislocations (Borio 2014).

[4] For example, the savings and loans crisis of the 1980s, the great crash of October 1987, the burst of Japanese real estate and stock market bubbles in 1991, the emerging markets bubbles and crashes in 1994 and 1997, the LTCM crisis of 1998, the dotcom bubble bursting in 2000, the subprime bubble bursting in 2007 and others (Sornette and Cauwels 2014).

It is possible that there are trade-offs between designing a financial system in which smaller bubbles develop that burst more frequently, with minor repercussions on the economy, and a system with a prolonged build-up of large bubbles, longer apparent calm periods (like the "Great Moderation") but with potentially major repercussions on the real economy upon their burst. One indicator that we have been moving towards the latter system could be the lengthening of the "financial cycle",[5] as documented by Drehmann, Borio, and Tsatsaronis (2013).

Full-reserve banking would reduce liquidity creation at the banking level and could therefore theoretically reduce the build-up of financial bubbles. However, as we have clarified before, much liquidity creation is taking place in the global financial markets from institutions financed only indirectly by deposits through short-term debt liabilities. Moreover, outright money creation by central banks as well as indirect influence on bank credit creation through interest rates also has a strong influence on the development of financial bubbles. Several studies document the relationship between quantitative easing measures and rising asset prices (for example, Breedon, Chadha, and Waters 2012 for the UK and references therein for the U.S.). Ultra-low interest rates entice new borrowing and push investors towards more risky asset classes. Central bank's large-scale purchases of securities (money creation) did not lead to inflation in the real economy but to a price inflation of financial assets and other assets assumed as reliable storage of value, such as real estate. These central bank actions have generally been credited with averting a major depression but at the cost of strong distortions of the price discovery in the financial markets and of serious underfunding of retirement liabilities, as pension funds are no more able to get the needed revenues on their capital. In this way, central banks have seriously augmented the intergenerational problem.

It is too early to conclude whether the overall consequences of such policies are positive on the medium and long-term. We are concerned by deep-rooted long-term

[5] The term 'financial cycle' refers to the "self-reinforcing interactions between perceptions of value and risk, attitudes towards risk and financing constraints, which translate into booms followed by busts. These interactions can amplify economic fluctuations and possibly lead to serious financial distress and economic dislocations" (Borio 2013 183). It is hence closely related to the concept of positive feedback we described earlier.

pervasive adverse consequences, such as the intrinsic loss of creativity by the misallocation of resources and talents and possible innate build-up of novel systemic instabilities. The irony of our times is that we have forgotten how to grow even in the presence of almost an infinite amount of available credit. Despite record levels of debt in much of the Western world, we are trying to generate demand by encouraging even more debt with ultra-low interest rates and an unprecedented amount of asset purchases by central banks, forgetting that growth (above the population-driven level) is in the end generated by genuine innovations in technology. In principle, whether it is money creation by commercial banks, shadow banks or central banks, we must not fall prey to the illusion of the "perpetual money machine", the belief of wealth creation from increasing financial assets rather than productive innovation in the real economy (Sornette and Cauwels 2014). Our concern is not that banks can create deposit money but that we must learn how to employ the enormous amounts of global financial capital in a productive and sustainable manner.

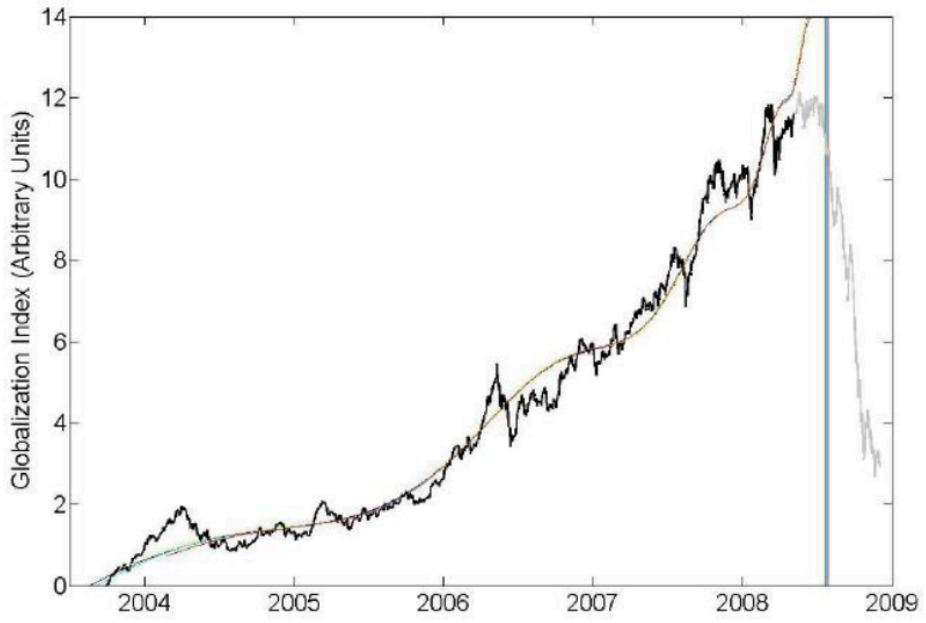


Figure 7: The globalization bubble.
The time series represent a proprietary index of emerging markets equities and currencies, freight prices, soft commodities, base and precious metals and energy. The smooth curves show the fit of the model, the vertical green line is the best estimate of the correction time. Only the black data was used to calibrate the model back in 2008.
Source: ETH Financial Crisis Observatory in Sornette and Cauwels (2014).

3.5 Conclusion

The intrinsic existence of the loop in the hierarchy of money and credit explains one fundamental origin for the opacity of the discourses on money and credit. Not only is money at one level credit at the previous level, but credit can also become money at a distant, deeper level. This creates confusion in the understanding of the relationship between money and credit. But in fact, once this is understood, there is no complexity, only the fact that something that stores value can be exchanged for other things (it acts as money at all possible levels of the hierarchy) and can be used as a collateral for another form of accepted support of exchange (it acts as credit).

Advocating that banks be banned from creating money fails to understand bank money creation in this fundamental hierarchical context. Not only would such an initiative be unlikely to succeed due to money's natural tendency towards expansion; banks or other financial institutions are likely to develop money-like assets to provide liquidity when demanded. It also neglects the importance of securities and global capital markets in the creation of money and credit.

Credit creation, whether bank financed or capital market financed, matters because it is an essential engine of innovations and use of capital, while it is also always a claim to the profits from future growth. It allows us a more efficient use of our assets but it also makes our balance sheets more vulnerable to liquidity mismatches and falling asset prices. The accelerated growth in securities since the 1980s coincided with an increase in debt to GDP levels and more frequent financial bubbles.

Money creation and global cross-border flows expand and contract the sea of liquidity and hence the potential for developing local asset booms and busts. Consequently, a loose monetary policy in the form of historically low interest rates and historically large purchases of securities by central banks has led to new asset booms. Because any financial instrument is just a derivative of the real economy, value can ultimately only be generated in the real economy. This is the foundation of the value of securities, which in turn is increasingly the foundation of money creation. The fundamental problem of our time seems to be the attempt to create future growth through more credit and more money creation rather than productive growth in the real economy. However, financial markets (and also governments) can be powerful

supporters of innovation. There is no need to restrict banks from creating money but rather we must learn to use credit and money more productively via carefully designed incentives.

3.6 References

Adrian, Tobias, and Hyun Song Shin. “Money, Liquidity and Monetary Policy.” *American Economic Review* 99, no. 2 (May 2009): 600–605.

Adrian, Tobias, Emanuel Moench, and Hyun Song Shin. “Financial Intermediation, Asset Prices, and Macroeconomic Dynamics.” *Staff Report, Federal Reserve Bank of New York* 422 (January 2010): 1–43.

Bell, Stephanie. “The Role of the State and the Hierarchy of Money.” *Cambridge Journal of Economics* 25 (2001): 149–163.Bezemer, Dirk J. “Causes of Financial Instability: Don’t Forget Finance” (April 4, 2011): 1–28.

Benes, Jaromir, and Michael Kumhof. “The Chicago Plan Revisited.” *IMF Working Paper* (August 2012): 1–71.

Bezemer, Dirk J. “The Credit Crisis and Recession as a Paradigm Test.” *Journal of Economic Issues* 45, no. 1 (March 2011): 1–18.

Borio, Claudio. “The International Monetary and Financial System: Its Achilles Heel and What to Do About It.” *BIS Working Papers* (August 2014): 1–33.

Braithwaite, Tom, Martin Arnold, and Tracy Alloway. “Shadow Banks Step Into the Lending Void.” *Financial Times*. London, June 17, 2014.

Breedon, F, J S Chadha, and A Waters. “The Financial Market Impact of UK Quantitative Easing.” *Oxford Review of Economic Policy* 28, no. 4 (2012): 702–728.

Brunnermeier, M K, and L H Pedersen. “Market Liquidity and Funding Liquidity.” *Review of Financial Studies* 22, no. 6 (May 14, 2009): 2201–2238.

Brunnermeier, Markus K, and Yuliy Sannikov. “A Macroeconomic Model with a Financial Sector .” *American Economic Review* 104, no. 2 (February 2014): 379–421.

Chamley, Christophe, Laurence J Kotlikoff, and Herakles Polemarchakis. “Limited-Purpose Banking—Moving From “Trust Me” to “Show Me” Banking.” *American Economic Review* 102, no. 3 (2012): 113–119.

Chiarella, Carl, Peter Flaschel, Florian Hartmann, and Christian R Proaño. “Stock Market Booms, Endogenous Credit Creation and the Implications of Broad and Narrow Banking for Macroeconomic Stability.” *Journal of Economic Behavior and Organization* 83, no. 3 (2012): 410–423.

Corsi, Fulvio, and Didier Sornette. “Follow the Money: the Monetary Roots of Bubbles and Crashes.” *International Review of Financial Analysis* 32 (2014): 47–59.

de Soto, Hernando. “The Mystery of Capital.” *Finance and Development, Quarterly Magazine of the IMF* 38, no. 1 (March 2001): 1–9. https://www.imf.org/external/pubs/ft/fandd/2001/03/desoto.htm.

Drehmann, Mathias, Claudio Borio, and Kostas Tsatsaronis. “Charactarizing the Financial Cycle: Don't Lose Sight of the Medium Term.” *BIS Working Papers* (June 2012): 1–43.

Fisher, Irving. *100 % Money*. 2nd ed. New York: Adelphi Company, 1936.

Foley, Duncan K. “Money in Economic Activity.” In *Money*, edited by John Eatwell, Murray Milgate, and Peter Newman, 248–262. 2nd ed. New York and London: The New Palgrave, 1989.

Friedman, Milton. *A Program for Monetary Stability*. New York: Fordham University Press, 1960.

Gisler, Monika, and Didier Sornette. “Bubbles Everywhere in Human Affairs.” In

Modern RISK-Societies, Towards a New Framework for Societal Evolution, edited by L Kajfez-Bogataj, Karl H Müller, I Svetlik, and N Tos, 117–134. Vienna: Edition Echoraum, 2010.

Goodfriend, Marvin, and Monica Hargraves. "A Historical Assessment of the Rationale and Functions of Reserve Requirements." *Economic Review, Federal Reserve Bank of Richmond* (March/April 1983): 1–19.

Gorton, Gary, and Andrew Metrick. "Journal of Financial Economics." *Journal of Financial Economics* 104, no. 3 (2012): 425–451.

Gray, Simon. "Central Bank Balances and Reserve Requirements." *IMF Working Paper* (February 2011): 1–56.

Krainer, Robert E. "Towards a Program for Financial Stability." *Journal of Economic Behavior and Organization* 85 (2013): 207–218.

McLeay, Michael, Amar Radia, and Ryland Thomas. "Money Creation in the Modern Economy." *Bank of England Quarterly Bulletin* 54, no. 1 (1st Quarter 2014): 1–14. http://www.bankofengland.co.uk/publications/Documents/quarterlybulletin/2014/qb14q101.pdf.

Mehrling, Perry. *The New Lombard Street: How the Fed Became the Dealer of Last Resort*. New Jersey: Princeton University Press, 2011.

------. "The Inherent Hierarchy of Money." *Prepared for Duncan Foley Festschrift Volume, and Conference April 20-21, 2012* (April 2012): 1–21.

Pozsar, Zoltan, and Manmohan Singh. "The Nonbank-Bank Nexus and the Shadow Banking System." *IMF Working Paper* (December 2011): 1–19.

Reinhart, Carmen M, and Kenneth S Rogoff. *This Time Is Different*. Princeton University Press, 2009.

Romer, Paul M. "The Origins of Endogenous Growth." *Journal of Economic Perspectives* 8, no. 1 (Winter 1994): 3–22.

Roxburgh, Charles, Susan Lund, Charles Atkins, Stanislas Belot, Wayne W Hu, and Moira S Pierce. "Global Capital Markets: Entering a New Era." *McKinsey Global Institute* (September 24, 2009): 1–32.

Schularick, Moritz, and Alan M. Taylor. "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870–2008." *American Economic Review* 102, no. 2 (April 2012): 1029–1061.

Singh, Manmohan, and James Aitken. "The (Sizable) Role of Rehypothecation in the Shadow Banking System." *IMF Working Paper* (July 2010): 1–16.

Singh, Manmohan, and Peter Stella. "Money and Collateral." *IMF Working Paper* (April 2012): 1–21.Soddy, Frederick. *The Role of Money*. London: George Routledge & Sons, 1934.

Soddy, Frederick. *The Role of Money*. London: George Routledge & Sons, 1934.

Sornette, Didier. *Why Stock Markets Crash: Critical Events in Complex Financial Systems*. Princeton, New Jersey: Princeton University Press, 2003.

------. "Financial Bubbles: Mechanisms and Diagnostics" (April 8, 2014): 1–26.

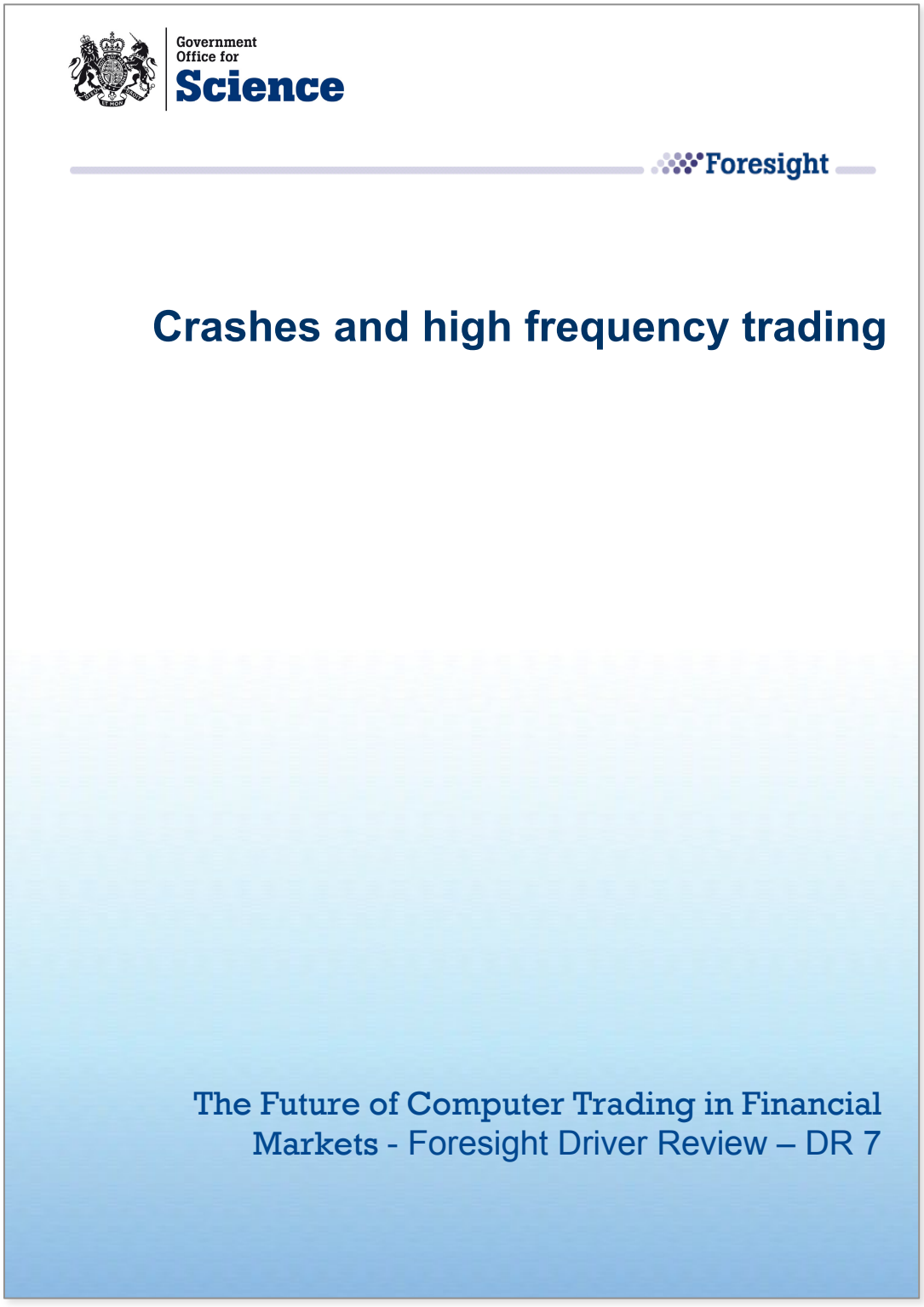
Sornette, Didier, and Peter Cauwels. "1980–2008: the Illusion of the Perpetual Money Machine and What It Bodes for the Future." *Risks* 2, no. 2 (June 2014): 103–131.

4. Crashes and liquidity at high frequency

4.1 Introduction

The following section introduces our article “Crashes and high frequency trading”, which was published by the UK Foresight Project in September 2011. It presents a partial review of the potential for bubbles and crashes associated with high frequency trading. Subsequently we provide an “Afterthought on liquidity and instability through HFT”, which presents an overview and discussion of the current state of academic empirical findings.

4.2 Crashes and high frequency trading



Contents

Crashes and High Frequency Trading

An evaluation of risks posed by high-speed algorithmic trading

D. Sornette and S. von der Becke

August 2011

This review has been commissioned as part of the UK Government's Foresight Project, The Future of Computer Trading in Financial Markets. The views expressed do not represent the policy of any Government or organisation.

Executive summary

We present a partial review of the potential for bubbles and crashes associated with high frequency trading (HFT). Our analysis intends to complement still inconclusive academic literature on this topic by drawing upon both conceptual frameworks and indicative evidence observed in the markets. A generic classification in terms of Barenblatt's theory of similarity is proposed that suggests, given the available empirical evidence, that HFT has profound consequences for the organization and time dynamics of market prices. Provided one accepts the evidence that financial stock returns exhibit multifractal properties, it is likely that HFT time scales and the associated structures and dynamics do significantly affect the overall organization of markets. A significant scenario of Barenblatt's classification is called "non-renormalizable", which corresponds to HFT functioning essentially as an accelerator to previous market dynamics such as bubbles and crashes. New features can also be expected to occur, truly innovative properties that were not present before. This scenario is particularly important to investigate for risk management purposes. This report thus suggests a largely positive answer to the question: "Can high frequency trading lead to crashes?" We believe it has in the past, and it can be expected to do so more and more in the future. Flash crashes are not fundamentally a new phenomenon, in that they do exhibit strong similarities with previous crashes, albeit with different specifics and of course time scales. As a consequence of the increasing inter-dependences between various financial instruments and asset classes, one can expect in the future more flash crashes involving additional markets and instruments. The technological race is not expected to provide a stabilization effect, overall. This is mainly due to the crowding of adaptive strategies that are pro-cyclical, and no level of technology can change this basic fact, which is widely documented for instance in numerical simulations of agent-based models of financial markets. New "crash algorithms" will likely be developed to trade during periods of market stresses in order to profit from these periods. Finally, we argue that flash crashes could be partly mitigated if the central question of the economic gains (and losses) provided by HFT was considered seriously. We question in particular the argument that HFT provides liquidity and suggest that the welfare gains derived from HFT are minimal and perhaps even largely negative on a long-term investment horizon. This question at least warrants serious considerations especially on an empirical basis. As a consequence, regulations and tax incentives constitute the standard tools of policy makers at their disposal within an economic context to maximize global welfare (in contrast with private welfare of certain players who promote HFT for their private gains). We believe that a complex systems approach to future research can provide important and necessary insights for both academics and policy makers.

Crashes and high frequency trading

Introduction

The way stocks are traded on stock exchanges has evolved enormously over time as a result of technological advancement and arguably changes in regulation[1]. Nowadays the majority of volume is traded electronically, based on systematic computer algorithms. The ultra-high-speed version of algorithmic trading, high frequency trading, is estimated to account for over 77% of transactions in the UK market according to Tabb Group[2], but there are lower estimates of about 25% for futures in 2010[3]. The May 6 flash crash in 2010, which saw the Dow Jones lose about 1 trillion USD of market value and individual stocks trading at fractions or multiples within minutes, put increased focus on HFT. Even though high frequency traders were subsequently mostly cleared from having caused the crash, doubts remain as to whether this new form of trading bears potentially destabilizing risks for the market.

Being a fairly new phenomenon, academic research on this subject is still limited in numbers and to some extent inconclusive with respect to potential risks posed by HFT. Advocates often point to HFT's role as liquidity providers, hence reducing transaction costs, lowering spreads and volatility. Several studies lend support to this view. Brogaard (2010) analyses the impact HFT has on US equities market and finds that high frequency traders add to price discovery, provide best bid offer quotes for most of the day and do not seem to increase volatility but may even reduce it. Studies on algorithmic trading (not necessarily at high frequency) also find it improves liquidity and price discovery (Hendershott and Riordan (2009); Hendershott, Jones and Menkveld, (2010)). Menkveld (2011) demonstrates that the success of a new equities market critically benefited from HFTs role as "new market makers". Gsell (2008) simulates the impact of algorithmic trading on markets and finds indications that, for large trade volumes, algorithmic trading has a negative impact on market prices and that lower latency decreases market volatility. In contrast, Zhang (2010) finds a positive correlation between HFT and stock price volatility, which seems to be stronger in times of high market uncertainty. He finds that HFT hinders the incorporation of fundamental information into asset prices, causing stock prices to overreact to fundamental news. Smith (2010) finds that HFT have an increasingly large impact on the microstructure of equity trading and finds trades are showing significantly higher degrees of self-similarity.

An important point is that the focus on liquidity provision by HFT may be misguided. First, liquidity is not equal to volume. HFT arguably increases the volume of transactions. But volume is roughly the product of order sizes by their number per unit time (a kind of velocity). In the same way that the momentum of a body is the product of its mass by its velocity, volume can be large with just small order sizes contributing with a very large velocity or rate of transactions. Second, the hypothesis that HFT is a positive development is often based on the underlying assumption that more liquidity is necessarily good for investors and companies.

In the following section of this report, we will develop the above points and question the value of liquidity provided by HFT. We will develop the hypothesis that the utility of the real economy is likely to be an increasing function of liquidity, concave and asymptotically saturating to a plateau, and perhaps even decreasing when liquidity is many times the need of the real economy. It is conceivable that liquidity reaches a point beyond which the real economy does

[1] Reg NMS in the US and MiFID in Europe have been argued to have changed the incentive structure of stock exchanges.
[2] http://www.bloomberg.com/news/2011-01-24/high-frequency-trading-is-77-of-u-k-market-tabb-group-says.html
[3] http://www.futuresmag.com/Issues/2011/May-2011/Pages/Highfrequency-trading-Good-bad-or-just-different.aspx

not benefit anymore and where additional liquidity increases the risk of herding, of strong correlations, possibly leading to systemic instabilities and ultimately to crashes and their aftermath. Consequently, the third section of this article will examine risks posed by high-speed algorithmic trading. Preliminary evidence suggests the system of price formation to be indeed "non-renormalizable" which leads us to believe that HFT is likely to accelerate future market crashes. The systemic danger lays in the possibility of cross-excitations to other markets causing additional herding of low latency and/or fundamental traders. We believe that a complex systems approach to future research is crucial in the attempt to capture this inter-dependent and out-of-equilibrium nature of financial markets. Particularly relevant in assessing HFT risk is to understand their behaviour in conjunction with other market participants across various asset classes. Agent-based-modelling (ABM hereafter) offers a key method to improve our understanding of the systems' dynamics. Section 4 of this report will discuss the complex systems approach (and often associated agent-based modelling) and identify possible avenues for future research. Finally in section 5, we develop considerations for policy makers and regulators drawing upon our current analysis of the system.

2 Rethinking the value of liquidity

As shown above, several academic papers suggest that HFT increases liquidity in the market and advocates of HFT point to this liquidity provision as a key contribution to the well-functioning of financial markets. What is consequently overlooked is firstly that high frequency traders can also be significant liquidity takers and, secondly, that there are indications that larger liquidity increases herding effects and crashes thereby potentially reducing the value the real economy derives from liquidity above a certain threshold.

Market makers vs. market breakers

HFT can play an important role as market makers, for example, generating trading volume on new electronic exchanges (King and Rime, 2010; Menkveld, 2011). Trade volume, however, is not liquidity but all too often mistaken for it. Liquidity means "there is a bid/offer on the other side when I need it, for the amount I need it (market depth) at a reasonable level (market breadth). Volume is not the same as liquidity, since volume is approximately like the product of liquidity x velocity, and a large volume does not necessarily imply a large liquidity. This is illustrated by the May 6 flash crash when a fundamental trader's algorithm started selling based on previous trade volume, creating a positive feedback between its own selling and the trading activity of other market participants.

The same event also demonstrated that HF Traders can turn into significant liquidity takers[4]; while they are liquidity providers when it suits them (they have no obligation to make quotes[5]). This is also described as "flow toxicity", when market makers provide liquidity at their own loss or when informed traders take liquidity from uninformed traders[6]. In fact it seems HFT provides liquidity in good times when it is perhaps least needed and takes liquidity away when it is most needed, thereby contributing rather than mitigating instability (a point that will be discussed in the following section).

[4] "…it appears that the 17 HFT firms traded with the price trend on May 6 and, on both an absolute and net basis, removed significant buy liquidity from the public quoting markets during the downturn." (CFTC-SEC report on May 6, 2010, p. 48).
[5] We need to keep in mind, however, that even brokers with this obligation turn to sub quotes during the flash crash.
[6] See D. Easley et al. "Measuring flow toxicity in a high frequency world" (2010) for a development of a volume based metric to measure flow toxicity.

A recent report showed that the frantic development of HFT has slowed down in developed markets, and there is a transfer of activity to emerging markets such as Russia, Brazil and Mexico where exchanges are beginning to revamp their systems to attract such players. Low market volumes and stiff competition have led to a sharp fall in "high-frequency" (Grant, 2011). This illustrates the fact that, as HFT market participants flock into a given market, the opportunities shrink, dispelling the possibility for further growth.

It is also conceivable that HFT liquidity is provided at the expense of other market participants. Short term traders may be specifically prone to herd to the same information, driving the price further away from its fundamentals (Froot et al., 1992). The more momentum traders there are in a market and the higher the diversion from fundamentals, the fewer fundamental traders survive, further strengthening momentum traders. Various equilibria are possible between short and long-term investors[7]. The question is what is the right mix of investment strategies and horizons that best serves the well-functioning of financial markets and ultimately social welfare?

Liquidity vs. volatility

If the main argument for the benefits of HFT is liquidity, we need to ask whether liquidity is always "a good thing", whether additional liquidity above a certain threshold becomes only marginally more useful or if too much liquidity can even be a "bad thing". Finding answers to these questions is crucial for balancing potential benefits with potential risks associated with HFT.

Higher liquidity and higher trading volumes are generally associated with lower transaction costs, narrowing bid/ask spreads and thereby reducing volatility. Several studies have shown that HFT or algorithmic trading have improved market efficiency in this way. The real economy benefits from lower volatility as for example a company's stock price is an indication of market confidence in the management of the company. In contrast, higher volatility is perceived as higher riskiness and may translate in higher funding costs, lower consumer, supplier and investor confidence. Investors will expect higher returns for higher volatility.

There is, however, evidence that there can be indeed too much so-called "liquidity" (actually trading volume). While volatility appears to be reduced at the level of individual stocks' bid/ask prices, it may have amplified tail risk and increased volatility at the macro level. Dichev et al. (2011) analysed the effect of higher trading volumes and stock volatility and find that higher trading volumes can be destabilizing and produce "its own volatility above and beyond that based on fundamentals". Interestingly, there appears to be an inflection point at which an increase in trading volume increases volatility to the extent that only a small circle of investors benefit and that "benefits to investors dominate at low to medium levels of trading". In similar vein, Haldane recently pointed to the danger of normalising deviance at the micro level and concluded suggesting "thinner technological slices may make for fatter market tails. Flash Crashes, like car crashes, may be more severe the greater the velocity" (Haldane, 2011).

The flash crash of May 6, 2010 started in one of the most liquid markets, the E-Mini S&P 500 futures contracts. What is the role of liquidity or its scarcity in the occurrence of crashes? On the one hand, one can argue that deep markets should absorb new players more easily. On the other hand, it could be possible that deeper markets are more prone to pandemics as their

[7] See A.G. Haldane "Patience and Finance" (2010) for a good discussion of this point.

impact and connection to other markets is larger. It turns out that crashes occur in both types of markets. The fact that the flash crash started in one of the most liquid markets provides additional support for the hypothesis that flash crashes are not incompatible with large and deep markets. One reason is that the large number of participants can herd and therefore form large destabilizing crowds, whose size may be comparable to the global market size. In this perspective, it is important to distinguish this type of flash crash in the presence of large volume (herding effect) and the more localized ones occurring in single stocks with low volume (liquidity effect). Indeed, there is also evidence of crashes in not-so-liquid stocks. It seems single stocks are equally prone to crash but have less pandemic like consequences. The linking of assets through derivative instruments amplifying correlations is an important factor which will be discussed in more detail later in this document.

This leads to the question of whether there is a relationship between "incidents", large volatility events, market disruptions, flash crashes on the one hand and the volume of transactions on the other hand. We conjecture that there exist regimes in which larger so-called liquidity (actually volume) leads to larger extreme risks. We would like to see plotted some measures of extreme risks as a function of volume of transactions. This would give an important insight and is suggested as a line of future actions.

Summarizing, we formulate the hypothesis that the utility of the real economy could be an increasing function of liquidity with decreasing marginal gains, that is, with a concave shape and asymptotically saturating to a horizontal plateau for large liquidity. There could even be a decline in utility through possibly negative consequences for very large liquidity (or volume), such as the risks associated with e.g. increased volatility and crash risks. We suggest that testing this hypothesis has large priority in order to pose the problem in its core fundamentals.

Finally, the utility derived from liquidity provided by HFT could be argued to be lower than from other market participants. Why? Because HFT does not absorb risks. If a fundamental trader sells a position as on May 6, it can only be absorbed by counterparties wanting to be long. HFT books are flat by the end of the day. They carry no inventory; there is no transfer of risk apart for some milliseconds. HFT are opportunistic, they arbitrage what is referred to as "inefficiencies", but may often result from differences in time scales and technology. It remains to be seen if liquidity is a real robust externality of the behaviour of HFT.

The "law of the few"

Another aspect in assessing the value of liquidity could be the concentration of liquidity providers. If from around 12,000 market participants, 30% of liquidity is provided by 15 participants, the liquidity is less reliable than if it was more evenly distributed[8]. It is probable that Zipf's law applies here[9]. At least with a rough approximation, the number of participants contributing a liquidity of L or larger is roughly proportional to 1/L. This means in general that a few largest participants contribute a major fraction. In addition, there could be "dragon-kings" that correspond to even more concentration (Sornette, 2009). An important question is how does the concentration evolve as a function of time, by following secular trends versus short-term adaptive transients, or both? Obtaining data on trading volumes of individual players

[8] See table "Summary statistics of E-mini traders" from the CFTC-SEC report on market events of May 6, 2010.
[9] The evidence for concentration is fuzzy, and it is not clear that investment banks and the biggest funds are the major players. A possible clue is provided by the advertisement for HFT programmers by headhunting agencies, which are almost all for "a top investment bank" (http://www.wilmott.com/messageview.cfm?catid=5&threadid=83435 or http://www.wilmott.com/messageview.cfm?catid=5&threadid=85840).

would be very meaningful. Some sources suggest that HFTs make up 2% of approximately 20,000 trading firms in the U.S. and account for about 60-70% of equity trading volume. These are suggested to include a small number of investment banks, less than 100 hedge funds and hundreds of specialist prop shops[10]. This suggests that Zipf's law applies (Saichev et al., 2009), as we can presume that the few investment banks are the largest players and the many prop shops the smallest ones with specific hedge funds in the middle. So far we cannot prove it.[11] In the presence of the scarcity of data, we propose to use Zipf's law as a normative model, rather than an empirical question at this stage (which will be falsified as data becomes available). Indeed, Zipf's law is so well verified in many contexts that it can be used as a guide in the absence of sufficient data (Saichev et al., 2009).

3 Understanding the risks of HFT

3.1 Similarity classification of possible HFT regimes

In order to gain a better appreciation of the nature of the possible impact that HFT has on price dynamics, we can frame the question as follows: How do the different properties of price dynamics change as the rate of trading increases or, equivalently when the time τ between trades shrinks to smaller and smaller values. In other words, is calendar time playing a role? It is well documented that financial time series exhibit self-similarity properties, to a first approximation (Mandelbrot and Hudson, 2006; Mantegna and Stanley, 2007; Calvet and Fisher, 2008). This means that time units are arbitrary and the properties are related at all time scales. In details, of course, this simple "fractal" or scale invariance view is naïve and needs updating, as for instance with the development of the most sophisticated multifractal models (see Filimonov and Sornette (2011) and references therein). In addition, with the development of HFT, the issue of how microstructure impacts large scale properties (at the time scale of minutes, hours, days, weeks, months and years) is of paramount importance and a priori not trivial.

To make the discussion more precise, let us consider some statistical property denoted $P(\{r\}, t, \tau, \theta)$ of the price dynamics $\{r\}$ at time scale t, given a minimum time scale for trading τ and the presence of other unspecified control parameters θ. The time scale τ results from physical and regulatory limits that control the smallest time scale at which transactions can occur (we neglect for simplicity that in reality there will be a distribution of time scale; here τ is the typical micro-time scale). It can be called the ultraviolet (UV) cut-off (using the physical analogy that a short period is the same as high frequency, and the UV spectrum is in the high frequency range above visible light). As τ approaches zero (as with the development of HFT that reduces the waiting time between trades to milliseconds or lower), there are three possible impacts this could have on price dynamics.

As $\tau \Rightarrow 0$, $P(\{r\},t, \tau, \theta)$ converges to a function $P^*(\{r\}, t, \theta)$ that is independent of τ. This means that the UV cut-off is not important: the characteristic of price dynamics and other important properties are the same at the minute, hourly, daily time scales if the frequency of trades is per second or per millisecond. This is called "complete similarity of the first kind" in the classification of Barenblatt (1996). Concretely, suppose that, at some time T, by innovation and

[10] Rob Iati from TABB Group in "The real story of trading espionage": http://advancedtrading.com/algorithms/showArticle.jhtml?articleID=218401501

[11] In the UK, HFT make up 77% of transactions and 35% of turnover according to TABB group. They estimate that there are between 35 and 40 independent HFT firms http://www.advancedtrading.com/articles/229100205.

via the introduction of new technologies, the UV cut-off is reduced from $\tau 1$ to $\tau 2$ that is much smaller than $\tau 1$, say by a factor of 10 or 100 or 1000. Then, the characteristics of the price dynamics at time scale $t > \tau 1$ are unchanged. This implies that HFT should not have any impact if "complete similarity of the first kind" holds. Only the properties at time scales between $\tau 2$ and $\tau 1$ may be novel. Concretely, suppose that t1=1 second and t2=1 millisecond. The above claim means that the properties of market price dynamics at scales above 1 second are unchanged by the introduction of HFT below the 1 second time scale. In the language of Barenblatt's (1996) classifications of similarity, such "complete similarity of the first kind" holds in this instance, which implies that HFT would have essentially no effect on the price dynamics. The microscopic time scale τ is irrelevant to the organization of the financial markets.

The second possible regime is called "complete similarity of the second kind", which holds if, as $\tau \Rightarrow 0$, the properties embodied in $P(\{r\}, t, \tau, \theta)$ converge to the product $f(t/\tau)\, P^*(\{r\}, t, \theta)$. Note that the presence of the UV cut-off τ only appears via some function of the dimensionless ratio t/τ. This means that, in absence of physical or regulatory constraints, the dynamics at a given time scale should consequently be similar to that of any other time scales and HFT should not have any significant impact, apart from a rescaling of the properties that can be absorbed into a suitable regulatory or risk management framework. In other words, as $\tau \Rightarrow 0$, time accelerates and the movie of the price dynamics is just running faster. The implication is that one should observe more often bubbles and crashes, in proportion to an acceleration of the rate of trading captured by the function $f(t/\tau)$. This scenario suggests that HFT adds to market instability *per unit of calendar time* and increases significantly the probability of crashes and crises. Indeed, consider the limit where HFT accounts for all the volume of transactions. Then the whole market is moving at the HFT rate. Now, imagine a movie in which you slow down frame by frame. Then, HFT slows down and become low frequency trading, such as daily trading. If the correspondence is 1 second of HFT corresponds to 1 day of low frequency trading in 1962, say, then one crash per year in 1962 would corresponds to one crash every 4 minutes in HFT time!

In the third scenario, $P(\{r\}, t, \tau, \theta)$ does not converge as $\tau \Rightarrow 0$. This means that the presence of a minimum time scale τ has profound consequences for the organization and time dynamics of market prices. This regime is called "non-renormalizable" in mathematics and physics and is for instance the case of hydrodynamic turbulence, for which the limit $\tau \Rightarrow 0$ leads to multifractal properties. Given the significant evidence of the multifractal properties in financial stock prices (Calvet and Fisher, 2008), it is thus plausible that the HFT time scale and the associated structures and dynamics do cascade and affect profoundly the overall organization of markets. In this "non-renormalizable" regime, HFT can be expected to have significant impact on market price dynamics, essentially functioning as an accelerator to previous market dynamics such as bubbles and crashes. New features can also be expected to occur, truly innovative properties that were not present before. This scenario is particularly important to investigate for risk management purpose.

3.2 Destabilizing effects of HFT

The present section aims to present several observations that could provide clues as to what kind of regime we are faced with when analysing the risks of HFT. Are the underlying algorithms in fact stabilizing or the reverse?

Indications of herding during the May 6, 2010 flash crash

On May 6, 2010, HFT created a "hot potato effect"[12]. Paired with other sellers, this translated in a negative spiralling effect. This can give a hint to what can happen if HFTs start trading mainly among each other. Why did they keep buying? Minority agent-based games in the crowding phase provide examples of such behaviour, in which buys and sells alternate as a result of the anti-correlation between recent individual actions and aggregate behaviour (Challet et al., 2005; Coolen, 2005).

According to the CFTC-SEC report, it was the algorithm of a mutual fund and not HFT that created a negative feedback loop on "volume" during the May flash crash. As it sold at 9% of previous volume, this was to a large degree absorbed by HFT, who later needed to sell their net long position, thereby increasing volume and selling pressure. As mentioned previously, this is an example of when "volume" is mistaken for liquidity. However, in our view, the event as described in the report was indeed a problem created through an algorithm of a fundamental trader, but it was then amplified by the strategic behaviour of the HFT.

Nanex analysed the trade flows on May 6, 2010 and found that it was aggressive high frequency selling that "would often clear out the entire 10 levels of depth before the offer price could adjust downward. As time passed, the aggressiveness only increased, with these violent selling events occurring more often, until finally the e-Mini circuit breaker kicked in and paused trading for 5 seconds, ending the market slide"[13]. Nanex also reports that the algorithm from the mutual fund was mostly active after stocks had already fallen. This should not be misconstrued as removing the influence of the mutual fund, since its algorithm was targeting volume in its strategy to pass its larger order.

The second liquidity crisis on May 6, 2010, in stocks, seems to have been impacted more by fundamental and discretionary traders than by HFT. Trading of HFTs after 2.45pm was back to previous levels, nevertheless many stocks saw drawdowns of 60%. How does this fit in with the findings of the E-mini crash? This is an illustration of the interplay between an overall climate of uncertainty with the on-going Greek crisis developing since April 2010, and panic herding with pro-cyclical mutual excitations between HFT and the rest of the investor population. Preliminary unpublished calibrations of self-excited Hawkes processes performed in our group suggest that the self-excitation component (or viral epidemic) of trades was indeed abnormally large during May 6, 2010 compared to other trading days. This supports the hypothesis that HFT may have a destabilizing effect through its endogenous self-excitation nature within the (small) pool of participants.

On May 6, 2010, the fundamentals in the stock market were shaky (Greece, flight to quality, higher volatility) so we cannot claim that a purely technical issue caused the E-mini and later individual stocks to tank. Perhaps, there needs to be a general instability and increased volatility in the market, which is then pushed over the edge through HFT. This is in line with the understanding of the authors of this report concerning the causes of financial crashes: a proximate cause triggers the crash that is rooted fundamentally on the existence of an intrinsic

[12] Between 2:45:13 and 2:45:27, HFTs traded over 27,000 contracts, which accounted for about 49 per cent of the total trading volume, while buying only about 200 additional contracts net. (CFTC-SEC report on May 6, 2010, p. 15).
[13] Nanex Report on May 6th Flash Crash http://www.nanex.net/FlashCrash/FlashCrashAnalysis.html

instability that has matured progressively, preparing the field for major disruptions that are triggered by local or proximate causes (Sornette, 2003).

General arguments for the existence of herding

The Kauffman Report (Bradley and Litan, 2010) points out the unprecedented level of correlation in equity markets and identifies ETFs as a major destabilizing factor, more so than HFT[14]. JP Morgan concludes that the high level of correlation can be explained by "macro-driven environment, record use of index derivatives such as futures and to a lesser extent ETFs, and high-frequency trading". They point out that "the share of futures and ETFs steadily grew over the past five years, and is now ~140% of cash equity volume (i.e., futures and ETFs are roughly ~60% of all equity volumes – perhaps not a coincidence that realized stock correlation is ~60%). The growth in index volumes coincided with a rise in correlation over the past ten years. More importantly, the growth of index volumes is directly driving excess market correlation (levels of correlation above the levels implied by macro volatility)"[15]. The reason why J.P. Morgan gives relatively less weight to the impact of ETFs on correlation than Kauffman could be explained by the fact that J.P. Morgan differentiates between broad based ETFs and specialist ETFs.

When different instruments (equity ETFs/Futures) are connected to the same underlying (stocks), it seems logical that there would be mutual excitation and increased inter-dependencies (correlations). Our own (still unpublished) research at the Financial Crisis Observatory (www.er.ethz.ch/fco/) supports the hypothesis that bubbles and crashes are in general mutually excited, with interesting dynamics and fluxes in different sectors. This occurs not only at times of great crashes but also for events developing over 6 months characterized with loss amplitudes of 10 percent or so. This supports the notion that HFT in broader market indices may pose greater systemic risk.

As HFT use short-term information as well as adaptive algorithms, there is potential for herding as the strategies can crowd to the same signal, synchronize and lead to transient large instabilities. Froot et al. (1992) find that "if speculators have short horizons, they may herd on the same information, trying to learn what other informed traders also know. There can be multiple herding equilibria, and herding speculators may even choose to study information that is completely unrelated to fundamentals."

Finally, we note that HFT generally has stop losses built in the algorithms plus human oversight that can withdraw trading in critical market circumstances altogether[16]. This can be seen as a stabilising factor for the HFTs and a mechanism to mitigate the risk of herding.

[14] http://ftalphaville.ft.com/blog/2010/11/08/397431/kauffman-etfs-are-the-problem-not-hft and http://www.kauffman.org/uploadedFiles/etf_study_11-8-10.pdf

[15] J.P. Morgan „Why we have a correlation bubble" (5 October 2010).

[16] 6 of the 12 HFTs scaled back their trading during some point after the broad indices hit their lows at about 2:45 p.m. Two HFTs largely stopped trading at about 2:47 p.m. and remained inactive through the rest of the day. Four other HFTs appear to have each significantly curtailed trading for a short period of time, ranging from as little as one minute (from 2:46 p.m. to 2:47 p.m.) to as long as 21 minutes (from 2:57 p.m. to 3:18 p.m.). (CFTC-SEC report on May 6th, 2010, p.45).

Observations of mini-crashes

Mini-flash-crashes in single stocks seem to happen rather frequently[17]. In the case of the mini crash of "Progress Energy" in September 2010, the company reported a "big ramp-up in trades, hundreds of trades a second" for an otherwise "sleepy stock", a fact that points to HFT[18]. Also an interesting account of events is the day when Apple saw a mini flash crash – followed by other tech stocks and even a sharp move in USD/Yen[19]. The involvement of HFT is not evident. However, other mini flash crashes, for example April 28[20] or 27 September 2010[21] also seem to have been accompanied by increased frequency in quotes.

Most of HFT trading is currently taking place in stocks, futures and options. Even though the focus so far has been mostly on equity markets, there is no reason other markets will not become equally vulnerable to mini-crashes. It seems that we already see this happening. For example, on March 9, 2011 the price of Cocoa plummeted 12.5% in less than a minute. Raw sugar dropped 6% in 1 second on February 3 this year and trading in cotton was halted several times[22]. Mini-crashes (or flash rises) have also been observes in the currencies markets although, as often, the link to HFT is not clear[23].

Nanex identifies "thousands" of mini-crashes over the last few years. We are not sure though how useful this is because in order "To qualify as a down-draft candidate, the stock had to tick down at least 10 times before ticking up -- all within 1.5 seconds and the price change had to exceed 0.8%". We are probably looking for more severe impacts. Moreover, the frequency of those occurrences has not increased over time. This makes it hard to link to HFT[24].

Our experience with other complex systems, including earthquakes and epileptic seizures, suggests that one should not discard the precursory information of such smaller events that can announce the "great ones" (Helmstetter and Sornette, 2003; Ouillon and Sornette, 2004; Osorio et al., 2010; Sornette and Osorio, 2010). They may also be symptomatic of more structural changes, as argued in a recent work of our group concerned with nuclear risks (Sornette et al., 2011).

Evidence of operational risk

Another important risk dimension is associated with so-called operational risks, resulting from infrastructure disruptions, computer bugs, hacking and others, collectively known as "cyber-risks". Such cyber-risks are now at the top of concerns of the 500 largest companies in the USA, according to a study by Swiss Re in 2006. Maillart and Sornette (2010) report the first quantitative analysis of cyber-risks, quantified by the number of identity thefts per event. They find a power law distribution with tail exponent equal to 0.7, implying that the variance and the mean of the losses do not exist mathematically, and that larger and larger risks are expected to surface in the future. This corresponds to the regime of "wild" risks, according to the

[17] http://ftalphaville.ft.com/blog/2010/09/28/354876/the-apparent-rise-of-the-mini-flash-crash or http://wallstreetpit.com/61727-apple-aapl-mini-flash-crash-renews-market-structure-worries or http://www.observer.com/2010/wall-street/mini-flash-crash-nucor-shares
[18] http://www.nytimes.com/2010/11/09/business/09flash.html
[19] http://www.ft.com/cms/s/0/ddf14a8a-506f-11e0-9e89-00144feab49a.html#axzz1Ifuk6rCi
[20] http://www.nanex.net/FlashCrash/FlashCrashAnalysis_042810_MiniFlashCrash.html
[21] http://www.nytimes.com/2010/11/09/business/09flash.html?pagewanted=1&_r=1
[22] http://www.ft.com/cms/s/0/dbfb15d6-4a83-11e0-82ab-00144feab49a.html#axzz1Ifuk6rCi
[23] http://ftalphaville.ft.com/blog/2010/10/25/381381/flash-a-ha-hell-strike-everyone-of-our-security-markets/ or http://www.ft.com/cms/s/0/ddf14a8a-506f-11e0-9e89-00144feab49a.html#axzz1Ifuk6rCi
[24] http://www.nanex.net/FlashCrashEquities/FlashCrashAnalysis_Equities.html

terminology of Mandelbrot, for which conventional methods are invalid. One should thus keep in mind the possible collision and interplay between the endogenous dynamics of investors that can lead to crashes and such operational risks. In the case of “Infinium Capital Management”, HFT is blamed for a significant market disruption in the Oil Market and a $1 million loss within a few seconds of trading. Some highlights from a Reuters report: “The algorithm was turned on at 2:26:28 p.m. (Eastern) on Feb. 3, less than four minutes before NYMEX closed floor trading and settled oil prices. It immediately started uncontrollably buying oil futures… Infinium placed 2,000 to 3,000 orders per second before its flooded order router "choked" and was "dead in the water" a few seconds later… Infinium's burst of buying and selling represented about 4 percent of average daily trading volume in the contract, and caused a brief 1.3 percent jump in oil prices, from $76.60 to $77.60, before settling at $76.98, Reuters’ data show. Trading volume spiked nearly eight-fold in less than a minute”[25] Infinium blamed the mistake on a “broken algo”, a flaw with the computer that did not properly record the order. This could be an example of “operational risk” or an example of deliberate market manipulation such as “flash orders” or “banging the close”, something HFT is frequently accused of.

This leads us naturally to the issue of “market manipulation”. A market can also be manipulated through rumours, insider trading, etc. However, the algorithms seem to offer very specific new ways of manipulation. Remember an ex Goldman Sachs employee being arrested by the FBI because of fears that the stolen algorithm could be used to manipulate markets. Why do we worry so much about 32MB of this specific code but not about all the codes that are still with and in constant development at Goldman Sachs?

Synthesis and recommendations

Some defenders of HFT point to the fact that we already had a flash crash in May 1962, before high speed trading was invented. There are indeed some parallels[26]. Even though this shows flash crashes can occur without HFT, the question is whether HFT has increased the likelihood of flash crashes occurring (either frequently in single stocks with minor market impact or less frequently in large, connected markets (Futures/ETFs) with larger impact). The above presented observations lead us to conclude that this is indeed the case.

If nothing else, HFT can be understood as accelerating time, so to speak. Indeed, take in consideration that HFT accounts for most of the volume. Take the limit where it is all the volume. Then the whole market is moving at the HFT rate. Now, imagine a movie in which you slow down frame by frame. Then, HFT slows down and becomes low frequency trading, such as daily trading. If the correspondence is 1 second of HFT corresponds to 1 day of low frequency trading in 1962, say, then one crash per year in 1962 would corresponds to one crash every 4 minutes in HFT time ! This reasoning is of course naïve and misses a lot of ingredients, but it nevertheless captures what is a key aspect of the problem. By definition and intrinsically by its time-acceleration nature when it dominates the trading volume, HFT will give many more crashes per unit calendar time (not per unit transaction time or HFT time).

What is needed is a better understanding of the relationship between trade volume and systemic risk. Is there a “right amount of liquidity”? What is the right mix of trading strategies that maximises social welfare? We also need a better understanding of the interplay between different trading methods (e.g. high frequency, low frequency, fundamental, technical) and

[25] http://af.reuters.com/article/energyOilNews/idAFN2511929020100825
[26] http://online.wsj.com/article/SB10001424052748703957604575272791511469272.html

investment instruments (e.g. stocks, ETFs, futures) and markets (e.g. equities, FX, commodities). In our view, current research does not make the distinction between these factors explicit enough. We believe that in the quest for answers to those questions, much is to be gained by a complex systems approach to future research as we will argue in the following section.

4 A complex systems approach to future research

4.1 Brief summary of main insights about crises from agent-based models

Key to understand financial market risk of various players is to gain a better understanding of the interactions of various market participants and the resulting patterns emerging in the markets. We propose that greater transparency allowing the identification and observation of market participants should be used to improve monitoring and early warning systems. These warning systems should be based on models that capture the complex evolutionary nature and the non-linearity of financial markets (Hommes and Wagener, 2009; Evstigneev, Hens and Schenk-Hoppe, 2009). Traditional macro-economic models such as the DSGE (dynamic stochastic general equilibrium) models, based on the assumption of rational agents that are drawn to equilibrium, have proven insufficient in forecasting or identifying large systemic financial risks. Agent-based models (ABM) can be used to group various market participants, assign behavioural preferences (for example short-term systematic vs. long-term fundamental trading) and simulate their behaviour over time. Harras and Sornette (2011) used ABM to study the emergence of bubbles and consequently crashes in financial markets. Their findings demonstrate how feedback mechanisms lead to the development of transient collective herding regimes resulting in unsustainable high prices that are then corrected by a crash. They state that “Paradoxically, it is the attempt for investors to adapt to the current market regime which leads to a dramatic amplification of the price volatility. A positive feedback loop is created by the two dominating mechanisms (adaptation and imitation) which, by reinforcing each other, result in bubbles and crashes”. These findings applied to HFT demonstrate how “learning algorithms” can indeed be expected to accelerate the formation of bubbles.

Chiarella, Dieci and He (2009) emphasise the importance of agent heterogeneity and the formation of expectations through economically intuitive rules of thumb. They find that bounded rational heterogeneous agent (BRHA) models are “able to accommodate market features that seem not easily reconcilable for the standard financial market paradigm, such as fat-tail behaviour, volatility clustering, large excursions from the fundamental, and bubbles”.

Minority games (Challet et al., 2005; Coolen, 2005), and more generally first-entry games, can be taken to be simplified models of investors trying to be first movers either to buy in or to sell out before their competitors. These ABM show clearly that agents who try to optimize their utility function tend to crowd in with similar strategies that have been recent winners. This leads in general to enhanced financial volatility and sometimes to big swings. It seems indeed that adaptive and learning algorithms interacting by buying and selling on the same market tend to develop collective dynamical modes that are prone to large moves.

One of the most pressing subjects is to come up with a realistic agent-based model where crisis and complexity arise from simple rules and interactions in a universal way, robust against specific assumptions. Indeed, current economic theories are inadequate and one of the most promising alternative of today is agent-based modelling. From there, we need to build policy making devices (a "policy wind tunnel", as Nigel Gilbert would call it, or an "economic flight

simulator"). In the limit of large system sizes, universality classes may appear, and we need to identify and classify them for economic systems. But the high dimensionality of agent-based models makes them hard to calibrate and validate. There is an extreme sensitivity to control parameters, a single factor can matter ("butterfly effect") and we need to pay careful attention to the calibration-overfitting-validation problem (Sornette et al., 2007; 2008; Satinover and Sornette, 2011).

4.2 Financial markets as truly "complex adaptive systems"

We argue that markets and economies in general are truly "complex systems" in a technical sense. As such, they are intrinsically characterized by periods of extremity and by abrupt state-transition and spend much time in a largely unpredictable state. The world of financial engineering has seen extraordinary growth in recent years and many extremely sophisticated methods have been developed to assess and distribute risk, largely by the development of new instruments derived from packaging and then re-dividing large number of underlying simpler instruments. In addition, technology innovations, such as HFT, have led to new markets and new opportunities. While many of these developments are quite sophisticated, they generally fail to incorporate the crucial insight that financial markets and economies have become very complex systems. Financial instruments are designed making a convenient and desirable assumption of independence. Complex systems typically contain many instances of hidden interdependences, tight couplings and other subtle (and inconvenient!) features (Satinover and Sornette, 2010).

i. Complex systems are usually open and dynamic - the underlying components of the system are in flux. Nonetheless, complex systems usually demonstrate stability of patterning, which lends itself to a mistaken presumption of equilibrium, as in classical economics and control theory.

ii. Most frequently the stability of patterning may be considered a "meta-stability" - it includes multiple quasi-stable states with dynamic, abrupt and difficult to predict transitions among states.

iii. Complex systems often have a memory. The future state depends not only on one or more preceding states but upon the dynamic sequence of preceding states - i.e., they demonstrate path dependency. This feature lends these systems the power of self-organization.

iv. Complex systems often consist of nested hierarchies of smaller-scale complex systems. This is most evident in the neurobiology of the brain where, e.g., cortical brain tissue forms a self-organizing complex systems "sheet," but is itself at a lower level composed of cortical processing units which "compute" an output passed up to the higher level. The cortical units are themselves composed of individual units (neurons) whose computational capacity arises from the complex systems nature of their internal components. In the other direction, economies and markets may be thought of as composed of many individual brains, or agents (Satinover, 2002).

v. Complex systems often yield outputs that are emergent: the interactions among agents/individual units may be deterministic, but the global behaviour of the system as a whole conforms to rules that are only rarely deducible from knowledge of the interactions and topology of the system. Financial services systems are intractable, which means that it is impossible fully to specify them.

vi. In complex systems, the relationship between input and output is typically non-linear so that a small perturbation may yield a very large overall disturbance while a large perturbation may be absorbed with little or no effect. Complex systems are typically exquisitely sensitive and at the same time resilient, in ways that are difficult to predict.

vii. Complex systems are also characterised by having both negative (damping) and positive (amplifying) feedback loops. The output of the system alters the nature of the (next) input.

4.3 Financial bubbles and crashes: implications of and for HFT

Let us come back to the simple picture according to which HFT corresponds approximately to an accelerated movie of the financial time series prior to its existence, as described above. Given that algorithms involved in HFT adapt and learn (and therefore imitate) somewhat similarly to human investors, we can draw on our previous research on financial market crashes to suggest that financial instabilities can be expected to flourish in a world dominated by HFT (Jiang et al., 2010; Johansen and Sornette, 2010; Sornette, 2003; Sornette and Johansen, 2001; Sornette and Zhou, 2006). Pro-cyclicality mechanisms, also known as positive feedbacks, are numerous in a world in which automated hedging strategies are implemented. This leads to unsustainable regimes, ending in crashes and crises.

Specifically, our previous works support the proposition that (i) the presence of a bubble can be diagnosed quantitatively before its demise and (ii) the end of the bubble has a degree of predictability. We hypothesize that the same holds true, probably to an even larger degree, for instabilities occurring at the intraday HFT time scales. This opens the road for systematic studies and a large research program. Of course, these two claims are highly contentious and collide against a consensus both in the academic literature (Rosser, 2008) and among professionals. For instance, in his recent review of the financial economic literature on bubbles, Gurkaynak (2008) reports that “for each paper that finds evidence of bubbles, there is another one that fits the data equally well without allowing for a bubble. We are still unable to distinguish bubbles from time-varying or regime-switching fundamentals, while many small sample econometrics problems of bubble tests remain unresolved” (page 1). Similarly, the following statement by former Federal Reserve chairman Alan Greenspan (2002), at a summer conference in August 2002 organized by the Fed to try to understand the cause of the ITC bubble and its subsequent crash in 2000 and 2001, summarizes well the state of the art from the point of view of practitioners: “We, at the Federal Reserve recognized that, despite our suspicions, it was very difficult to definitively identify a bubble until after the fact, that is, when its bursting confirmed its existence. Moreover, it was far from obvious that bubbles, even if identified early, could be pre-empted short of the Central Bank inducing a substantial contraction in economic activity, the very outcome we would be seeking to avoid.”

To break this stalemate, Didier Sornette, together with Anders Johansen (from 1995 to 2002), with Wei-Xing Zhou (since 2002 (now Professor at ECUST in Shanghai)) and with the FCO group at ETH Zurich (since 2008, www.er.ethz.ch/fco) have developed a series of models and techniques at the boundaries between financial economics, behavioural finance and statistical physics. Our purpose here is not to summarize the corresponding papers, which explore many different options, including rational expectation bubble models with noise traders, agent-based models of herding traders with Bayesian updates of their beliefs, models with mixtures of nonlinear trend followers and nonlinear value investors, and so on (Sornette (2003) and references therein for the period 2002 and the two recent reviews in Kaizoji and Sornette (2010) and Sornette and Woodard (2010) and references therein). In a nutshell, bubbles are identified as “super-exponential” price processes, punctuated by bursts of negative feedback

spirals of crash expectations. These works have been translated into an operational methodology to calibrate price time series and diagnose bubbles as they develop. Many cases are reported in Chapter 9 of the book (Sornette, 2003) and more recently successful applications have been presented with ex-ante public announcements posted on the scientific international database arXiv.org and then published in the referred literature, which include the diagnostic and identification of the peak time of the bubble for the UK real-estate bubble in mid-2004 (Zhou and Sornette, 2003), the U.S. real-estate bubble in mid-2006 (Zhou and Sornette, 2006), and the oil price peak in July 2008 (Sornette et al., 2009).

Kindleberger (2000) and Sornette (2003) have identified the following generic scenario developing in five acts, which is common to all historical bubbles: displacement, take-off, exuberance, critical stage and crash. Applied to HFT, the development of unsustainable mispricing follows similar pro-cyclical mechanisms, in particular amplified by the tendency for algorithms and technical trading that dominates at short time scales to crowd.

In fine, let us conclude this subsection by mentioning that preliminary calibrations of intraday high-frequency price time series with the bubble-diagnostic model developed in our group (see for instance Jiang et al. (2009) and Filimonov and Sornette (2011)) do support the evidence for the presence of bubble-like behaviours at arbitrary short time scales, that are often followed by strong corrections and swings.

5 Considerations for regulators and policy makers

Potential consequence of increased market crashes

If the system is indeed “non-renormalizable” so that HFT leads to singular or non-convergent limiting behaviours, it is an almost certainty that HFT will lead to a higher frequency of crashes. Anecdotal evidence seems to confirm this statement as we pointed out earlier with respect to different mini-crashes that have been observed mostly but not only in equities related markets.

One may rightly ask why we should seek to prevent these crashes from occurring, especially as markets so far have demonstrated an equally fast recovery. Perhaps these volatility bursts are the price to pay for higher liquidity in the market (during normal market situations)? In this respect, there is an interesting paradox in the fact that HFT is justified by innovations that are thought to provide large liquidity and lower cost to investment and access to capital. But these innovations also create the risks of liquidity freezes. In a sense, “more on average” is associated with “much less” or zero at certain times. This phenomenon is well-illustrated by Louzoun et al. (2003), who use a simple auto-catalytic model of innovation and growth, with positive feedbacks and varying interaction range. Louzoun et al. (2003) show that, in such models, the total measure of welfare (wealth) is maximum when the dynamics is the most turbulent and risky, with huge spikes and collapses punctuating a very intermittent dynamics (as shown in the figure below). This is suggestive that more liquidity may similarly be associated with high turbulence, volatility and crashes.

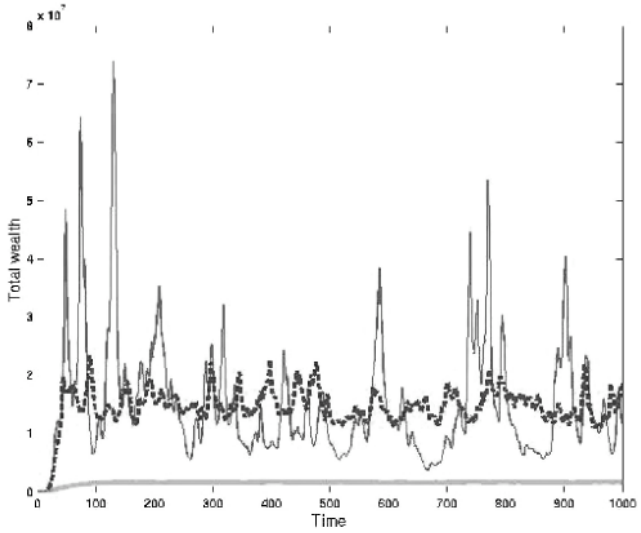


Figure: The time evolution of the total wealth for R = 0 (bottom smooth solid line), R=∞ (spiky solid line), and intermediate R (dashed line), where R is the interaction range between agents. Note that the intermediate competition case R = 40 (dashed line) ensures the maximal average. Note also that the totally globalized case (R = system size = 200) is better even at the worst moments than the completely localized market case (R = 0). However, the dramatic crashes involve of course massive human suffering (loss). This is avoided for R = 40. Reproduced from Louzoun et al. (2003).

This higher turbulence in the form of an increasing number of crashes could raise overall market risk due to the possibility of excitation to other markets and possible herding, specifically when the market is already fragile (e.g. May 6, 2010; the Greece crisis). It is conceivable that, as a consequence, we could see much larger “system failures”, specifically if paired with general pessimism and a mistrust in the financial system. Those failures might result in losses in the real economy that take much longer to recover than the recovery after flash crashes so far.

Regulating complex systems

Two images arise in our mind when we think about the role of a governing agency with respect to financial markets: (1) a conductor in front of an orchestra, who coordinates very talented musicians – who can all play beautifully on their own, but need a coordinator to play a symphony in harmony or (2) a biologist in charge with the complex ecology of a forest.

The conductor does not need to know how to play each individual instrument but he needs to understand them and know when each instrument/musician should play its part. There are two problems with this image. Firstly, the conductor decides which piece to perform and the musicians are willing to follow him because their interests are aligned. This, in financial markets is not a given, as the individual players are generally only concerned with the sound of their own music (profits) and whether or not this goes in harmony with other instruments to create a symphony (growth in the real economy) has so far been of secondary concern (if at all). The second problem with this image of government agencies as conductors is that it is a very powerful position. This view undermines the general free market ideology underlying capitalism. Alternatively, the image of the agency as a biologist seems more appropriate. She plays an active role but lets nature and ecology complexity do its part. She understands the role of all the different species in the ecosystem and when necessary (for example, if excessive

growth of certain animals or plants threatens the balance of the system), steps in to help the system maintain or return to a balance. The difference to a conductor is an understanding for a constantly emerging and evolving system and the consciousness to never fully be in control. This view of regulation emphasises the need to add to current academic research on financial markets and HFT with out-of-equilibrium dynamical system theory.

It is always difficult to forbid something per se via regulations, as it will emerge in a different form somewhere else because professionals are rational in their quest to work at the limit of legality. This can even be transformed as a theorem: optimization of utility in the presence of many constraints is bound to occur somewhere on the boundary of the authorized simplex of possible states, hence at the limit of legality.

That banks serve their own interests on the one hand and play a key role in lubricating the economy, thus serving as public good entities, on the other hand has been widely recognized in recent debates. Many discussions, with different emphasis across the Atlantic, focus on what kind of regulations should therefore be imposed to align the private interests of banks with the public interests. The recent Dodd-Frank act (2010) can be seen as a rather timid step towards a working solution, if not just because many of the changes implied by its implementation are not expected to be fully enacted until 2015 (five years is really like eternity for financial markets!).

Consider in contrast that the fifty years following WWII have constituted arguably the most stable economic period in the history of the United States and of Europe. Most scholars attribute a key role for this stability to the Glass-Steagall Act of 1932, which successfully prevented the occurrence of “super-spreader” instabilities, by separating by law investment banking, commercial banking, retail banking and insurance. This disaggregation provided completely separated waterproof compartments to prevent any Titanic like event of crisis spreading. Only with deregulation that started taking place in the 1980s culminating in the repelling of the Glass-Steagall act by the Gramm–Leach–Bliley Act of 1999, banking mutated into a new highly interconnected form that recovered basically its pre-1929 role within the ecosystem. Much of the risks that we currently face both in Europe and in the US originate from too much leverage and uncontrolled indebtedness spreading across all networks that build on the incorrect belief that transfers of debts to bigger and bigger entities will solve the problem.

We cannot afford and do not need to wait another decade or more until new super high tech models are developed. Faster solutions are possible by revisiting policies that worked in the past and by relearning and expanding some of the old wisdom in economics, specifically related to the role of banks. These theories should be anchored on rigorous analyses of empirical evidence and enhanced by fertilization with various branches of the natural sciences, network analysis, and out-of-equilibrium agent-based models (Sornette and von der Becke, 2011).

References

Aldridge, I. (2010) "High Frequency Trading: a practical guide to logarithmic trading strategies and trading systems", *John Wiley & Sons, Inc*.

Barenblatt, G. I. (1996) Scaling, self-similarity, and intermediate asymptotics, *Cambridge University Press.*

Black, F. (1976) "Studies of Stock Price Volatility Changes", Proceedings of the 1976 Meetings of the American Statistical Association, Business and Economical Statistics Section, 177–181.

Bradley, H. and R.E. Litan (2010) "Choking the recovery (why new growth companies aren't going public and unrecognized risks of future market disruptions)", Ewing Marion Kauffman Foundation, Published Nov. 8, 2010; Revised Version with Corrections and Clarifications Nov. 12, 2010. (http://www.kauffman.org/uploadedFiles/etf_study_11-8-10.pdf)

Berry, M. (1991) "Asymptotics, Singularities and the reduction of Theories", *Logic, Methodology and Philosophy of Science IX, 597-607.*

Brogaard, J. A. (2010) "High Frequency Trading and its Impact on Market Quality", http://www.gsb.stanford.edu/facseminars/events/finance/documents/fin_02_11_brogaard.pdf

Calvet, L.E. and A.J. Fisher (2008) Multifractal Volatility: Theory, Forecasting, and Pricing (Academic Press Advanced Finance), Academic Press.

Cantono, S. and S. Solomon (2010) "When the collective acts on its components: economic crisis autocatalytic percolation", *New Journal of Physics 12.*

Chaboud, A., B. Chiquoine, E. Hjalmarsson, C. Vega, "Rise of the machines: algorithmic trading in the foreign exchange market", International Finance Discussion Paper (2009) http://ssrn.com/abstract=1501135

Challet, D., M. Marsili and Yi-Cheng Zhang (2005) "Minority Games: Interacting Agents in Financial Markets" (Oxford Finance), *Oxford University Press, USA.*

CFTC and SEC Staff report (2010) "Findings regarding the market events of May 6", http://www.sec.gov/news/studies/2010/marketevents-report.pdf

Chiarella, C. Dieci R., and He X.-Z. (2009) "Heterogeneity, Market Mechanisms, and Asset Price Dynamics" in *Handbook of Financial Markets: Dynamics and Evolution*. Chapter 5, 277-344.

Coolen, A.C.C. (2005) "The Mathematical Theory of Minority Games: Statistical Mechanics of Interacting Agents" (Oxford Finance), *Oxford University Press, USA*.

Dichev, I. D., Huang, K and Zhou, D. (2011) "The dark side of trading", Law & Economics Research Paper Series, Research Paper No. 11-95.

Easley, D. M. M. Lopez de Prado, M. O'Hara (2010) "Microstructure of the flash crash", http://ssrn.com/abstract=1695041

Easley, D., M. M. Lopez de Prado, M. O'Hara (2010) "Measuring Flow Toxicity in a High Frequency World", http://ssrn.com/abstract=1695596

Evstigneev, I.V., Hens, T.; Schenk-Hoppe R. K.,(2009) "Evolutionary Finance" in *Handbook of Financial Markets: Dynamics and Evolution, Chapter 9, 507-566.*

Filimonov, V.A. and D. Sornette (2011) "Self-Excited Multifractal Dynamics", *Europhysics Letters 94, 46003 (http://arxiv.org/abs/1008.1430).*

Filimonov, V.A. and D. Sornette (2011) A Stable and Robust Calibration Scheme of the Log-Periodic Power Law Model, submitted to Computational Statistics (http://arxiv.org/abs/1108.0099)

Froot, K.A., D.S. Scharfstein, and J.C. Stein, (1992) "Herd on the street: Informational inefficiencies in a market with short-term speculation". *Journal of finance*, 47(4):1461–1484.

Goldstein, M.A., J.E. Evans, and J.M. Mahoney, "Circuit breakers, volatility, and the U.S. equity markets", 385-405 (http://www.imes.boj.or.jp/cbrc/cbrc-16.pdf)

Grant, J. (2011) The Financial Times, April 12 2011 (http://www.ft.com/cms/s/0/e364be1a-6529-11e0-b150-00144feab49a,_i_email=y.html)

Greenspan, A. (August 30 2002) Economic volatility, symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming. www.federalreserve.gov/boarddocs/speeches/2002/20020830/default.htm

Greenwood, J. and P. Krusell (2007) "Growth accounting with investment-specific technological progress: A discussion of two approaches", *Journal of Monetary Economics 54, 1300–1310.*

Gsell, Markus (2008), "Assessing the Impact of Algorithmic Trading on Markets: A Simulation Approach" ECIS 2008 Proceedings. Paper 225. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1134834

Gurkaynak, R.S. (2008) "Econometric tests of asset price bubbles: Taking stock", *Journal of Economic Surveys 22~(1), 166-186.*

Haldane, A. G. (2010) "Patience and Finance", Speech at Oxford China Business Forum, Beijing. http://www.bankofengland.co.uk/publications/speeches/2010/speech445.pdf

Haldane, A. G. (2011) "Race to zero, Speech at International Economic Association Sixteenth World Congress, Beijing, China. http://www.bankofengland.co.uk/publications/speeches/2011/speech509.pdf

Harras G., Sornette D., (2011) "How to grow a bubble: A model of myopic adapting agents," in press in J. Economic Behavior and Organization (in press) (http://arXiv.org/abs/0806.2989)

Helmstetter, A. and D. Sornette (2003) "Predictability in the ETAS Model of Interacting Triggered Seismicity", *J. Geophys. Res., 108, 2482, 10.1029/2003JB002485*.

Hendershott, T. and R. Riordan (2009) "Algorithmic Trading and Information", Working Paper #09-08, NET Institute

Herndershott, T., C. M. Jones, A. J. Menkveld (2011) "Does Algorithmic Trading Improve Liquidity?" *The Journal of Finance, LXVI, NO.* 1.

Hommes, C., Wagner F. (2009) "Complex Evolutionary Systems in Behavioral Finance" in *Handbook of Financial Markets: Dynamics and Evolution*. Chapter 4, 217-276.

Jiang, Z.-Q., W.-X. Zhou, D. Sornette, R. Woodard, K. Bastiaensen and P. Cauwels (2010) "Bubble Diagnosis and Prediction of the 2005-2007 and 2008-2009 Chinese stock market bubbles", *Journal of Economic Behavior and Organization 74, 149-162.*

Johansen, A. and D. Sornette (2010) "Shocks, Crashes and Bubbles in Financial Markets", Brussels Economic review (Cahiers economiques de Bruxelles) 53 (2), 201-253 (summer 2010) (http://arXiv.org/abs/cond-mat/0210509)

Kaizoji, T. and Sornette, D. (2010) "Market bubbles and crashes", *Encyclopedia of Quantitative Finance (Wiley, West Sussex)*, http://www.wiley.com//legacy/wileychi/eqf/ (long version of the preprint at http://arXiv.org/abs/0812.2449).

Kindleberger, C.P. (2000) "Manias, panics, and crashes: A history of financial crises", 4th Edition. *Wiley, New York.*

King, M. R. and Rime, D. (2010) "The $4 trillion question: what explains FX growth since the 2007 survey?", BIS Quarterly Review, December 2010

Louzoun, Y., S. Solomon, J. Goldenberg and D. Mazursky (2003) "World-Size Global Markets Lead to Economic Instability", *Artificial Life 9, 357-370.*

Maillart, T. and D. Sornette (2010) "Heavy-tailed distribution of cyber-risks", *Eur. Phys. J. B 75, 357-364.*

Mandelbrot, B.B. and R.L. Hudson (2006) The Misbehavior of Markets: A Fractal View of Financial Turbulence, Basic Books; annotated edition.

Mantegna, R.N. and H. E. Stanley (2007) Introduction to Econophysics: Correlations and Complexity in Finance, Cambridge University Press.

Matheson, T. (2010) "Taxing Financial Transactions: Issues and Evidence", IMF Working Paper

Menkveld, A, J. (2011) “High Frequency Trading and The New-Market Makers”(http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1722924)

Moffatt, H.K. (2000) “Euler’s disk and its finite-time singularity”, *Nature 404, 833-834.*

Osorio, I., M.G. Frei, D. Sornette, J. Milton and Y.-C. Lai (2010) “Epileptic Seizures, quakes of the brain?”, *Physical Review E 82 (2), 021919.*

Ouillon, G. and D. Sornette (2004) “Search for Direct Stress Correlation Signatures of the Critical Earthquake Model”, *Geophys. J. Int., 157, 1233–1246.*

Rosser, J.B. (2008) “Econophysics and economic complexity”, *Advances in Complex Systems 11, 745-760.*

Saichev, A., Y. Malevergne and D. Sornette (2009) “Theory of Zipf's law and beyond”, Lecture Notes in Economics and Mathematical Systems 632, Springer (November), ISBN: 978-3-642-02945-5.

Satinover, J. B. (2002) “The Quantum Brain*”. New York: Wiley.*

Satinover, J. and D. Sornette (2010)” Taming Manias: On the Origins, Inevitability, Prediction and Regulation of Bubbles and Crashes”, chapter of the book “Governance and Control of Financial Systems: A Resilience Engineering Perspective,” Gunilla Sundström and Erik Hollnagel, eds., published by Ashgate Publishing Group in their Resilience Engineering Perspectives series. (http://ssrn.com/abstract=1646428)

Satinover, J. and D. Sornette (2011) Cycles, determinism and persistence in agent-based games and financial time-series, in press in Quantitative Finance (2011) (http://arXiv.org/abs/0805.0428)

Securities and Exchange Commission, 17 CFR Part 242, Concept Release on Equity Market Structure; Proposed Rule http://www.sec.gov/rules/concept/2010/34-61358fr.pdf

Smith, R. (2010) “Is high-frequency trading inducing changes in market microstructure and dynamics?” http://arxiv.org/abs/1006.5490v2

Sornette, D. (2003) “Why Stock Markets Crash (Critical Events in Complex Financial Systems)” *Princeton University Press.*

Sornette, D. (2009) “Dragon-Kings, Black Swans and the Prediction of Crises”, *International Journal of Terraspace Science and Engineering 2(1), 1-18 (2009)* (http://arXiv.org/abs/0907.4290) and (http://ssrn.com/abstract=1470006)

Sornette, D.,A. B. Davis, K. Ide, K. R. Vixie, V. Pisarenko, and J. R. Kamm (2007) Algorithm for Model Validation: Theory and Applications, Proc. Nat. Acad. Sci. USA 104 (16), 6562-6567.

Sornette, D., A. B. Davis, J. R. Kamm, and K. Ide (2008) A General Strategy for Physics-Based Model Validation Illustrated with Earthquake Phenomenology, Atmospheric Radiative Transfer, and Computational Fluid Dynamics, Book series: Lecture Notes in Computational Science and Engineering, vol 62, Book Series: Computational Methods in Transport: Verification and Validation

F. Graziani and D. Swesty (Eds.), Springer-Verlag, New York (NY), 2008, pp. 19-73. (http://arxiv.org/abs/0710.0317).

Sornette, D. and A. Johansen (2001) "Significance of log-periodic precursors to financial crashes", *Quantitative Finance 1 (4), 452-471.*

Sornette, D., T. Maillart and B. Sovacool (2011) "Reassessing nuclear power accidents after Fukushima", Nature (submitted 26 April 2011), available upon request to the first author.

Sornette, D. and I. Osorio (2010) Prediction, chapter in "Epilepsy: The Intersection of Neurosciences, Biology, Mathematics, Physics and Engineering," Editors: Osorio I., Zaveri H.P., Frei M.G., Arthurs S., CRC Press, Taylor & Francis Group (2010) (http://arxiv.org/abs/1007.2420).

Sornette, D. and S. von der Becke (2011) "Complexity clouds finance-risk models", *Nature 471, 166.*

Sornette, D. and R. Woodard (2010) Financial Bubbles, Real Estate bubbles, Derivative Bubbles, and the Financial and Economic Crisis, in Proceedings of APFA7 (Applications of Physics in Financial Analysis), M. Takayasu, T. Watanabe and H. Takayasu, eds, Springer (http://arxiv.org/abs/0905.0220)

Sornette, D., Woodard, R. and Zhou, W.-X. (2009) "The 2006-2008 oil bubble: Evidence of speculation and prediction", *Physica A 388, 1571-1576.*

Sornette, D. and W.-X. Zhou (2006) "Predictability of Large Future Changes in Major Financial Indices", *International Journal of Forecasting 22, 153-168.*

Thurner, S. (2010) Systemic financial risk: agent based models to understand the leverage cycle on national scales and its consequences, OECD project "Future Global Shocks".

Vives, X. (1995) "Short-term investment and the informational efficiency of the market", *Oxford Journals, Review of Financial Studies, Vol. 8, Issue 1, pp 125-160*

Zhang, X.F. (2010) "The Effect of High-Frequency Trading on Stock Volatility and Price Discovery", http://ssrn.com/abstract=1691679

Zhou, W.-X. and Sornette, D. (2003) "2000-2003 real estate bubble in the UK but not in the USA", *Physica A 329, 249-263.*

Zhou, W.-X. and Sornette, D. (2006) "Is there a real-estate bubble in the US?" *Physica A 361, 297-308.*

4.3 Afterthought: HFT, liquidity and instability

At the time of writing the above article, academic literature on high frequency trading (HFT) was scarce and inconclusive. Today, the picture that emerges is slightly more complete, as we will show below. However, the debate on how high frequency technology has changed the market microstructure, and with what consequences, is still subject to many differing viewpoints (Abergel et al. 2012). Advocates of HFT usually emphasize its role in providing liquidity and improving market efficiency. Skeptics generally point to accusations of "unfair" technology advantages that facilitate market manipulations, a view that recently received substantial public attention through Michael Lewis' book "Flash Boys" (Lewis 2014). Policy makers have voiced concerns in particular over potential systemic risks associated with high frequency trading (Haldane 2011; Biais and Woolley 2012).

Given the current state of empirical evidence, we provide a brief discussion of how HFT impacts liquidity and financial stability. Table 3 summarizes the key findings of empirical academic studies.[1] The list includes published work as well as working papers and indicates whether the authors investigated HFT specifically or algorithmic trading (AT) generally.[2] Our aim is not to provide a general review of the literature, but to infer what conclusions may be drawn in light of the current state of empirical findings related to liquidity creation and financial stability. Biais and Faucault (2014) provide an excellent literature review, giving a more detailed overview of individual studies as well as discussing important limitations of empirical literature, mainly due to a lack of data availability and issues of endogeneity.

The overall picture that emerges from the studies summarized in table 3 is one of high frequency traders (HFTs) as facilitators of liquidity and price discovery. Of the 18 studies, only five report neutral or negative effects on market liquidity: Lee (2015) identifies HFTs as net buyers of liquidity and finds no evidence of narrowing spreads. Chaboud et al. (2014) find that depending on the trading strategy e.g., arbitrage versus

[1] This list should give a fairly complete overview. However omissions are possible due to rapidly advancing research and not all working papers available from a central database.

[2] For simplicity, we refer to HFT as a particularly fast version of AT. However, it should be noted that algorithmic trading can be automated (such as HFT) but it can also be discretionary, i.e. the final decision to trade being taken by a human rather than a computer.

market making, HFTs demand or supply liquidity. Boehmer, Fong and Wu (2014) find that algorithmic trading improves liquidity on average but that it reduces liquidity for the smallest stocks. Egginton, Van Ness and Van Ness (2014) investigate "quote stuffing" and find that intense quoting activity reduces liquidity. Finally, Gai, Yoa and Ye (2013) find no evidence for a reduction in spreads and a negative impact on market depth. In contrast, 10 studies find that HFT and AT improve liquidity as evidenced by the ratio of nonmarketable to marketable orders, decreases on spreads, and increases in market depth (Brogaard, Riordan, et al. 2014; Brogaard, Hendershott, and Riordan 2014; Brogaard, Hagstömer, et al. 2014; Frino, Mollica, and Webb 2013; Hagströmer and Nordén 2013; Hasbrouk and Saar 2013; Hendershott and Riordan 2013; Menkveld 2013; Riordan and Storkenmaier 2012; Hendershott, Jones, and Menkveld 2011). Two studies show that spreads are wider when HFTs provide liquidity and tighter when they take liquidity, suggesting that HFTs stabilize the liquidity supply by consuming when there is plenty and providing when it is scarce (Carrion 2013; Brogaard, Hendershott, and Riordan 2014). This is an interesting interpretation, as the finding serves equally well as a reminder that proprietary traders provide liquidity when it is profitable yet not when it is costly. Tighter spreads naturally decrease the profit margin.

With respect to price discovery, eight studies report an increase in efficiency through a reduction in arbitrage opportunities and the faster transmission of information, which leads to permanent price changes (Boehmer, Fong, and Wu 2014; Brogaard, Hendershott, and Riordan 2014; Brogaard, Riordan, et al. 2014; Chaboud et al. 2014; Gerig 2014; Carrion 2013; Riordan and Storkenmaier 2012; Hendershott, Jones, and Menkveld 2011). Two studies report a negative effect on price discovery (Lee 2015; Zhang 2010). However, Lee (2015) finds a negative impact on overall market quality only true for very short time intervals and finds a neutral impact in longer time intervals.

What then can we infer from these studies with respect to HFT and financial stability? Brogaard and Riordan (2014) find that HFT stabilizes markets by providing liquidity also during periods of extreme price movements. Their data covers the turbulent market times between 2008 and 2009, but their findings contradict reports of an "evaporation of liquidity" on the day of the Flash Crash of May 6th, 2010 (Easley, Lopez de Prado, and O'Hara 2011; CFTC-SEC 2010).

The evidence on volatility is mixed: four studies report an increase in short-term volatility (Boehmer, Fong, and Wu 2014; Egginton, Van Ness, and Van Ness 2014; Gai, Yao, and Ye 2013; Zhang 2010), one finds no change (Frino, Mollica, and Webb 2013), and two studies find that HFT reduces short-term volatility (Hagströmer and Nordén 2013; Hasbrouk and Saar 2013). At this point, it is not clear what causes these contradictory results and hence would be an interesting subject for future investigation. However, volatility is not necessarily a good indicator of financial stability. One example, at low frequency, is the low volatility experienced during the "Great Moderation", which gave a false sense of security before the impending global financial crisis.

Moreover, it is possible that after a certain threshold, more speed does not translate into narrower spreads, as supported by the findings of Gai, Yoa and Ye (2013) analyzing a transition from microseconds to nanoseconds. Similarly, Budish, Cramton and Shim (2013) show that market correlations break down at high frequency time horizons, thereby creating technical arbitrage opportunities that can be exploited by whoever is fastest. The result is a technical arms race that, according to their model, is socially wasteful and eventually leads to wider spreads and thinner markets.[3]

Finally, two studies report strong evidence of the synchronization of trading strategies (Chaboud et al. 2014; Gerig 2014). This type of automated herding is what we have argued to be at the core of positive feedbacks that can lead to market crashes (Sornette and von der Becke 2011). Moreover, the fact that ATs and HFTs process price relevant information faster, or that they trade in the direction of permanent price change, is not necessarily evidence of greater market efficiency. This interpretation is based on the assumption that markets are essentially efficient, incorporating externally generated news that is relevant to the fundamental value of the underlying stock. This neglects the fact that markets also exhibit features of "reflexivity" (Soros 1987). From this perspective, the price movement itself influences the fundamentals and is hence driven

[3] Consequently, Budish, Cramton and Shim (2013; 2014) propose the introduction of uniform-price sealed-bid double auctions conducted at frequent but discrete time intervals.

endogenously.[4] In this spirit, Filimonov and Sornette (2012) and subsequently Filimonov et al. (2014) develop a measure of endogeneity, which they apply to high frequency data on the E-mini S&P 500 futures. Their results show a significant increase in endogeneity from 1998 to 2012, with less than 30% of price changes in 2012 resulting from exogenous information, as compared to 70% in 1998.

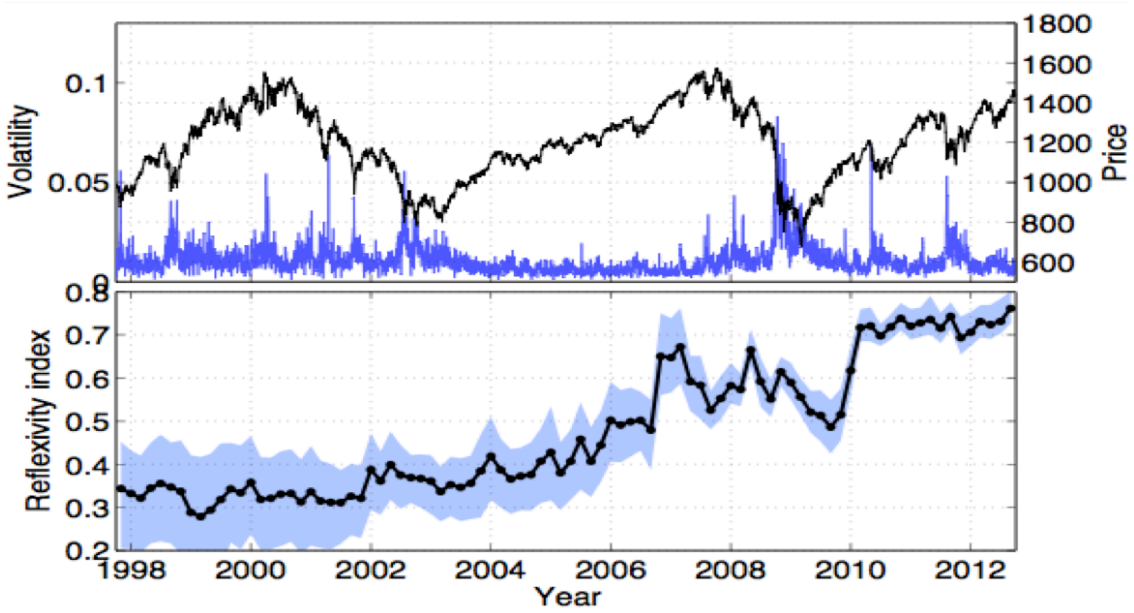


Figure 8: Stock market endogeneity: E-mini S&P 500 futures 1998-2012
The top graph depicts the price development and volatility of the E-mini S&P 500 futures from 1998 to 2012. The bottom graph shows the "reflexivity index", which measures price movements due to endogenous news rather than exogenous news using high frequency data. It shows a steady increase in reflexivity, with more than 70 percent of the price due to endogenous feedbacks by 2012, compared to about 30 percent in 1998.
Source: Filimonov et al. (2014)

Positive feedbacks are the mechanism through which complex systems approach phase transitions, a critical state that is followed by a change in regime (Sheffer 2009; Scheffer 2012; Sornette 2003). The systemic risk associated with HFT does not lie in its propensity to lead to high frequency booms and crashes. Instead it lies in the possibility of interaction with other computer-based or human-based trading strategies when fundamentals are already weak. In such an event, HFT could accelerate a crash in a

[4] Evidence of endogeneity in financial markets can be found, for example in Shiller (1981), Cutler, Poterba and Summers (1987) and Joulin et al. (2008).

system that has matured towards instability, also at lower frequencies. The findings by Filimonov et al. (2014) show that stock market prices at high frequency intervals are increasingly driven by endogenous rather than exogenous factors and suggest the increasing decoupling of financial markets from fundamental news in the real economy. As mentioned in our previous articles on credit creation, we can observe a more frequent occurrence of financial bubbles using lower frequency data. HFT appears to be just the tip of the iceberg of a longer-term trend facilitating more liquidity and greater speed.

In this context, it is important to stress the fact that the new high frequency market microstructure is not just a result of enormous advances in technology; it is also the direct consequence of intentionally fragmented exchanges by regulators. According to a press release on the European Markets in Financial Instruments Directive (MiFID), the intention of new regulation was to "foster competition between traditional stock exchanges and alternative trading platforms in order to promote innovations that reduce the costs of trading, in turn to free up capital for investments and, therefore, ultimately increase economic growth" (European Commission 2002)[5]. The general assumption is that liquid financial markets can facilitate growth in the real economy, for example, by making their equity or debt readily tradable and reducing their funding costs. The question that remains unanswered is "how liquid do financial markets have to be, in order to best serve the real economy"?

[5] Own translation from German into English.

Table 3: Empirical academic literature: HFT's impact on liquidity and efficiency

Author(s)	HFT / AT	Asset class / Data	Findings liquidity provision	Findings price efficiency
Lee 2015	HFT	Korean Stock Futures, KOSPI 200	HFTs are net buyers, hence do not provide liquidity HFT activity is linked to lower market depth No narrowing of spreads	HFT is detrimental to price discovery Negative impact on market quality only within very short time intervals, neutral in longer time intervals
Boehmer, Fong, and Wu 2014	AT	Global Stocks, 42 equity markets	AT improves liquidity on average AT intensity reduces liquidity for the smallest stocks	AT improves informational efficiency AT increases volatility, especially for smaller stocks
Brogaard, Riordan, et al. 2014	HFT	U.S. Stocks, NASDAQ	HFTs act as net liquidity suppliers during extreme price movements	HFT increases efficiency, evidenced by being particularly active in providing liquidity that leads to permanent price change HFT stabilizes markets
Brogaard et al. 2014	HFT	Swedish Stocks, NASDAQ OMX Stockholm	Optional co-location upgrade is taken up mainly by market makers Upgrade reduces adverse selection and inventory constraints Increasing the speed improves market liquidity for high and low latency traders	
Brogaard, Hendershot, and Riordan 2014	HFT	U.S. stocks, NASDAQ	Efficiency enhancing trades demand liquidity (marketable orders) Liquidity supplying orders (non-marketable) are adversely selected but compensated by bid-ask spreads and liquidity rebates	HFT facilitates efficiency by trading in the direction of permanent price change and in the opposite direction with transitory prices
Chaboud et al. 2014	AT	FX market, euro-dollar, dollar-yen, euro-yen	Liquidity supply depends the trading strategy, arbitrage consumes liquidity	AT leads to a reduction in arbitrage opportunities AT leads to a reduction in autocorrelation of returns AT strategies are highly correlated
Egginton, Van Ness, and Van Ness 2014	HFT	U.S. Stocks, NYSE, NASDAQ	Liquidity decreases in periods of intense quoting activity ("quote stuffing)	Intense quoting activity is associated with higher volatility
Gerig 2014	HFT	U.S. Stocks, NASDAQ	HFT reduces transaction costs	HFT synchronizes prices HFT increase information efficiency during normal times but is likely to lead to instability in times of stress
Carrion 2013	HFT	U.S. Stocks, NASDAQ	Spreads are wider when HFTs provide liquidity and tighter when they take liquidity, suggesting that HFT provide liquidity when scarce and take liquidity when plenty	Prices incorporate information more efficiently when HFT participation is high
Frino, Mollica, and Webb 2013	HFT	Australian futures, ASX	Decrease in bid-ask spreads after introduction of co-location Increase in market depth after introduction of co-location	No change in volatility after co-location

Gai, Yoa, and Ye 2013	HFT	US Stocks, NASDAQ	An increase in speed from microsecond to nanosecond does not decrease spreads and decreases depth	An increase in speed does increase short-term volatility An increase in speed increases order cancellations HFT increases noise
Hagströmer and Nordén 2013	HFT	Swedish Stocks, NASDAQ-OMX	HFT provides net liquidity Market-making accounts for 63-72% of trade volume	Market-making HFT mitigates intraday price volatility
Hasbrouck and Saar 2013	HFT	US Stocks, NASDAQ	HFT increases liquidity in normal times and in times of falling prices/anxiety	HFT reduces short-term volatility
Hendershott and Riordan 2013	AT	German Stocks, Dax	ATs represent 52% of market order volume and 64% of nonmarketable limit order volume AT consume liquidity when cheap (bid-ask narrow) and provide liquidity when expensive (bid-ask wide)	At is likely to reduce volatility in liquidity supply
Menkveld 2013	HFT	Dutch Stocks, Chi-X and Euronext	Observation of a single trader shows that four out five trades are passive, i.e. market making	
Riordan and Storkenmaier 2012	HFT	German Stocks, Xetra	Spreads decreased after a latency reduction Latency reduction decreased competition among liquidity suppliers	Lower latency increased price efficiency, as measured by the contribution of quotes to price discovery
Hendershott, Jones, and Menkvelt 2011	AT	U.S. Stocks, NYSE	For large stocks in particular, AT narrows spreads and reduces adverse selection	AT enhances informativeness of quotes and reduces trade related price discovery
Zhang 2010	HFT	U.S. Stocks, CRSP and TRIH		HFT is negatively related to the market's ability to process information on firm fundamentals, stock prices over-react when HFT is high HFT increases volatility

HFT = High Frequency Trading

AT = Algorithmic Trading

4.4 Conclusion

We have argued that high frequency trading can lead to booms and crashes at short time-scales, based on positive feedback dynamics similar to those observable at lower frequencies. This is supported by current empirical findings of the synchronization of algorithmic strategies. However, the current empirical literature is inconclusive with respect to HFT's effect on volatility and provides little evidence of HFT contributing to financial instability.

The majority of studies find HFTs to be primarily liquidity providers, although some studies report either no net or a negative effect on liquidity. Most studies investigating HFT's impact on price discovery find an increase in market efficiency. We have argued that these findings are based on the assumption that prices are driven exogenously and ignore the fact that markets exhibit features of reflexivity. Taking this into account, HFT facilitating permanent changes in price or processing information faster is not proof of increased efficiency. This view is supported by empirical evidence that measures increasing levels of endogeneity in the U.S. stock markets. These findings suggest increasing positive feedbacks in high frequency price formation and a growing decoupling from fundamental news in the real economy.

Finally, we stressed that HFT is not just the consequence of advances in technology; it is also a direct consequence of regulation that intentionally facilitates a competitive market structure for stock exchanges and trading platforms. In this new market environment, trading venues do rely on trade volumes provided by high frequency traders. In this context, HFT can be understood as the tip of the iceberg of a much longer-lasting global trend of more liquid and "efficient" financial markets. The systemic risk in HFT lies not in its propensity to foster booms and crashes within very short time scales, but in its potential coupling with other market players when fundamentals are weak and systemic risk at low frequency is high.

4.5 References

Abergel, Frederic, Jean-Philippe Bouchaud, Thierry Foucault, Charles-Albert Lehalle, and Mathieu Rosenbaum, eds. 2012. *Market Microstructure: Confronting Many Viewpoints*. Chichester, West Sussex: John Wiley & Sons ,Ltd.

Biais, Bruno, and Paul Woolley. 2012. "The Flip Side: High Frequency Trading." *Financial World*, February.

Biais, Bruno, and Thierry Foucault. 2014. "HFT and Market Quality." *Bankers, Markets & Investors* 128 (January): 1–15.

Boehmer, Ekkehart, Kingsley Fong, and Julie Wu. 2014. "International Evidence on Algorithmic Trading." *AFA 2013 San Diego Meetings Paper*, June, 1–49. doi:10.2139/ssrn.2022034.

Brogaard, Jonathan, Björn Hagstömer, Lars Nordén, and Ryan Riordan. 2014. "Trading Fast and Slow: Colocation and Liquidity." *Working Paper*, August, 1–53. http://dx.doi.org/10.2139/ssrn.2317797.

Brogaard, Jonathan, Ryan Riordan, Andriy Shkilko, and Konstantin Sokolov. 2014. "High-Frequency Trading and Extreme Price Movements." *Working Paper*, November, 1–40. doi:10.2139/ssrn.2531122.

Brogaard, Jonathan, Terrence Hendershott, and Ryan Riordan. 2014. "High-Frequency Trading and Price Discovery." *Review of Financial Studies* 27 (8): 2267–2306. doi:10.1093/rfs/hhu032.

Budish, Eric, Peter Cramton, and John Shim. 2013. "The High-Frequency Trading Arms Race: Frequent Batch Auctions as a Market Design Response." *Working Paper*, December, 1–70. http://faculty.chicagobooth.edu/eric.budish/research/HFT-FrequentBatchAuctions.pdf.

Budish, Eric, Peter Cramton, and John Shim. 2014. "Implementation Details for Frequent Batch Auctions: Slowing Down Markets to the Blink of an Eye." *American Economic Review* 104 (5): 418–24. doi:10.1257/aer.104.5.418.

Carrion, Allen. 2013. "Very Fast Money: High-Frequency Trading on the NASDAQ." *Journal of Financial Markets* 16 (4). Elsevier: 680–711. doi:10.1016/j.finmar.2013.06.005.

CFTC, SEC. 2010. *Findings Regarding the Market Events of May 6, 2010*. Report of the staffs of the CFTC and SEC to the joint Advisory Committtee on emerging regulatory issues.

Chaboud, Alain P, Benjamin Chiquoine, Erik Hjalmarsson, and Clara Vega. 2014. "Rise of the Machines: Algorithmic Trading in the Foreign Exchange Market." *The Journal of Finance* 69 (5): 2045–84. doi:10.1111/jofi.12186.

Cutler, David M, James M Poterba, and Lawrence H Summers. 1987. "What Moves Stock Prices?." *The Journal of Portfolio Management* 15 (3): 4–12.

Easley, David, Marcos M Lopez de Prado, and Maureen O'Hara. 2011. "The Microstructure of the 'Flash Crash': *Flow Toxicity, Liquidity Crashes, and the Probability of Informed Trading*." *The Journal of Portfolio Management* 37 (2): 118–28.

Egginton, Jared, Bonnie F Van Ness, and Robert A Van Ness. 2014. "Quote Stuffing." *Working Paper*, March, 1–56. http://dx.doi.org/10.2139/ssrn.1958281.

European Commission. 2002. "Wertpapierdienstleistungen: Vorgeschlagene Neue Richtlinie Soll Anleger Schützen Und EU-Weite Tätigkeit Von Wertpapierhäusern Erleichtern." Europäische Kommission. http://europa.eu/rapid/press-release_IP-02-

1706_de.pdf.
Filimonov, Vladimir, and Didier Sornette. 2012. “Quantifying Reflexivity in Financial Markets: Toward a Prediction of Flash Crashes.” *Physical Review E* 85 (5): 056108. doi:10.1103/PhysRevE.85.056108.
Filimonov, Vladimir, David Bicchetti, Nicolas Maystre, and Didier Sornette. 2014. “Quantification of the High Level of Endogeneity and Structural Regime Shifts in Commodity Markets.” *Journal of International Money and Finance* 42 (April). Elsevier Ltd: 174–92. doi:10.1016/j.jimonfin.2013.08.010.
Frino, Alex, Vito Mollica, and Robert I Webb. 2013. “The Impact of Co-Location of Securities Exchanges‘ and Traders’ Computer Servers on Market Liquidity.” *The Journal of Futures Markets* 34 (1): 20–33. doi:10.1002/fut.21631.
Gai, Jiading, Chen Yao, and Mao Ye. 2013. “The Externalities of High-Frequency Trading.” *Working Paper*, August, 1–56. http://dx.doi.org/10.2139/ssrn.2066839.
Gerig, Austin. 2014. “High-Frequency Trading Synchronizes Prices in Financial Markets.” *Working Paper*, November, 1–28. http://arxiv.org/pdf/1211.1919v1.pdf.
Hagströmer, Björn, and Lars Nordén. 2013. “The Diversity of High-Frequency Traders.” *Journal of Financial Markets* 16 (4). Elsevier: 741–70. doi:10.1016/j.finmar.2013.05.009.
Haldane, Andrew G. 2011. “The Race to Zero.” July 8. http://www.bis.org/review/r110720a.pdf.
Hasbrouck, Joel, and Gideon Saar. 2013. “Low-Latency Trading.” *Journal of Financial Markets* 6 (May): 646–79.
Hendershott, Terrence, and Ryan Riordan. 2013. “Algorithmic Trading and the Market for Liquidity.” *Journal of Financial and Quantitative Analysis* 48 (04): 1001–24. doi:10.1017/S0022109013000471.
Hendershott, Terrence, Charles M Jones, and Albert J Menkveld. 2011. “Does Algorithmic Trading Improve Liquidity?.” *The Journal of Finance* 66 (1): 1–33.
Joulin, Armand, Augustin Lefevre, Daniel Grumberg, and Jean-Philippe Bouchaud. 2008. “Stock Price Jumps: News and Volume Play a Minor Role.” *Working Paper*, December, 1–14. http://arxiv.org/pdf/0803.1769.pdf.
Lee, Eun Jung. 2015. “High Frequency Trading in the Korean Index Futures Market.” *The Journal of Futures Markets* 35 (1): 31–51. doi:10.1002/fut.21640.
Lewis, Michael. 2014. *Flash Boys: a Wall Street Revolt*. New York, NY: W. W. Norton & Company, Inc.
Menkveld, Albert J. 2013. “High Frequency Trading and the New Market Makers.” *Journal of Financial Markets* 16 (4). Elsevier: 712–40. doi:10.1016/j.finmar.2013.06.006.
Riordan, Ryan, and Andreas Storkenmaier. 2012. “Latency, Liquidity and Price Discovery.” *Journal of Financial Markets* 15 (4). Elsevier: 416–37. doi:10.1016/j.finmar.2012.05.003.
Scheffer, M, S R Carpenter, T M Lenton, J Bascompte, W Brock, V Dakos, J van de Koppel, et al. 2012. “Anticipating Critical Transitions.” *Science* 338 (6105): 344–48. doi:10.1126/science.1225244.
Scheffer, Martin. 2009. *Critical Transitions in Nature and Society*. Princeton: Princeton University Press.
Shiller, Robert J. 1981. “Do Stock Prices Move Too Much to Be Justified by Subsequent Changes in Dividends?.” *American Economic Review* 71 (3): 421–36.
Sornette, Didier. 2003. *Why Stock Markets Crash: Critical Events in Complex Financial Systems*. Princeton, New Jersey: Princeton University Press.

Sornette, Didier, and Susanne von der Becke. 2011. *Crashes and High Frequency Trading*. *Foresight Driver Review*. The Future of Computer Trading in Financial Markets - Foresight Driver Review. https://www.gov.uk/government/publications/computer-trading-crashes-and-high-frequency-trading.

Soros, George. 1987. *The Alchemy of Finance: Reading the Mind of the Market*. John Wiley & Sons, Inc.

Zhang, Frank X. 2010. "High-Frequency Trading, Stock Volatility, and Price Discovery." *Working Paper*, December, 1–54. http://ssrn.com/abstract=1691679.

5. Final conclusion

Our first paper introduced a conceptual framework of credit creation based on three key variables: (i) the amount of eligible collateral assets, (ii) the level of leverage and (ii) the level of trust and confidence in future cash flows. The related dynamics are non-linear and subject to positive feedbacks, which give rise to endogenous instabilities. By building on the works of previous authors that underlined instabilities associated with credit, we proposed that, as credit expands along these variables, the financial system becomes more liquid and vulnerable to internally generated instabilities manifested as booms and busts.

We consequently applied the framework to analyze the global financial crisis. We showed that the decades preceding the crisis were characterized by strong growth in financial assets, increasing leverage relative to GDP and a false sense of security as evident in the concept of a "Great Moderation". Using US flow of funds data, we demonstrated a shift in the components of US bank balance sheets and a decoupling of bank assets from deposits since the mid-1980s. We termed this "the rise of securitized fractional reserve banking", where credit creation takes place not through traditional commercial banks but other financial intermediaries in the global financial markets. Whereas traditional banking creates deposit-money by granting loans, securitized banking creates money-like securities. Both systems are fractional and subject to bank-runs. As a result, central banks transitioned from being lender of last resort to being dealers of last resort, as characterized by unprecedentedly large asset purchasing programs.

We argued that, as financial markets become more complete through credit creation, inherent instabilities build up and a small external perturbation can have large repercussions on financial stability, transmitting from the financial markets to the real economy. From this perspective, the subprime crisis was only one possible trigger in an increasingly unstable financial system. As trust receded, so did the amount of assets acceptable as collaterals as well as the level of leverage and liquidity. Subsequent measures by policymakers can be interpreted as attempts to avoid further contraction along the three dimensions of acceptable assets, leverage and trust.

Historical evidence suggests that credit existed before money and that it is a key driver of financial crises since centuries, independent of the prevailing financial and monetary system. We consequently discussed the potential broader applicability of an asset-based understanding of credit creation. From this perspective, credit is never created "out of nothing", because it is implicitly or explicitly always backed by collateral assets. The implication of this is that we are not primarily reserve or capital constrained but asset constrained. Most importantly, it matters what type of assets we create and how we use existing assets.

In our second paper, we extended the concept of hierarchical money to our current monetary and financial system. This exposed a feedback loop between the upper and lower level of the hierarchy. What is money at one level is credit at the previous level. Moreover, credit can become money at a distant, deeper level as something that stores value and can be exchanged for other things (it acts as money at all possible levels of the hierarchy) and can be used as a collateral for another form of accepted support of exchange (it acts as credit). This structure allows a more efficient use of our assets but it also makes our balance sheets more vulnerable to liquidity mismatches and the booms and busts of asset prices.

We consequently argued that the call to ban banks from creating money fails to understand bank money creation in this fundamental hierarchical context. Not only would such an initiative be unlikely to succeed due to credits' natural tendency towards expansion; banks or other financial institutions are likely to develop money-like assets and to provide liquidity when demanded. Moreover, it neglects the importance of market-based credit creation. The accelerated growth in securities since the 1980s coincided with an increase in debt-to-GDP levels in most advanced countries and more frequent financial bubbles. Independent of whether the credit was generated through deposit-creating bank loans or deposits transferred in the capital markets, credit creation is an essential engine of innovations and use of capital, while also always a claim to the profits from future economic growth.

In our third paper, we analyzed the potential of high frequency trading to facilitate market crashes. We argued that high frequency trading and, more specifically, algorithmic trading in general could facilitate market crashes due to herding behavior.

This behavior is not the result of emotionally driven “animal spirits”, but of adaptive learning, when in some circumstances herding is the most winning strategy to pursue. The dynamics are similar to those underlying the booms and busts observable at lower frequencies and over longer time horizons.

High frequency trading is the result of tremendous technological advancements over the past two decades as well as intentionally fragmented financial markets, encouraged by regulators to facilitate competition and efficiency. In this market environment, high frequency trading has become a significant source of trade volume in some of the most liquid electronic markets. By taking on inventory risk for relatively short periods of time, high frequency trading can create market liquidity. Indeed, empirical evidence shows a narrowing of bid-ask spreads in US equities markets. Conclusive evidence on the overall impact of high frequency trading continues to be difficult, considering the limited availability of data and the large computer powers necessary to dissect price movements at the levels of microseconds. However, the majority of studies suggest that high frequency trading has improved market liquidity and improved price efficiency. We have argued that although high frequency trading strategies can remove arbitrage possibilities at the level of microseconds, this does not necessarily improve the information content in the price. Subsequent research showed that high frequency price movements in US stock market indices exhibit a steady increase in reflexivity. This means that price movements can increasingly be attributed to prior price changes rather than new information affecting the fundamentals of the stock.

The overall conclusion from these articles can be summarized as follows. Financial markets have, particularly over the past three decades, become increasingly liquid due to our ability to create funding liquidity by using financial assets as collateral for credit creation and due to our ability to trade securities at very fast speeds. On the positive side, this uses otherwise dormant assets and can unleash innovations that form the basis of future economic growth. On the negative side, it can lead to financial instability with potentially detrimental effects on the real economy. The fundamental challenge of our time seems to be the attempt to create future growth through more credit, more money, higher trading volumes and faster execution. However, any financial instrument is just a derivative of the real economy and hence value can,

ultimately, only be created in the real economy. Therefore, we must use liquidity creation productively. More liquid financial markets do not necessarily translate into a productive lubrication of the real economy.

References

(Used in the introduction)

Beck, Thorsten, Andrea Colciago, and Damjan Pfajfar. 2014. “Journal of Economic Dynamics & Control.” *Journal of Economic Dynamics and Control* 43 (C). Elsevier: 1–11. doi:10.1016/j.jedc.2014.04.010.

Benes, Jaromir, and Michael Kumhof. 2012. “The Chicago Plan Revisited.” *IMF Working Paper*, August, 1–71.

Berger, Allen N, and Christa H S Bouwman. 2012. “Bank Liquidity Creation, Monetary Policy, and Financial Crises.” *Working Paper*, March, 1–48. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1952728.

Bernanke, Ben S., and Mark Gertler. 1989. “Agency Costs, Net Worth, and Business Fluctuations.” *American Economic Review* 79 (1): 14–31.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist. 1999. “The Financial Accelerator in a Quantitative Business Cycle Framework.” In, edited by John Taylor and Michael Woodford, 1:1341–93. Handbook of Macroeconomics.

Biondi, Yuri. 2010. “Money Without Value, Accounting Without Measure: How Economic Theory Can Better Fit the Economic and Monetary System We Live in.” In *Money and Calculation: Economic and Sociological Perspectives*, edited by Massimo Amato, Luigi Doria, and Luca Fantacci, 34–62. London: Palgrave.

Borio, Claudio. 2014. “The International Monetary and Financial System: Its Achilles Heel and What to Do About It.” *BIS Working Papers*, August, 1–33.

Brunnermeier, M K, and L H Pedersen. 2009. “Market Liquidity and Funding Liquidity.” *Review of Financial Studies* 22 (6): 2201–38. doi:10.1093/rfs/hhn098.

Brunnermeier, Markus K. 2009. “Deciphering the Liquidity and Credit Crunch 2007–2008.” *Journal of Economic Perspectives* 23 (Winter): 77–100.

Chamley, Christophe, Laurence J Kotlikoff, and Herakles Polemarchakis. 2012. “Limited-Purpose Banking—Moving From “Trust Me” to “Show Me” Banking.” *American Economic Review* 102 (3): 113–19. doi:10.1257/aer.102.3.113.

Easley, David, Marcos M Lopez de Prado, and Maureen O'Hara. 2011. “The Microstructure of the ‘Flash Crash’: *Flow Toxicity, Liquidity Crashes, and the Probability of Informed Trading*.” *The Journal of Portfolio Management* 37 (2): 118–28.

Fantacci, Luca. 2013. “Why Banks Do What They Do. How the Monetary System Affects Banking Activity.” *Accounting, Economics and Law: a Convivium* 3 (3): 333–56. doi:10.1515/ael-2013-0017.

Fisher, Irving. 1936. *100 % Money*. 2nd ed. New York: Adelphi Company.

Haldane, Andrew G, and Robert M May. 2011. “Systemic Risk in Banking Ecosystems.” *Nature* 469 (7330). Nature Publishing Group: 351–55. doi:10.1038/nature09659.

Jorda, Oscar, Moritz Schularick, and Alan M. Taylor. 2012. “When Credit Bites Back: Leverage, Business Cycles, and Crises.” *Federal Reserve Bank of San Francisco Working Paper Series*, no. 2011-27 (October): 1–42.

Kiyotaki, Nobuhiro, and John Moore. 1997. “Credit Cycles .” *The Journal of Political Economy* 105 (2): 211–48. doi:10.1086/262072.

Mathias, Drehmann, and Kleopatra Nikolaou. 2010. “Funding Liquidity Risk:

Definition and Measurement." *BIS Working Papers* 316 (July): 1–35.
Mehrling, Perry. 2011. *The New Lombard Street: How the Fed Became the Dealer of Last Resort*. New Jersey: Princeton University Press.
Mendoza, Enrique G, and Marco E Terrones. 2012. "An Anatomy of Credit Booms and Their Demise." *Nber Working Paper Series*. http://www.nber.org/papers/w18379.pdf.
Menkveld, Albert J. 2013. "High Frequency Trading and the New Market Makers." *Journal of Financial Markets* 16 (4). Elsevier: 712–40. doi:10.1016/j.finmar.2013.06.006.
Minsky, Hyman P. 1986. *Stabilizing an Unstable Economy*. New Haven and London: Yale University Press.
Minsky, Hyman P. 1992. "The Financial Instability Hypothesis." *Levi Economics Institute, Working Paper*, May, 1–10.
Reinhart, Carmen M, and Kenneth S Rogoff. 2009. *This Time Is Different*. Princeton and Oxford: Princeton University Press.
Schularick, Moritz, and Alan M. Taylor. 2012. "Credit Booms Gone Bust: Monetary Policy, Leverage Cycles, and Financial Crises, 1870–2008." *American Economic Review* 102 (2): 1029–61. doi:10.1257/aer.102.2.1029.
Wolf, Martin. 2014. "Strip Private Banks of Their Power to Create Money." *Financial Times*, April 24. http://www.ft.com/intl/cms/s/0/7f000b18-ca44-11e3-bb92-00144feabdc0.html#axzz34Dg4PXba.
Zhou, Wei-Xing, and Didier Sornette. 2004. "Causal Slaving of the U.S. Treasury Bond Yield Antibubble by the Stock Market Antibubble of August 2000." *Physica A* 337 (3-4): 586–608.

Appendices

A. Demystifying credit creation our of nothing

This appendix is based on excerpts of an earlier version of our "asset-based framework of credit creation". It was motivated by trying to understand exactly, what was meant by the expression that banks create credit, and hence money, "out of nothing". For this purpose, we contrasted the explanations of money and credit creation by two different schools of thought: Austrian and Post Keynesian, which both claim that credit is created ex nihilo.

We found the contrasting of the opposing positions on money and credit creation within each school very helpful for our own learning process. However, the contrasting often relies on significant simplifications, highlighting some extreme positions and almost invariably does injustice to each school when looking at it in a more differentiated way. Nevertheless, we provide it for the interested reader as it may offer some clarifying background.

Of hard money, fractional reserves and boom-bust cycles

Mainstream economics textbooks generally describe money as an evolution from barter, a "medium of exchange" that is more efficient than the direct exchange of goods, surpassing the need for a "double coincidence of wants"[1]. Its two other functions are as a "unit of account", providing the terms in which prices are quoted and debts recorded, as well as a "store of value", by which one can transfer purchasing power from the present to the future. From the Mainstream perspective, the rise of fiat money was a natural development of and for decreasing transaction costs[2]. The first stage in this development was the minting of coins and certification

[1] See, however, the historical evidence against this textbook representation by Graeber (2011).

[2] In contrast, in a rather extreme position not common to all Austrian scholars, Rothbard (2008) argued that the transition to fiat money was not an evolutionary process of efficiency but an unlawful act by the government, establishing a monopoly currency in the place of a market currency. In order to

of their purity and weight, followed later by the issuance of gold certificates, which replaced burdensome transactions in actual gold. Finally, the gold backing of those certificates was no longer necessary, and fiat money evolved as the natural means for making transactions.

To Austrian scholars, money is a commodity and not a social construct. "It is the most marketable good which people acquire because they want to offer it in later acts of interpersonal exchange. Money is the thing, which serves as the generally accepted and commonly used medium of exchange. This is its only function" (von Mises 1964, 401). Historically, hard money in the form of metals, such as gold and silver, has been a "most marketable good". Horwitz (2000, 3) explains that "rather than general equilibrium's picture of what are essentially barter exchanges occurring only after equilibrium prices are found by the hypothetical auctioneer, the Austrian perspective argues that real market exchanges using money are the process through which existing (disequilibrium) prices are formed". Money is hence fundamental to the price discovery process; "Excess supplies or demands for money undermine the coordinative ability of the market process" (Horwitz 2000, 4).

The key problems associated with fiat money are its propensity to foster inflation and its wealth distribution effects. Money is not neutral and an increase in money does not benefit all citizens equally. "The increase in the quantity of money does not mean an increase of income for all individuals. On the contrary, those sections of the community that are the last to be reached by the additional quantity of money have their incomes reduced, as a consequence of the decrease in the value of money called forth by the increase in its quantity" (von Mises 1953, 139). Consequently, a commodity currency, whose quantity is by and large constant, is preferable because its value will fluctuate less than under a fiat currency. The problem with inflation is not just the obvious one of wealth destruction at the expense of the creditors to the benefit of debtors[3] but also the system's continuous

get the paper money accepted, governments removed the right of individuals to use gold and silver and later removed the right to convertibility altogether and declared fiat money of equal value to the previously redeemable bank notes.

[3] "And since it is the creditors who are harmed and the debtors who benefit, most people do not particularly mind, at least until they realize that, in modern society, the most important and numerous

need for unexpected rises in prices to make profits. As described by Hayek: "I am *not* saying that once we embark on inflation we are bound to be drawn into a galloping hyper-inflation. I do not believe this is true. All I am saying is that *if* we wanted to perpetuate the peculiar prosperity-and-job creating effects of inflation we would have progressively to step it up and must never stop increasing its rate" (Mises et al. 1996, 89–99). In the United States, prior to moving to fiat money, deflations were indeed at least as common as inflations with several episodes of stable prices. Since the abandoning the gold standard, deflations have become rare and there is a clear bias toward inflation[4].

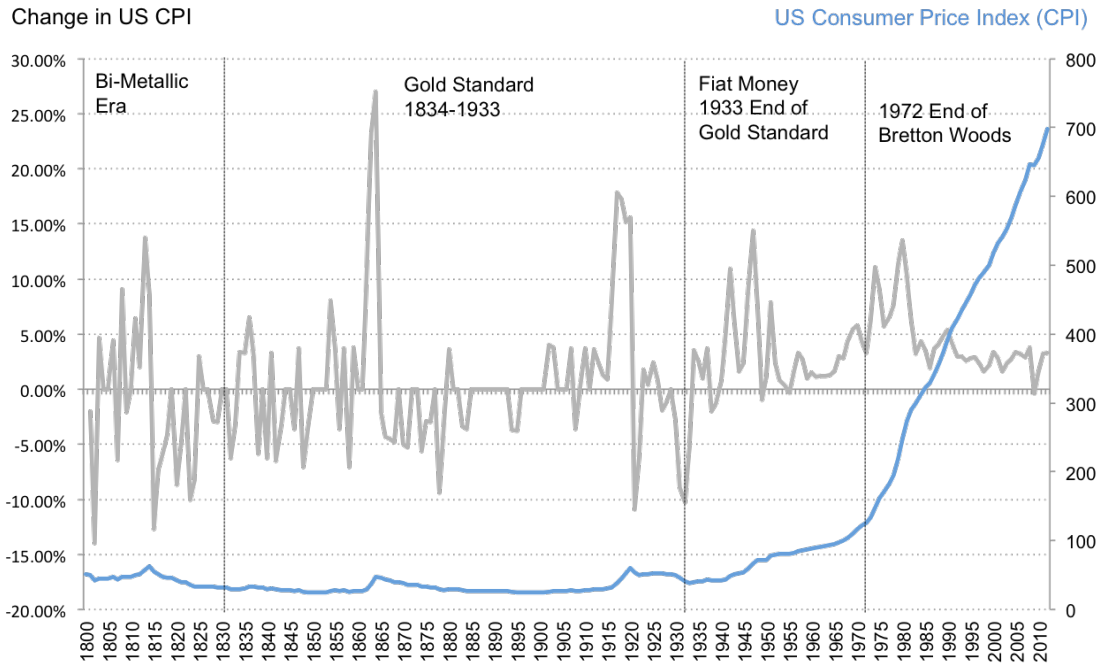


Figure 1: Inflations and deflations in the United States 1800–2012.
Data: Our own compilation based on estimates from the Federal Reserve Minneapolis.

class of creditors are the wage and salary earners (in particular through their pension funds, our addition) and the small savers, and the representative groups of debtors who profit in the first instance are the enterprises and credit institutions" (Hayek in Mises et al. 1996, 83).

[4] However, there are also examples of high inflation under a metallic standard. Throughout history, the supply of gold was not always constant and varied considerably across countries, for example through mercantilism or the depletion of gold reserves in occupied colonies. Philip II of Spain imported galleons of gold and silver, giving him enormous power to buy armies, cities and countries, eventually building "the empire on which the sun never sets" but that subsequently led to large inflation.

Just as governments can increase the supply of fiat money, credit creation increases money supply. Credit creation as a result of fractional reserve banking is regarded as the main driver of economic booms and busts and is central to the Austrian Trade Cycle Theory. Deposits created in excess of the actual reserves held are termed "fiduciary media" and, once in circulation, they are indistinguishable from fully backed money substitutes. By issuing fiduciary media, banks supply excess credit that lowers interest rates below the rate of the market. This low interest rate artificially stimulates the economy, leading to a boom in which projects, which otherwise would not have been deemed profitable are suddenly being financed. As economic activity accelerates, prices for raw materials, labor and ultimately consumption goods increase. The boom continues as long as credit expands. The collapse occurs when banks become skeptical of the accelerated boom and stop expanding credit. The result is what has been described in modern days as a "credit crunch" or "liquidity crisis". The longer the credit expansions last, the larger are the economic "malinvestments" and longer the subsequent periods of depression. "There is no use in interfering by means of a new credit expansion with the process of readjustment. This would at best only interrupt, disturb, and prolong the curative process of the depression, if not bring about a new boom with all its inevitable consequences" (von Mises 1964, 578).

The actual process of credit creation is much the same as that described in Mainstream textbooks. For example, Huerta de Soto gives the following example in the case of a 10 percent reserve requirement. From an initial deposit of 1,000 "monetary units" with Bank A, a loan of 900 is created for customer Z. As Z withdraws 900 monetary units to pay Y at Bank B, Bank A is left with 100 in cash. Bank B consequently creates a loan of 810, and so on. Finally, a total of 9,000 in loans is created *ex nihilo*, resulting in 10,000 in demand deposits against 1,000 monetary units in cash (2009, 230).

	Money remaining in each bank's vault	Credit expansion (Loans created *ex nihilo*)	Deposits
Bank A	100	900	1000
Bank B	90	810	900
Bank C	81	729	810
Bank D	73	656	720
……			
Total Banking System	**1 000**	**9 000**	**10 000**

Figure 2: Example of Austrian credit creation *ex nihilo*.
From Huerta de Soto (2009, 230). Figures have been altered for comparison.

Huerta de Soto adds that, in reality, new money enters the system not through a single bank but through many banks. As banks extend credit simultaneously and receive deposits from other banks' loan creation, each bank is able to maintain its initial cash reserves of 1,000 and create *ex nihilo* 9,000 monetary units in new loans backed by new fiduciary media (2009, 232–233). Consistent with the mainstream money multiplier view, deposits are a multiple of reserves, which under fiat money can be increased by the central bank "out of nothing". However, why are these loans created *ex nihilo*, when clearly they are created from initial deposits just as in the Mainstream textbook example? Because these loans were made without the transfer of purchasing power from prior savings. When "deposit taking" and "lending" are separated, deposits are similar to warehouse receipts and lending requires the transfer of purchasing power from the investor to the borrower. When banks can perform both functions, money redeemable on demand and deposited for safekeeping is used to fund loans, which creates new "fiduciary" deposits and consequently boom-bust cycles. Moreover, some authors stress the illegitimacy of fractional reserve banking: "Commercial banks—that is, fractional reserve banks—create money out of thin air. Essentially, they do it in the same way as counterfeiters. Counterfeiters, too, create money out of thin air by printing something masquerading as money or as a warehouse receipt for money" (Rothbard 2009, 98). This view was contradicted by Selgin and White (1996), who argued "in defense of fiduciary media". They argued that fiduciary media was not the same as fiat money and that a monetary system based on a commodity standard and competitive banking would be "consistent with justice, efficiency, and economic stability" (Selgin and White 2000, 105).

The Austrian solution to the economic instability created by credit creation is "full reserve banking" or/and "free banking" under a fixed money supply, best accomplished under a gold standard (e.g., Huerta de Soto 2009). Under "free banking", banks would be disciplined by market forces, without government guarantees, deposit insurances or central banks as lenders of last resort. Banks would hold 100 percent reserves against demand deposits, either enforced legally or through the threat of bankruptcy. By holding full reserves against deposits, banks could no longer add to money supply by issuing credit. Full reserve banking has recently received new attention from non-Austrian economists. Benes and Kumhof (2012) model, within a DSGE framework, the impact of full reserve banking as envisioned in the Chicago Plan and Irving Fisher's 100 percent Money proposal (1936). Just as Austrian theory would predict, the authors indeed find that it would reduce business cycle volatility and eliminate bank runs (Benes and Kumhof 2012). However, full reserve banking as envisioned by the Chicago Plan does not conform to Austrian thinking because the money would have been "nationalized" and controlled by the government rather than privatized and controlled by the market. Although governments may be trusted to keep money supply (and hence inflation) steady in normal times, they are far less certain to do so during exceptional times, for example, to finance government spending in times of economic distress or war. To the best of our knowledge, full reserve banking has never been put into practice on a broader scale. Free banking, however, has been practiced in several countries (such as Scotland and the United States) and has shown that completely unregulated banking industries can be quite successful when banks voluntarily form large cooperative networks (Freixas and Rochet 2008, 307)[5].

[5] Freixas and Rochet refer to empirical studies of free banking. US banking panics during the national banking era (1863–1913) were less severe than the banking collapse of the 1930s. During the national banking era, few banks actually failed and panics were limited by the temporary suspension of the convertibility of bank notes (2008, 307).

Of monetary circuits, endogeneity and inherent instabilities

Like Austrian scholars, Post Keynesian economists claim that banks create credit "out of nothing" and that "loans drive deposits". Yet, they have a different explanation of the process and even more different conclusions with respect to economic policy. Banks create credit "out of nothing" because they do not need prior deposits to do so. Let us start again with a numerical example to understand their reasoning. The following example is taken from Scott Fullwiler (2012)[6]: Bank A creates a loan of 1,000 dollars for a customer. For the bank, this results in a book entry of 1,000 dollars in assets (the loan) and 1,000 dollars in liabilities (the deposit). By the method of accounting, a loan entry requires a deposit entry; hence, a loan creates a deposit "out of nothing". However, what if the customer wants to hold the proceeds from the loan at Bank B? Bank A transfers the funds by taking an overdraft from the central bank. The central bank, in its role to facilitate a smooth functioning of the payment system, must always provide this overdraft facility (at some interest). However, the overdraft must be cleared by the end of the day. Consequently, Bank A borrows the funds in the money market to pay off the overdraft. The resulting book entry for Bank A is a credit of 1,000 dollars in reserves and a debit on the liability side with 1,000 dollars borrowed from the money market. The net result on the balance sheet is the 1,000 dollars loan with a corresponding liability of 1,000 dollars in borrowings. The customer now holds the loan from Bank A as a liability and the deposit at Bank B as an asset. Bank B records the proceeds transferred from Bank A as a deposit from the customer on its liability side and holds the received cash under assets. Thus, Bank A made a loan holding neither prior reserves nor deposits.

---

[6] Fullwiler advocates Modern Money Theory (MMT), which is a particular strand of Post Keynesianism.
MMT shares the same "endogenous" understanding of credit creation but places particular emphasis on the role of the state in the creation of money ("Neo-Chartalism"). Money exists because the state has the power to impose taxes and declare what it will accept in their payment (e.g., Wray 1998; Bell 2001; Tcherneva 2007). Contrary to the common understanding of state financing, MMT argues that the purpose of taxation is not to finance government spending but to act as a means of cancelling out government debt, i.e., money created and circulated within the economy. Government deficits under these systems are the normal and necessary condition. MMT advocates that nations that issue their own currency do not face any operational financial constraints and hence should not be threatened by bankruptcy in light of large deficits. For a Post Keynesian critique of MMT, see Lavoie (2013).

(1) Bank A creates loan and deposit for customer:

Bank A	
Assets	Liabilities
+ 1000 Loan	+ 1000 Deposit

Customer	
Assets	Liabilities
+ 1000 Deposit	+ 1000 Loan

(2) The deposit is transferred to Bank B:

Bank A	
Assets	Liabilities
+ 1000 Loan	+ 1000 Deposit
- 1000 Reserves	- 1000 Deposit
+ 1000 Reserves	+ 1000 Borrowings

Customer	
Assets	Liabilities
+ 1000 Deposit Bank A	+ 1000 Loan
- 1000 Deposit Bank A	
+ 1000 Deposit Bank B	

Bank B	
Assets	Liabilities
+ 1000 Reserves	+ 1000 Deposit

Total Bank A
+ 1000 Loan +1000 Borrowings

Figure 3: Post Keynesian credit creation "out of nothing".
From Fullwiler (2012). Figures have been added for comparison

It is argued that, in practice, banks extend loans first and search for reserves later. Because central banks set target interest rates, there is no quantity constraint to the amount of reserves they will provide. If the central bank were to restrain the quantity, banks would drive up the interbank market rates above the target. "Individual banks can always obtain additional reserves, at the market price, so long as lender confidence in their solvency (ability to repay) is preserved" (Moore 1991, 404). Hence, the banking system is not reserve-constrained. The amount of credit creation is endogenous to the banking system and the central bank has no control over the quantity of credit created, other than influencing its desirability by making it more or less expensive. Private banks are effectively "free to create as much credit as they wish" (Keen 2011, 314).

Whereas commodity money is a physical asset and not a financial claim, credit money is the set of financial claims making up the total liabilities of all institutions issuing transaction deposits (Moore 1988). In our current fiat system, money comes into existence through credit creation. If Mainstream economists hold a "monetary view of credit", Post Keynesians are best described as holding a "credit view of money". It is emphasized that in order to start producing something, and then pay wages, generate deposits and so on, firms need initial financing first. The circle of production closes as firms capture the savings of households through financial

intermediaries. “Investment requires neither prior saving nor a source of prior deposits. As long as the resources of a national economy are not fully utilized, the financing of economic activity depends only on the credibility of the borrower and on existing financial norms” (Lavoie 2009, 58). The consequence is that “loans drive deposits” and not vice versa. The quantity of high-powered money (reserves and currency) as well as that of bank deposits evolves “endogenously” according to the demand for credit rather than being controlled by the central bank. According to Moore, “the quantity theory paradigm once had some relevance and validity in very early chronological periods of commodity and fiat money. But it has absolutely no applicability for monetary analysis under current institutional conditions. In a world of sophisticated financial markets and complicated derivative instruments, quantity theory analysis is both wildly incorrect and directly misleading” (Moore, 2006, iixx). Rather than controlling the quantity of reserves, central banks control the price of reserves by setting the target interest rate, which in turn provides the benchmark for all other rates of financial assets and influences the “eligibility criteria” under which banks accommodate the demand for credit. The extent to which banks passively accommodate firms’ demand for credit, at a mark-up of the current interest rate, or to which they are driven to influence demand through financial innovations in the pursuit of profit maximization is subject to debate (Wray 2007). Credit rationing by banks is perceived to result from a “lack of confidence” rather than information asymmetry (Lavoie 2009, 56). It follows that because money supply is demand-driven, there cannot be “excess money supply”, and hence, inflation cannot be a monetary phenomenon. It is suggested that the causation is the reverse: inflation causes a growth in money supply. The causes of inflation can be manifold but are generally a result of conflicts over the distribution of income between different social classes and are not a given consequence of economic growth.

In contrast to the views of Austrian and Mainstream economics, free markets are regarded as “inherently unstable” and should therefore be harnessed by the government. Minsky’s instability hypothesis is also well known outside Post Keynesian circles. According to Minsky, economic cycles are strongly influenced by credit creation and speculative financial markets. During “stable” boom periods, households, firms and banks become less risk-averse, thereby sowing the seeds of

future instability. Lower lending standards and higher levels of debt lead to a transition from sustainable to unsustainable debt-income stages of the economy. First, from "hedge" (cash flow covers all payment obligations, including the principal) to "speculative" (cash flow meets interest payments only and hence depends on refinancing, the "rolling over" of debt) and finally to "ponzi" (insufficient cash flow, proceeds from new debt are used to meet obligations from older debt) (Minsky 1992). "In order to contain the destabilizing effect of banking, it is necessary to regulate the amount and the rate of increase of bank assets", such as an asset-equity ratio (Minsky 1986, 356). Capturing these dynamics requires the use of nonlinear, out of equilibrium models that capture the stocks and flows between firms, households and banks (Keen 2013). According to Post Keynesians, this complex and dynamic nature of finance can and should be tamed by government intervention: "Without state intervention, capitalism generates business cycles, and on its own can guarantee neither the full employment of labour nor a sufficient level of aggregate demand" (Lavoie 2009, 131). In this endeavor, it has been advocated that governments and central banks should become less focused on inflation and instead maintain full employment, for example by governments becoming "employers of last resort".

Pieces of a Puzzle: Credit creation "out of something"

Although the claim that banks create credit and with it money "out of nothing" gives the impression of "banking mysticism" (Krugman 2012) from the perspective of Mainstream economists, understanding the reasoning behind this claim provides pieces of a puzzle toward a broader perspective of credit creation. The difference between the Austrian and Mainstream views of how banks create credit is essentially normative. For Austrian economists, deposits should be fully backed and credit creation should involve the transfer, not the increase of purchasing power in order to limit harmful boom and bust cycles. Their emphasis that excess credit creation fuels financial bubbles sends an important and timely reminder. Even though Austrians and Post Keynesians are diametrically opposed in regard to policy, both stress the endogenous and inherently unstable nature of credit money. The Post Keynesian

claim that banks create credit out of nothing is not rooted in normative differences to the Mainstream proposition but rather in descriptive differences with respect to the process of credit creation, given interest rate targeting and reserve accommodating central banks in a fiat money regime. The ability of banks to acquire financing after making a loan by borrowing in the money markets could be argued to vindicate the Mainstream proposition that there must be cash somewhere from a prior deposit that another bank or institution is willing to lend. From our perspective, the debate over whether "loans drive deposits" (Austrian and Post Keynesian) or whether "deposits drive loans" (Mainstream) is as futile as the discussion about "the chicken and the egg". In reality, it is neither lending nor deposits first but assets first. There must have been capital, in some form or another, for credit to develop. Before we explore this more deeply, let us briefly clarify our understanding of the current process of credit creation and our distinction between money creation and credit creation. To begin, it is helpful to distinguish between central banks, commercial banks and other financial intermediaries.

Central banks can indeed create money (final settlement media for all financial obligations) "out of nothing". Unlike commercial banks, central banks do not face capital constraints[7] and can purchase assets with purchasing power that is limited only by the continued trust in the countries' currency. In a sense, what gives central banks this special status is that they represent the top of the hierarchy, the whole system. The central bank can create its own purchasing power to extend loans or to buy securities. When it adds to reserves by purchasing securities with money created "out of nothing", it changes the liquidity profile of its member banks and affects their asset sides. In contrast, when it extends credit, it does so generally against collateral (eligible securities) and creates a liability for the borrowing bank in the process. In normal times, central banks do accommodate increased demand for reserves[8]. Clearly, if banks were always and under every circumstance able to

[7] Stella analyzes various cases of central banks incurring chronic losses. He finds that they can operate "perfectly well" with negative equity and that "central bank capital as conventionally defined is not strictly necessary". However, weak central bank balance sheets can lead to the abandonment of price stability, financial repression and the loss of independence (1997).

[8] Goodfriend and Hargraves analyze the rationales and functions of reserve requirements imposed by the Federal Reserve from an historical perspective and find that even though the role of reserve

receive funding, they could not go bankrupt, as many of them did particularly during 2008 and the following years[9]. Lending to illiquid or insolvent institutions is a blurry line. The ability of reserve requirements to control credit creation is quite similar to that of controlling credit creation through interest rates – both mechanisms alter the cost and profitability of credit creation. Minimum reserves are no longer a direct constraint, but they can affect credit creation indirectly by altering the relative opportunity costs between different funding methods as well as by affecting the profitability and riskiness of potential investments. Monetary policy is often implemented without significant changes to the central bank's balance sheet, in which case the size of the balance sheet is generally determined by slowly changing external factors such as the demand for reserves, government deposits and demand for currency[10]. The central bank can, however, use its balance sheet as an additional policy tool, such as under the Federal Reserve's "quantitative easing" policy. In this case, the level of reserves is controlled by the central bank. Consider, for example, the unprecedented level of excess reserves currently held at the Federal Reserve as a consequence of its monetary policy. It is important to understand that banks cannot just "draw down" these reserves and "lend them out"[11]. The level of reserves is determined by the amount of assets the central bank holds on its balance sheet and can only be reduced if the Federal Reserve were to sell back its assets to the banks or if customers of commercial banks were to withdraw their deposits in currency. Excess reserves could be eliminated by raising the reserve requirement or if banks extended so many new loans that the new required level of reserves were equal to the current amount of reserves. Banks can lend reserves to each other, but they cannot

requirements has varied over time, the Federal Reserve has always followed an accommodative policy on reserves (1983). A recent IMF study based on a survey of 121 central banks also finds reserve requirements for "prudential" (liquidity) management and "monetary control" to be rather outdated and only effective under particular circumstances. The study suggests that central banks are right to manage reserves in an accommodating manner in order to avoid unwanted surpluses or shortages of reserve balances, and that reserve averaging can be an effective tool for reducing the short-term interest rate volatility induced by liquidity shocks (Gray 2011).

[9] Most often, a competitor acquires banks under this circumstance. For a list of recent bank failures, see http://www.fdic.gov/bank/individual/failed/banklist.html.

[10] For a detailed explanation and an enlightening discussion on the supposed "specialness" of reserves as well as the supposed "unconventionality" and "inflationary potential" of recent monetary policy, see Borio and Disyatat (2009).

[11] This fact is commonly misunderstood. For further explanations, see Keister and McAndrews (2009) and Sheard (2013).

lend them out to final borrowers. Hence, the quantity of reserves says very little about credit creation by commercial banks[12].

Commercial banks, in contrast to central banks, cannot create purchasing power to buy securities for their own balance sheets. They can only create credit[13]. What makes them special is that as a consequence of credit creation, they create liabilities (deposits) that function as money because they can be redeemed at par on demand against currency and serve as settlement media. Note that the availability of reserves matters with respect to liquidity[14] but not with respect to funding new loans. The funding of loans and other investments can only come from bank equity, deposits or other liabilities such as long- or short-term debt. To the extent that bank loans create deposits, banks can, from an accounting perspective, create their own funding. However, this is constrained by their own capital, the cost of obtaining some liquidity later as well as the availability of collateral for their own borrowing. Of course, liquidity and funding are related because insufficient liquidity can quickly lead to bankruptcy. This is true, however, not only for commercial banks but also for other institutions engaged in maturity transformation.

Over recent decades, money has been increasingly invested ("deposited") with asset managers, such as pension or mutual funds. In this process, financial intermediaries engage in maturity transformation as well as "reverse maturity

---

[12] Carpenter and Demiralp (2010) study reserve balances, money and lending in the United States and conclude the following: "The relationships implied by the money multiplier do not exist in the data for the most liquid and well-capitalized banks. Changes in reserves are unrelated to changes in lending, and open market operations do not have a direct impact on lending. We conclude that the textbook treatment of money in the transmission mechanism can be rejected".

[13] Our distinction between money creation by the central bank and money creation by commercial banks resembles Gurley and Shaw's (1960) distinction between "outside" and "inside money". The former is a net asset to the private sector and either fiat- or asset-backed (e.g., gold) and the latter refers to money backed by private sector liabilities in zero net supply. Under current practices, in which "outside money" is backed by government debt, we would argue that it is also a liability to the private sector to the extent that the government debt is to be paid off with future taxes on households and firms.

[14] The United States currently requires 3 percent reserves on transaction accounts between 12.4 and 79.5 million US dollars and 10 percent reserves on net transaction accounts above that threshold. There are no requirements on time deposits and vault cash counts toward the reserve requirement. Several countries require zero minimum reserves, such as Australia, Canada, Denmark, Norway, Sweden and the United Kingdom (Gray 2011). The imposition of reserve requirements makes demand for reserves more interest-elastic and hence interest rates less volatile. The decision of whether to impose minimum reserves is primarily an operational choice in the conduct of monetary policy.

transformation" as asset managers make short-term loans to other financial intermediaries from long-term investments (Pozsar and Singh 2011)[15]. Credit creation has consequently shifted from traditional banking to what we describe as "securitized fractional reserve banking", where credit is not financed from deposits but rather from short-term collateralized loans from institutional investors, such as financial intermediaries (e.g., commercial banks, broker-dealers, asset managers, custodians) as well as nonfinancial corporates. Credit creation in securitized banking increases money supply not by issuing deposits but by issuing short-term, money-like securities such as commercial paper or repos. To the extent that these provide financing to commercial banks, cash deposits with nonbank intermediaries are channeled back to commercial banks. Either way, whether credit is intermediated through banks, though other nonbank financial intermediaries or the capital markets, credit creation matters because it is an enabler of but also a claim to future growth.

Integrating Austrian, Mainstream and Post Keynesian credit creation

In a highly stylized view, the Austrian, Mainstream and Post Keynesian description of credit creation can be argued to represent different points along the three variables of credit creation proposed in our "asset-based-framework". The Austrian point of view is that of hard assets, commodity money such as gold and a separation between deposit banking and lending with no maturity transformation (full reserve banking). Consequently, the Austrian perspective is placed in the left-hand corner of the diagram shown in Figure 8. The Mainstream view of credit creation corresponds to the traditional fractional reserve banking system where credit is financed by deposits and banks leverage existing assets through maturity transformation. A higher level of trust is required because more claims to cash exist than actual cash held by the banks. Hence, the Mainstream view is positioned to the

[15] From this perspective, credit creation – and the resulting supply of money-like liabilities – is a complex process of interacting agents that optimize their asset portfolios across different time, liquidity and risk preferences.

right of the Austrian view with a decreasingly physical understanding of assets and money. The Post Keynesian view of credit creation is best understood in the present context of "securitized fractional reserve banking", where maturity transformation is taken to another level and credit creation is primarily financed by short-term debt instruments among financial intermediaries. In this system, the assets qualifying as collateral for credit creation are increasingly virtual and comparatively ample in supply. The leveraging of existing assets takes place not only at the level of ultimate creditors but also at the level of financial intermediation. This system is highly reliant on trust and confidence because of procyclical feedback and interconnectedness. Consequently, this perspective is placed to the far right-hand side of the diagram.

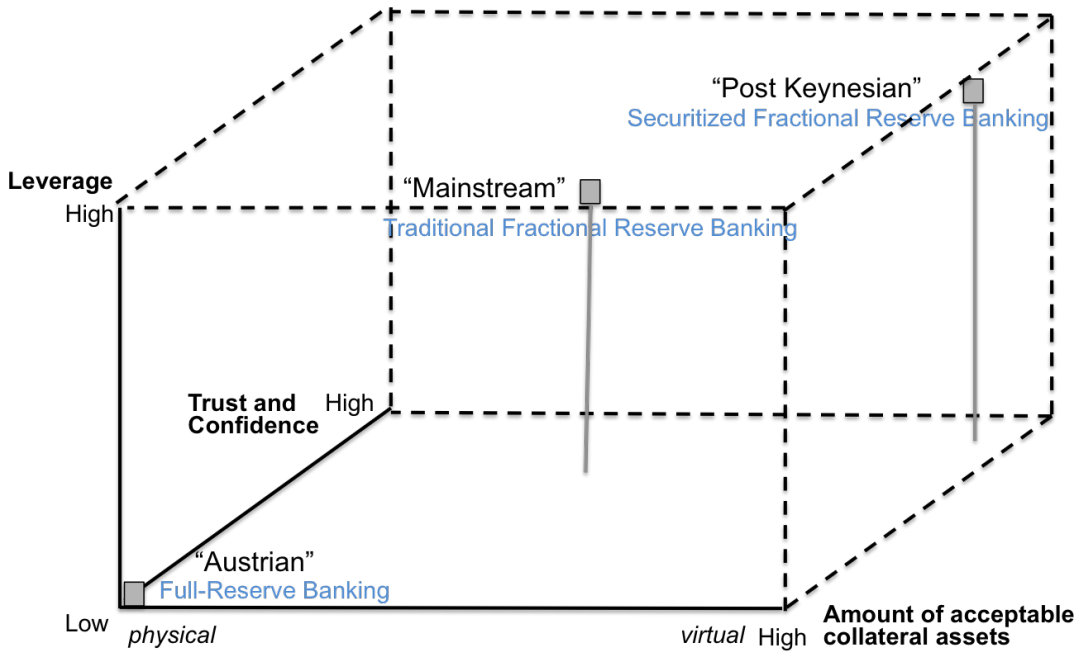


Figure 4: Stylized integration of the Austrian, Mainstream and Post Keynesian perspective of credit creation in an "asset-based framework" along the three variables of (1) amount of acceptable collateral assets, (2) level of leverage and (3) level of trust/confidence.

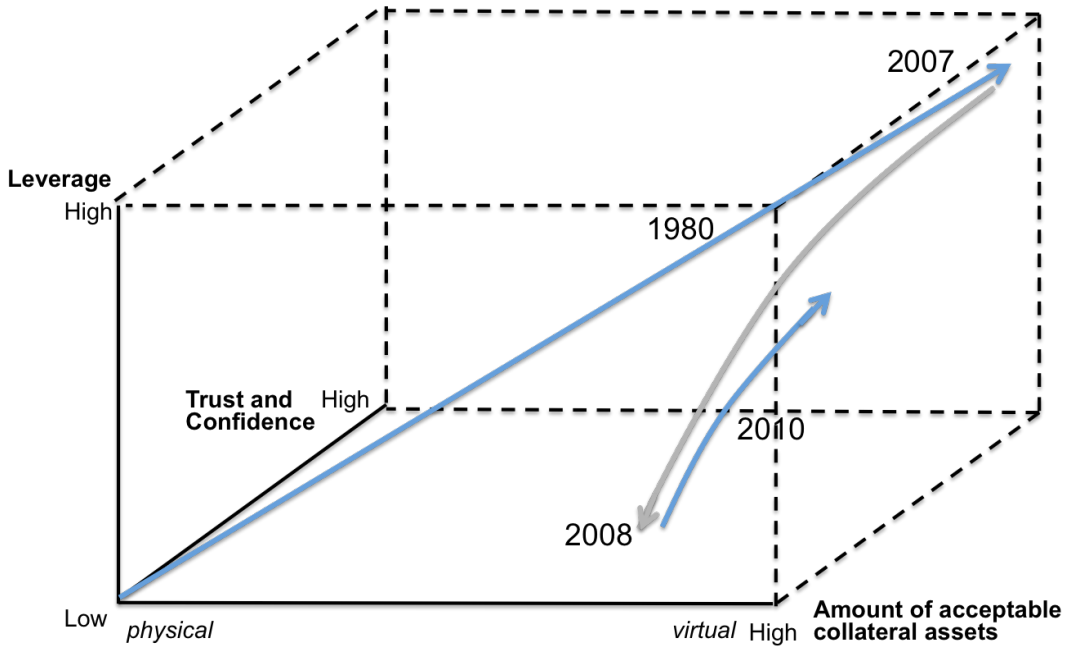


Figure 5: Credit creation before and during the global financial crisis.
Credit creation expanded across the three variables of (1) amount of collateral assets accepted, (2) level of leverage and (3) level of trust/confidence until 2007, when the subprime crises triggered a contraction. Subsequent policy measures increased asset availability for credit creation and improved trust/confidence.

References

Bell, Stephanie. 2001. "The Role of the State and the Hierarchy of Money." *Cambridge Journal of Economics* 25: 149–63.
Benes, Jaromir, and Michael Kumhof. 2012. "The Chicago Plan Revisited." *IMF Working Paper*, August, 1–71.
Borio, Claudio, and Piti Disyatat. 2009. "Unconventional Monetary Policies: an Appraisal." *BIS Working Papers*, November, 1–37.
Carpenter, Seth B, and Selva Demiralp. 2010. "Money, Reserves, and the Transmission of Monetary Policy: Does the Money Multiplier Exist?." *Federal Reserve Board Finance and Economics Discussion Series*, May. Washington D.C., 1–58.
Fisher, Irving. 1936. *100 % Money*. 2nd ed. New York: Adelphi Company.
Freixas, Javier, and Jean-Charles Rochet. 2008. *Microeconomics of Banking*. second. Cambridge, Massachusetts: The MIT Press.
Fullwiler, Scott. 2012. "Krugman's Flashing Neon Sign." *New Economic Perspectives*. http://neweconomicperspectives.org/2012/04/krugmans-flashing-neon-sign.html.
Goodfriend, Marvin, and Monica Hargraves. 1983. "A Historical Assessment of the Rationale and Functions of Reserve Requirements." *Economic Review, Federal Reserve Bank of Richmond*, March/April, 1–19.
Graeber, David. 2011. *Debt: the First 5000 Years*. New York: Melville House Publishing.
Gray, Simon. 2011. "Central Bank Balances and Reserve Requirements." *IMF Working Paper*, February, 1–56.
Gurley, John G, and Edward S Shaw. 1960. *Money in a Theory of Finance*. Washington D. C.: The Brookings Institution.
Horwitz, Steven. 2000. *Microfoundations and Macroeconomics: an Austrian Perspective*. New York, NY: Routledge.
Huerta de Soto, Jesus. 2009. *Money, Bank Credit and Economic Cycles*. Second English edition. Ludwig von Mises Institute, Auburn, Alabama.
Keen, Steve. 2011. *Debunking Economics: the Naked Emperor Dethroned?* revised and expanded edition. London/New York: Zed Books Ltd.
Keen, Steve. 2013. "A Monetary Minsky Model of the Great Recession." *Journal of Economic Behavior and Organization* 86. Elsevier B.V.: 221–35. doi:10.1016/j.jebo.2011.01.010.
Keister, Todd, and James McAndrews. 2009. "Why Are Banks Holding So Many Excess Reserves?." *Federal Reserve Bank of New York Staff Reports*, July, 1–15.
Krugman, Paul. 2012. "The Conscience of a Liberal." *The New York Times*. http://krugman.blogs.nytimes.com/2012/03/30/banking-mysticism-continued/?_r=0.
Lavoie, Marc. 2009. *Introduction to Post-Keynesian Economics*. 2nd ed. Basingstoke: Palgrave Macmillan.
Lavoie, Marc. 2013. "The Monetary and Fiscal Nexus of Neo-Chartalism: a Friendly Critique." *Journal of Economic Issues* 47 (March): 1–31.
Minsky, Hyman P. 1986. *Stabilizing an Unstable Economy*. New Haven and London: Yale University Press.
Minsky, Hyman P. 1992. "The Financial Instability Hypothesis." *Levi Economics*

Institute, Working Paper, May, 1–10.
Moore, Basil J. 1991. “Money Supply Endogeneity: "Reserve Price Setting" or "Reserve Quantity Setting"?.” *Journal of Post Keynesian Economics* 13 (Spring): 404–13.
Moore, Basil J. 1988. *Horizontalists and Verticalists, the Macroeconomics of Credit Money*. Cambridge University Press.
Moore, Basil J. 2006. *Shaking the Invisible Hand Complexity, Endogenous Money and Exogenous Interest Rates*. Basingstoke: Palgrave Macmillan. doi:10.1057/9780230512139.
Pozsar, Zoltan, and Manmohan Singh. 2011. “The Nonbank-Bank Nexus and the Shadow Banking System.” *IMF Working Paper*, December, 1–19.
Rothbard, Murray. 2008. *The Mystery of Banking*. 2nd ed. Ludwig von Mises Institute.
Selgin, George, and Lawrence H White. 1996. “In Defense of Fiduciary Media-or, We Are *Not* Devo(Lutionists), We Are Misesians!.” *Review of Economic Dynamics* 9 (2): 83–107.
Sheard, Paul. 2013. “Repeat After Me: Banks Cannot and Do Not ‘Lend Out’ Reserves.” *Standard & Poor's Ratings Direct*, August, 1–15.
Stella, Peter. 1997. “Do Central Banks Need Capital?.” *IMF Working Paper*, July, 1–39.
Tcherneva, Pavlina R. 2007. “Chartalism and the Tax-Driven Approach to Money.” In *Alternative Monetary Economics*, edited by Philip Arestis and Malcolm Sawyer, 69–86. Edward Elgar Publishing Limited.
von Mises, Ludwig. 1953. *The Theory of Money and Credit*. New Haven: Yale University Press.
von Mises, Ludwig. 1964. *Human Action a Treatise on Economics*. 4 ed. San Francisco: Fox & Wilkes. http://mises.org/Books/humanaction.pdf.
von Mises, Ludwig, Gottfried Haberler, Murray N Rothbard, and Friedrich A. Hayek. 1996. *The Austrian Theory of the Trade Cycle and Other Essays*. Edited by Richard M Ebeling. Auburn, Alamana: Mises Institute.
Wray, Randall L. 1998. *Understanding Modern Money: the Key to Full Employment and Price Stability*. Edward Elgar Publishing Limited.
Wray, Randall L. 2007. “Endogenous Money: Structuralist and Horizontalist.” *The Levy Economics Institute*, September, 1–23.

B. A comment on complexity

CORRESPONDENCE

Complexity clouds finance-risk models

We question the usefulness of focusing on sophisticated ecosystem or other models for assessing financial risks (*Nature* **469**, 302–303 and 351–355; 2011) when practical solutions are to hand.

The main bottleneck is more political than technical, driven by a US banking oligarchy that effectively controls the economy. (Europe's and China's banks have more complex interactions with the state.)

We agree that traditional economic models need to be enhanced with interdisciplinary system theory in the medium and long term. But known short-term solutions have demonstrated their value in previous successful policies, and we should relearn and expand some of the old economic wisdom about the specific role of banks.

Banks are important because they create credit in a fractional reserve system, and credit markets are crucial allocators of capital to entrepreneurs. However, this is not considered in macro-economic models used by central banks (indirect influence through interest rates aside). The Austrian school of economists and scholars in the 1930s correctly emphasized that too much credit, encouraged by artificially low interest rates set by the central banks, can lead to bubbles and unsustainable booms. This is what happened in the run-up to the current financial crisis.

One problem that is often overlooked is the misalignment of interests between credit creation by banks for profit maximization versus the amount of credit required by the economy. The Glass–Steagall Act of 1933 reconciled these interests by separating investment, commercial and retail banking and insurance. Most scholars attribute much of the economic stability after the Second World War to this legislation. Its repeal in 1999 was the culmination of a decade of deregulation justified by the 'great moderation' (go.nature.com/ehkgvv), which turned out to be just a consequence of the actuation of a perpetual money machine that promised unrealistic economic growth.

We need to stop being blinded by complexity so that policy-makers can develop effective responses to the financial crisis and academics can create a genuine science of out-of-equilibrium system economics.

Didier Sornette, Susanne von der Becke *ETH Zürich, Switzerland.*
dsornette@ethz.ch

Science and religion are wise to talk

As recipients of several peer-reviewed grants from the John Templeton Foundation over the past decade, we agree with other recipients who report that the foundation has never sought to interfere with their grant-funded projects (*Nature* **470**, 323–325; 2011).

For those who think that this grant-giving body should not have funded some projects, we might say the same about all the other agencies that have funded our research in biomedical science and geophysics. Receiving a grant does not entail accepting the worth of all the other grants given by the same body.

As far as the mingling of scientific and religious language is concerned, we agree that this is a justifiable concern. In the United Kingdom, the Faraday Institute (our institution) is well known for its criticism of both creationism and intelligent design. Attempts to introduce theological language into the practice of science is as damaging for theology as it is for science. Each academic discipline has its own specialized language and its own criteria for justifying its claims; mixing them only creates confusion.

However, we disagree with the scientists you cite who oppose any kind of interdisciplinary engagement between science and religion, or who maintain that they are in conflict. Given that almost all organized science education in Europe was carried out by religious institutions for many centuries, and that the premises and practices of science have deep theological roots, such a stance is implausible. The world is as religious as it has ever been — perhaps more so. The scientific community is often embedded in highly religious societies, the United States being a prime example. Friendly dialogue is a wiser strategy than aloof isolationism.

Denis Alexander, Bob White *The Faraday Institute for Science and Religion, Cambridge, UK.*
dra24@hermes.cam.ac.uk

Infrastructure vital to genome success

Eric Lander's assessment of the impact of the publication of the human genome sequence (*Nature* **470**, 187–197; 2011) does not comment on the substantial progress made in research-infrastructure development in areas such as resources, technology, computational biology, training, education and ethical, legal and societal issues, as envisaged by the genome community (*Nature* **422**, 835–847; 2004).

Look at the key experimental resource of human cohorts. For example, more than 500,000 volunteers have now signed up for the world's largest prospective study, UK Biobank. Comparable studies are ongoing in Norway and China. A retrospective study, Biobank Japan, has already proved its investigational value. Researchers are also building a global network of cohort studies through the Canada-based Public Population Project in Genomics.

Biobanking networks are emerging across the European Union. Examples are the Biobanking and Biomolecular Resources Research Infrastructure and the UK DNA Banking Network.

Advanced data-management systems at the Cancer Biomedical Informatics Grid, the US National Center for Biotechnology Information and the European Bioinformatics Institute near Cambridge, UK, are facilitating meta-analysis and experimental design.

Across the European Research Area, under the aegis of the Innovative Medicines Initiative and the European Strategy Forum on Research Infrastructures, an ambitious programme of research-infrastructure development is under way for the entire 'value chain' of medicines. As part of this, biomedical education and training are being revamped through, for example, the public–private European Medicines Research Training Network.

Without such experimentation in and development of its research infrastructure, the fecundity of genome-based research will not fulfil its promise for health and society.

Martin Yuille *University of Manchester, UK.*
martin.yuille@manchester.ac.uk

SEE COMMENT P.159

CONTRIBUTIONS
Correspondence may be submitted to **correspondence@nature.com** after consulting the author guidelines at **http://go.nature.com/cmchno**.

© 2011 Macmillan Publishers Limited. All rights reserved

Systemic risk in banking: It is complex but not that complicated

A response to Andrew G. Haldane & Robert M. May, Neil Johnson and Thomas Lux

D. Sornette and S. von der Becke
Department of Management, Technology and Economics
ETH Zurich

The ongoing financial crises since 2007 painfully reminded us that systems can develop so-called "emergent" dynamics that are fundamentally different to what can be expected by studying their parts. The assumption that the economy as a whole can be understood by solely focusing on the equilibria resulting from utility optimization of its economic agents constitutes one of the major shortcomings of economics. A mantra in academic circles, exploited by bankers and policy makers to excuse their failures masterly exposed by the founder of the Vanguard group[1], is that with the rise of recent technological and financial innovations societal and economic networks have never been more complex and that this complexity has reached unmanageable levels within the current understanding and methodologies. Summarizing the message of Haldane and May[2], complemented by those of Johnson[3] and of Lux[4], one should invest seriously in understanding the dynamics of the financial and economic system, using a transdisciplinary approach adding system theory from various branches of the natural sciences, network analysis, and out-of-equilibrium agent-based models to traditional economics.

We cannot be more in tune with this message... for the medium and long term. However, we claim that concrete operational solutions on the short term might not lie so much in developing new and highly complex models. Rather than putting our hope in tackling the super complexity with super high tech solutions, we should remember simple truths that

demonstrated their value in the past but have been by and large forgotten. Academic and institutional memory loss includes the role of banks in credit creation, the benefits of certain (lost) forms of regulations, and the crucial role of central banks as fighters (rather than promoters) of bubbles.

In macro-economic models such as the class of Dynamic Stochastic General Equilibrium (DSGE) models used by central banks, the banks as separate agents directly influencing the economy are conspicuously absent, apart from their influence through interest rates. Why should then taxpayers' money bail them out if they are just transparent economic conduits? In contrast, stressing the role of banking in the wider context of economic systems was central to Austrian economists and scholars such as Hayek and Schumpeter. While not without weaknesses, the Austrian economic school emphasised correctly the role of banks and their creation of credit through the fractional reserve system. Too much credit, encouraged by artificially low interest rates set by central banks for instance, can lead to an unsustainable boom and the creation of economic and financial bubbles. This is exactly what happened in the run up to the current financial crises[5]. The concept that banks are in large part responsible for credit creation was well understood 30 years ago and discussed and taught in major economic textbooks. This knowledge seems to have been forgotten in mainstream macroeconomics[6]. This is a fundamental loss. Indeed, the forgotten problem is the misaligned interests between the credit creation chosen by banks in order to maximize their utility versus the amount of credit required by the real economy. Schumpeter also emphasised the crucial role of banks and credit markets through their function of active allocators of capital to entrepreneurs and hence fostering economic development. The reason for this memory loss may have been the inability and even resistance to apply these concepts in mathematical models. It seems, though, that much wisdom can be derived from revisiting these ideas, which carry valuable lessons on the role of banks within the financial and economic system.

In the spirit of the Haldane and May's analogy with ecosystems[2], what we are currently witnessing could be described as an ecosystem that has become unstable because some of its constituents act as auto-catalytic destabilizers through positive feedback loops. That banks serve their own interests on the one hand and play a key role in lubricating the economy, thus serving as public good entities, on the other hand has been widely recognized in recent debates. Many discussions, with different emphasis across the Atlantic, focus of what kind of regulations should therefore be imposed to align the private interests of banks with the public interests. The recent Dodd-Frank act (2010) can be seen as a rather timid step towards a working solution, if not just because many of the changes implied by its implementation are not expected to be fully enacted until 2015 (five years is really like eternity for financial markets!). Consider in contrast that the fifty years following WWII have constituted arguably the most stable economic period in the history of the United States and of Europe. Most scholars attribute a key role for this stability to the Glass-Steagall Act of 1932, which successfully prevented the occurrence of "super-spreader" instabilities, by separating by law investment banking, commercial banking, retail banking and insurance. This disaggregation provided completely separated waterproof compartments to prevent any Titanic like event of crisis spreading. Only with deregulation that started taking place in the 1980s culminating in the repelling of the Glass-Steagall act by the Gramm–Leach–Bliley Act of 1999, banking mutated into a new highly interconnected form that recovered basically its pre-1929 role within the ecosystem. Much of the risks that we currently face both in Europe and in the US originate from too much leverage and uncontrolled indebtedness spreading across all networks that build on the incorrect belief that transfers of debts to bigger and bigger entities will solve the problem.

We cannot afford and do not need to wait another decade or more until new super high tech models are developed. Faster solutions are possible by revisiting policies that worked in the past and by relearning and expanding some of the old wisdom in economics, specifically related to the role of banks. These theories should be anchored on rigorous analyses of empirical evidence and enhanced by fertilization with various branches of the natural sciences, network analysis, and out-of-equilibrium agent-based models.

The main bottleneck is not technical but political due to the control exerted by an oligarchy of bankers in effective control of the economy[7]. But this essential truth is hidden in the smoke of complexity and loss of memory of past solutions. It is also convenient to foster the belief of an illusion of the "perpetual money machine", promising unending economic growth from expanding leverage and indebtedness[5]. It is due time that we stop being lulled by these sirens and used either as scapegoats or future prophets. Only then might a genuine science of out-of-equilibrium system economics[2-4] become credible and useful.

---

[1] J.C. Bogle, The fiduciary principle: no man can serve two masters. *The Journal of Portfolio Management* **36** (1), 15-25 (2009).

[2] A.G. Haldane and R.M. May, Systemic risk in banking ecosystems. *Nature* **469**, 351-355 (2011).

[3] N. Johnson, Proposing policy by analogy is risky, *Nature* **469**, 302 (2011).

[4] T. Lux, Network theory is sorely required, *Nature* **469**, 303 (2011).

[5] D. Sornette and R. Woodard, Financial Bubbles, Real Estate bubbles, Derivative Bubbles, and the Financial and Economic Crisis, in Proceedings of APFA7 (Applications of Physics in Financial Analysis), M. Takayasu, T. Watanabe and H. Takayasu, eds., (Springer 2010) (http://arxiv.org/abs/0905.0220).

[6] R.A. Werner, *New Paradigm in Macroeconomics* (Basingstoke: Palgrave Macmillan 2005).

[7] S. Johnson, The quiet coup, *The Atlantic Online* (May 2009) (http://www.theatlantic.com/magazine/archive/2009/05/the-quiet-coup/7364/).