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Financial Frictions in Macroeconomic Models

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Abstract

In this chapter we: (i) Review the core DSGE workhorse models of financial frictions that existed ahead of the recent financial crisis. (ii) Summarize the recent empirical literature on the history of financial crises. (iii) Summarize the key modelling developments around credit intermediation in DSGE models since the crisis. (iv) Identify gaps in the literature that are especially important for policymakers and modelers.

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Non-technical summary

In recent decades, macroeconomic researchers have looked to incorporate financial intermediaries explicitly in business cycle models. These modelling developments have helped us to understand the role of the financial sector in the transmission of policy and external shocks into macroeconomic dynamics. They have also helped us to better understand the consequences of financial instability for the macroeconomy.

There remain large gaps in our knowledge of the interactions between the financial sector and macroeconomic outcomes. Specifically, the effects of financial stability and macroprudential policies are not well understood.

1. Introduction

Following the recent financial crisis, there has been an intensification of effort by economists and economic historians to understand better the role of financial factors in business cycles and especially around periods of severe economic disruption. There is still no clear consensus on what those lessons are. The role played by many factors such as financial innovation, financial regulation and other government policies, remain far from clear. This article selectively reviews that research effort. The focus is in particular, although not exclusively, on how insights from the long-run historical record of advanced economies are being developed and reflected in frictions in financial intermediation incorporated into closed economy dynamic, stochastic general equilibrium (DSGE) models.

The paper's principal aims, therefore, are: (i) To review the core workhorse models of financial frictions that existed ahead of the recent financial crisis. (ii) To identify the key facts emerging from the historical record as to what features ought to be built into DSGE models with financial frictions. (iii) To summarize the key modelling developments around credit intermediation since the crisis. (iv) To identify gaps in the literature that are especially important for policymakers and modelers.

2. Overview

Models of financial frictions are not necessarily models of financial crises. The pre-crisis workhorse macroeconomic models incorporating financial frictions, as discussed below, focussed on balance sheet constraints facing nonfinancial firms. Recent research efforts, in part reflecting new insights from long-run historical analyses, have sought to incorporate leveraged financial institutions into DSGE models. One result of the new models has been to extend the financial accelerator mechanism to new sets of agents. These more recent models, by introducing frictions and asymmetric information problems between banks, and by working in explicitly non-linear environments, have introduced financial crises into DSGE models. These non-linear models capture the possibility that balance sheet constraints may not always bind. Financial crises are then associated with periods during which the constraints do in fact bind. In this way, sharp changes in the level of aggregate economic activity can be modelled. Incorporating some of the insights of Diamond and Dybvig (1983) is another way to introduce non-linearity into macro models. These authors pointed out that banks may be structurally

vulnerable to runs and that these runs could have a self-fulfilling element; in the absence of the run banks are solvent, whilst in the presence of the run they are insolvent. That is not to say, of course, that banks may not become insolvent in the absence of a run. These extensions to the workhorse models reflect, in part, a substantial body of recent work that seeks better to understand the historical record of financial crises–especially banking crises coupled with the role of secured credit growth and asset price inflation in indicating the probability of a crisis.

The next section outlines, relatively briefly, the workhorse models that existed ahead of the recent financial crisis as well as some of the criticisms that have been levelled against those models. We then summarise some key themes emerging from the historical analyses of financial crises[1]. Our aim is to try to uncover features of these studies that may help inform the construction of new models useful for policy analysis. Some of the areas where the lessons from historical analyses are disputed, remain unclear or where potentially significant gaps remain are then discussed. These two sections indicate that the two core models, despite their insights, lacked a financial intermediaries sector capable of connecting with some key stylized facts emerging from historical analyses, as well as those from the 2008 crisis. The paper then summarizes some of the key DSGE models that have been developed since the crisis, emphasizing the incorporation of financial intermediaries. The intention is particularly to emphasize the key ideas underlying these extensions to the core models rather than a detailed technical exposition of the models. Finally, we outline what we believe are important questions for future research.

3. Core macro models with financial frictions: brief overview

The dominant perspective on financial frictions in macroeconomic models before the 2007/8 crisis derived from two related approaches[2]. These approaches high-

[1]The empirical literature on financial crises has focussed on banking, currency and sovereign debt crises as well as crises combining one or more of these. The focus in this paper will mainly be on banking crises, and specifically those related to periods of robust credit growth.

[2]Of course, many other models existed that addressed financial crises and frictions. The models reviewed in the text became the workhorse models because they could be incorporated into a core neoclassical growth and business cycle framework. There is also a vast literature analyzing financial markets and institutions from partial equilibrium perspectives. See for example many of the papers in Bhattacharya et al. (2004) and Allen and Gale (2007); also relevant is Minsky (1986). Many of the key ideas in these other approaches are, however, captured in recent extensions to the core models we review. For example, the idea of credit cycles, emphasized by

lighted credit market imperfections facing non-financial borrowers. The first of these approaches was developed by Bernanke and Gertler (1989), Carlstrom and Fuerst (1997) and Bernanke, Gertler and Gilchrist (1999) who situated it in a fully specified, sticky-price DSGE model. These contributions drew on the costly state verification literature pioneered by Robert Townsend (1979). The key idea was that a debt contract between a borrower and a lender was the best way to overcome asymmetric information between the parties to the contract. Moreover, the more capital the borrower could sink into the project, the lower the debt service costs would be[3]. The second approach is due to Kiyotaki and Moore (1997), drawing on the idea of the inalienability of human capital emphasized by Hart and Moore (1994). Borrowers may walk away from a project taking their valuable skills and jeopardizing a lender's investment. So, the lender requires the value of capital to which they have recourse in a bankruptcy to at least match the value of the outstanding debt.

Different in a number of details, these two approaches nevertheless share a number of common features.

[Figure 1 about here]

First, in both, leverage and exposure to aggregate shocks are key to both stories as are feedback effects from asset markets (so-called firesale effects). Specifically, firms are unable to purchase insurance against productivity (and other aggregate) shocks, so following a negative productivity shock firms sell capital, the effect of which compounds the initial negative shock. Second, and related, both are intended to capture the situation where credit frictions amplify other shocks, notably productivity shocks (and monetary policy shocks in the case of Bernanke et al. (1999)).

That amplification has both intratemporal and, more importantly, inter-temporal elements. Hence, both approaches emphasize the impact of financial frictions via the production of investment goods. In the Bernanke et al. (1999) model, the entrepreneur's net worth affects the production of new capital goods, which in turn

Minsky (1986), is captured in models by Azariadis et al. (2016) and Boissay et al. (2016).

[3]Duncan and Nolan (2017a) point out that debt contracts are, in fact, not the optimal contract in standard costly state verification environments. They incorporate audit errors into the model and show that, in that case, debt contracts often emerge as optimal. They pursue the macroeconomic implications of those insights in Duncan and Nolan (2017b).

affects next period production. In the Kiyotaki and Moore (1997) model, due to the presence of collateral constraints, higher net worth permits entrepreneurs to purchase more capital and increase production. In both models the financial friction amplifies the impact of productivity (and other) shocks and lays the foundation for more volatile and protracted economic fluctuations. The top panel of Figure 1 portrays what happens when there are no financial frictions. In that case, changes in returns to investment and asset prices work to *mitigate* the initial negative shock, helping more quickly to stabilize aggregate economic activity. The bottom panel, portrays what happens when a financial accelerator is present. Now, the equilibrating role of asset price changes is disrupted as the value of collateral, and not just the expected return to investment, is altered.

3.1. Core models: extensions

These workhorse models led to a large literature examining these frictions in a variety of model environments. Some models have focused on the interaction between mortgage lending, house prices and the wider economy.[4] An important contribution is Iacoviello (2005). He builds on the approach of Kiyotaki and Moore (1997). He constructs a New Keynesian (sticky price) model in which a subset of agents borrow as much as they can in *nominal* terms to purchase housing services. Firms are also constrained in their borrowing capacities as the aggregate value of loans is tied to the value of the housing stock. The rich structure of the model yields substantive insights relative to Bernanke et al. (1999) and Kiyotaki and Moore (1997). Shocks which induce a negative correlation between prices and output (such as a negative productivity shock) are ameliorated (as debtors net worth is boosted by rising prices). However following a demand shock, a financial accelerator mechanism kicks in as prices in the economy, including asset (house) prices, rise. That increases the borrowing capacity of debtors whilst reducing the real value of their outstanding debt. This process boosts debtors' net wealth and increases aggregate demand (since debtors' marginal propensity to spend is larger than lenders'). Together, these effects explain why Iacoviello finds that nominal debt improves the model economy's inflation-output variance trade-off (compared to an economy with indexed debt). Iacoviello (2005) also shows that the combined role of collateral and nominal debt helps the model fit the US data's implications for house price shocks. That the housing market may have wider implications for the economy has been a theme of much subsequent research; see for example,

[4]See Guerreri and Uhlig (2016).

Iacoviello and Neri (2010)[5].

Building on Bernanke et al. (1999), other researchers sought to examine whether these models provided justification for monetary policy to 'lean against the wind' (e.g., Gilchrist and Leahy (2002)); that is, to raise interest rates in response to rising asset prices. The consensus appeared to be that such a policy added little to the efficacy of monetary stabilization policy.[6] Another branch of the literature attempted to assess the wider empirical properties of the workhorse models. Some researchers argued that whilst the financial friction made investment more volatile, its impact on the capital stock was much less substantial. As a result, the labour input (a complement with capital) was not variable enough to match the US data. The consensus that emerged was that these frictions did not appear to be quantitatively substantial.[7]

That lead some researchers to add shocks to the friction. Nolan and Thoennissen (2009) do that arguing that the financial sector may also be a *source* of shocks. They suggest that extension helped the model to capture better the US data and that financial frictions shocks tended to be quite long lasting and quantitatively significant. Specifically, they found that these shocks (i) were tightly linked with the onset of recessions, more so than TFP or monetary shocks; (ii) remain contractionary after recessions have ended; (iii) account for a large part of the variance of GDP; (iv) are generally much more important than money shocks and (v) are strongly negatively correlated with the external finance premium. Gilchrist et al. (2009) via a very different empirical strategy to Nolan and Thoennissen (2009) also argued that credit market shocks contributed significantly to US economic fluctuations over the period 1990–2008. Other researchers found similar results using a variety of estimation procedures.[8] Hence, some argued that financial frictions appeared to be significant once one allowed for a stochastic, time-varying component to the friction. However, whilst a useful result (since the extension need not have helped these models fit the data), it suggested that more work was needed to understand that time-varying feature of the friction.

So, for some, (see e.g., Hall, 2010) these workhorse models provide a good basis

[5]See also Mian and Sufi (2016).

[6]That consensus appeared to chime with monetary policymakers' views, at least ahead of the crisis. Iacoviello (2005) also examines this issue.

[7]See the discussion in Quadrini (2011).

[8]For example, see Christiano et al., (2014). They explore the role of so-called 'risk shocks'. They extend the Bernanke et al. (1999) model such that borrowing entrepreneurs face idiosyncratic productivity, the cross section dispersion of which may widen stochastically. They find that fluctuations in risk are the most important shock driving the business cycle.

for understanding at least the initial contraction in durable expenditure and aggregate economic activity following the onset of the financial crisis[9]. For others, these models lack important features of modern financial economies (such as financial intermediaries and interbank lending) or sufficiently robust microfoundations.

3.2. Core models: assessment

The core models provide a mechanism, grounded in microeconomics, for incorporating financial frictions into the main body of macroeconomic theory. These models have proved useful for studying a variety of theoretical and applied questions and have been shown to connect in meaningful ways with actual data. Nevertheless, the work-horse models have a number of important shortcomings.

First, neither (the Bernanke et al. (1999) nor the Kiyotaki and Moore (1997)) approach develops a detailed role for financial intermediaries. Second, the microfoundations of the contracts/lending arrangements are indistinct meaning that policy recommendations, especially macroprudential recommendations, are unclear. For instance, the Townsend (1979) model of external finance does not typically promote debt contracts as optimal, at least not without considerable modification (See Krasa and Villamil (2000) and Duncan and Nolan (2017a)). As this microfoundation is not fully understood, the effects of policy changes on external finance contracts and ultimately on financial stability remain unclear. Third, and related to the previous point, both approaches assume that financial markets, or other mechanisms, to hedge macro risks (and hence the impact of financial frictions) are closed, despite there being no private information problem. For example, Carlstrom et al. (2016) show that agents in the Bernanke et al. (1999) model can write better contracts than Bernanke et al. (1999) assumed essentially neutralizing the effect of the financial accelerator.[10] Fourth, these models do not feature default, arguably a central issue during financial crises. Fifth, excluded from the core models are many institutions (e.g., financial intermediary

[9]Hall (2010) shows that his variant of the workhorse models does a reasonable job of capturing the initial fall in economic activity following the recent financial crisis, but that its dynamic properties are less impressive. This appears to reflect, as noted in the text, the need for a time-varying financial friction.

[10]See the analysis in Duncan and Nolan (2017b). For a similar result to Carlstrom et al. (2016) vis a vis the Kiyotaki and Moore (1997) model, see Krishnamurthy (2003) and Nikolov (2014). The essence of these results flows from the fact that aggregate shocks are publicly observable. That makes insurance contracts contingent on those risks possible to write and enforce. See Di Tella (2017) for an alternative perspective.

external capital and other financial regulations, deposit protection, tax shields for debt contracts) that may reasonably be expected to impact substantially on the vulnerability of the macroeconomy to certain shocks and the incentives underlying the credit intermediation process.

We argue later that progress has been made in making the core models descriptively richer but that the microfoundations remain unclear. Moreover, the role of financial regulations is largely absent in recent contributions. The upshot is that the guidance that the literature is able to provide to microprudential and perhaps especially macroprudential policymakers remains highly tentative.

Before turning to the recent theoretical extensions to the core models, the next section first discusses a mostly rather recent literature that seeks to uncover the key facts of financial crises in advanced economies.

4. Facts and features of financial crises

The principal focus here will be on the literature on banking crises.[11] Highly leveraged financial intermediaries–traditionally banks–appear to have played a central role in many so-called crisis events. And there is evidence that banks are, in some sense, special[12]. For example, Bernanke (1983) is an influential paper suggesting that bank failures and the damage done to the efficiency of credit intermediation are important for understanding the persistence of the Great Depression. More recently, Giesecke et al. (2014) contrast bond default crises with banking/credit crises (the latter taken from Schularick and Taylor (2012), see below). The authors constructs a data set to study corporate bond default crises in the U.S. from 1866 to 2010, a sample that includes examples of widespread corporate default.[13] Typically banks are more important overall as a source of debt finance although both sources are significant in absolute terms. The ratio of bank loans to GDP averages 33.2 percent over the sample whilst the ratio of

[11]Many of the key empirical/historical contributions in the study of financial crises have also covered currency and sovereign debt crises in addition to banking crises, as well as crisis events characterized by more than one type of crisis. See Bordo et al. (2001), Reinhart and Rogoff (2009) and Laevan and Valencia (2008, 2012).

[12]That specialness is sometimes referred to as the 'bank' or 'credit channel', in the context of the transmission mechanism of monetary policy.

[13]A crisis is taken to be a run of consecutive years when the default rate exceeds 2.5 percent (five times the median default rate). During 1871–1879 more than 50 percent of all outstanding bonds defaulted; this period is associated with railroad expansion. In total, there are 13 corporate default crises in their data.

corporate bonds to GDP averages 19.2 percent.[14] Moreover, bonds are typically unsecured.

Following World War II, bank lending grew more rapidly than corporate bonds (and currently is about twice as large). The authors find that banking crises and corporate default crises were largely distinct events; that is, there appeared to be a low correlation between the timing of corporate default and banking crises. Moreover, bank lending increased significantly shortly after a corporate default crisis but the corporate debt market did not pick up after a banking crisis.

Large corporate bond issuers seemed able to substitute sources of credit after a corporate default crisis, thereby mitigating the impact of the credit channel mechanism. These findings, the authors argue, seem broadly consistent with experience in the recent crisis insofar as big firms suffered less restricted access to credit than did small and medium sized enterprises.

Whilst, declines in housing and stock market values led to notable declines in subsequent bank lending, they had no apparent effect on the subsequent amount of corporate bond issuance. That appears to support the Kiyotaki and Moore (1997) insight that collateral values and credit availability are important and that they may be central to understanding the macroeconomic impact of banking crises. Moreover, Giesecke et al. (2014) show that unlike banking crises, corporate default crises do not appear to have a significant or systematic effect on aggregate activity (GDP or industrial production). Interestingly, Azariadis et al. (2016) find that, for the U.S. economy over the period 1981–2012, unsecured debt is quite strongly procyclical and with some tendency to lead GDP. On the other hand, secured debt seems more or less acyclical. They therefore argue that the Kiyotaki and Moore (1997) model is not supported by the data. However, it is worth noting that the Giesecke et al. (2014) analysis is specifically focused on periods of crisis. In any case, this is one of a number of complex signals emerging from recent empirical studies. We mention more such instances below.

One implication, then, from the Giesecke et al. (2014) study is that in analyzing crisis periods it is important to distinguish secured from unsecured borrowing, both for corporate and non-corporate borrowers, since the credit and collateral mechanisms are largely absent in bond default crises. Another lesson, is the importance of credit growth for wider economic stability.

Schularick and Taylor (2012) is an influential study of credit growth and banking crises. Banking crises are events during which a country's banking sector

[14]Notably, over the period 1933–1940 the outstanding stock of corporate bonds is larger than bank loans.

experiences bank runs, sharp increases in default rates leading to capital losses, public intervention, bankruptcy, and possibly forced merger of financial institutions. Their crises dates are largely derived from studies by Bordo et al. (2001) and Reinhart and Rogoff (2009) for the pre-WW1 era and from Laeven and Valencia (2008) and Cecchetti et al. (2009) for the post WW2 period. Their data include money and credit aggregates along with various other macroeconomic variables, covering 14 developed countries from 1870 to 2008[15]. In total, there are 79 major banking crises in their sample.

They find that the ratio of credit to money remained broadly stable between 1870 and 1930 whilst during the Great Depression there was a marked deleveraging of the banking system. In the post-war period, banks first grew their loan books relative to available deposits, before sustaining high credit growth through increasing reliance on non-monetary liabilities (debt securities and interbank borrowing). As Jordà et al. (2014) show, much of that lending is related to property: The share of mortgage loans in banks' total lending portfolios averaged across 17 advanced economies has roughly doubled over the past century—from about 30% in 1900 to about 60% in 2014.

Schularick and Taylor (2012) suggest that the increasing reliance on debt securities and markets to fund balance sheet lending growth may be a serious problem if it constitutes an unstable source of funding. That is because borrowing conditions, liquidity and market confidence move centre stage and these may be highly unstable variables in difficult times. Their central empirical finding is that "...all forms of [their empirical] model show that a credit boom over the previous five years is indicative of a heightened risk of a financial crisis." That is, they estimate that sustained credit growth one standard deviation above the mean increases significantly the likelihood of a crisis.[16] There is also in their dataset some indication that changes in the rate of credit growth–that is, accelerating credit growth–may indicate imminent problems. In related work, Jordà et al. (2014) calculate that three quarters of all episodes during which credit to GDP rose by at least 30

[15]The countries included are: Australia, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom and the United States. They (and coauthors) have since expanded this data set, in terms both of countries included (to 17, adding Belgium, Finland and Portugal) and many more variables. See Jordà et al. (2016b).

[16]See also the results of Gourinchas and Obstfeld (2012). They argue that over the period 1973–2010 their data suggest that, regardless of whether a country is emerging or advanced, domestic credit expansion and real currency appreciation have been the most robust and significant predictors of financial crises.

percentage points over a five-year period ended in a systemic crisis.[17] Figure 2 shows the relationship between credit growth and crisis probability in the expanded (see Footnote 15) data from Jordà et al. (2016b). It captures their key finding rather strikingly as strong growth in credit is reflected in sharp increases in crisis probability.

[Figure 2 about here]

4.1. Leverage and asset prices

Jordà et al. (2015) build on Schularick and Taylor (2012). They analyze an annual panel of data for 17 countries since 1870 including various macro, equity and house prices data. Their interest is in the economic impact of debt-financed 'bubbles'. If prices are above trend by more than one standard deviation, they label this a "price elevation episode". They also require, for a bubble to be identified, that at some point during such an episode a large price correction occurs ("the bubble bursts") and real asset prices fall by more than 15% over a 3-year window looking forwards from any year in the episode. In the Pre-WW2 era they find that financial crises were as likely as not to take place in association with a bubble episode in equities and/or housing (and mostly non-housing related). In the Post-WW2 era, 21 out of 23 financial crises are associated with a bubble episode in equities and/or housing, with 11 out of 21 bubble-related financial crisis recessions linked to bubbles in both asset classes.

The authors find that post-WW2 numerous equity price bubbles did not turn into financial crisis episodes whilst housing price bubbles, although less frequent, appeared to be more disruptive and more likely to be associated with a financial crisis episode.

In addition, credit fueled asset price bubbles, especially those in housing markets after WW2, are associated with a higher likelihood of a financial crisis recession. Thus, what seems to be important is whether the price bubble relates to equities or houses, and whether the bubble is accompanied by rapid growth

[17] Jordà et al. (2016a) analyze total (public plus private) debt levels in the same data set. They confirm that it is private credit that is linked to ensuing crisis episodes. Thus, historically in advanced economies, financial crises do not appear to be primarily caused by public debt problems. However, if a financial crisis strikes, and fiscal capacity is low, there is evidence that the ensuing recession is more costly.

in private credit; the worst outcomes are when the bubble is in house prices and there is a credit boom. In that case, even after five years, the economy typically has not yet quite recovered from the recession and is still struggling to regain its pre-crisis peak level of real GDP per capita.

More generally, Jordà et al. (2017) find that the ratio of credit to income (what they call the level of financialization) may be systematically related to business cycle features of advanced economies: More financialized economies, they find, tend to exhibit lower real volatility, but also lower growth and more tail risk. That is, leveraged economies appear to be more at risk of steeper downturns and slower recoveries (the latter often related to financial crisis recessions). That is what Figure 3 captures; higher debt going into a recession is associated with deeper subsequent recessions and slower recoveries. The authors suggest macroeconomists ought to reflect such features their core models. These models, they argue, ought also to reflect that real consumption and real investment exhibit a strong degree of co-movement with credit in more leveraged environments.[18]

[Figure 3 about here]

4.2. Good Booms, Bad Booms?

One of the issues identified by Jordà et al. (2015) and other researchers is that not all periods of 'boom' end in 'bust'. For example, Bordo and Meissner (2016) argue that not all banking crises are driven by credit booms and that not all housing or equity booms, or periods with high capital inflows, ended in crises. Gorton and Ordoñez (2016, 2017) argue that credit 'booms' are not unusual historically and set out to understand why some booms end in crises (bad booms), whilst others do not (good booms). The key to understanding what determines whether a boom will be 'good' or 'bad', they argue, is how sustained is the increase in productivity which appears to give rise to all the booms, good or bad, in their data set. Gorton and Ordoñez (2017) study 34 countries (17 advanced countries and 17 emerging market countries) over the period 1960 to 2010. The measure of domestic credit to the private sector that they adopt is wider than just bank

[18]Of less interest for present purposes, but nevertheless of some importance, they also note that advanced economies have become more synchronized, perhaps lessening the ability to hedge financial risk internationally.

credit[19].They adopt two measures of productivity, the Solow residual and labour productivity. The definition of financial crisis follows Laeven and Valencia (2012), and defines a systemic banking crisis as occurring if (1) there are "significant signs of financial distress in the banking system (as indicated by significant bank runs, losses in the banking system, and/or bank liquidations)" and (2) if there are "significant banking policy intervention measures in response to significant losses in the banking system."[20]

Gorton and Ordoñez (2017) adopt the following norm for their core analysis: A credit boom is identified whenever a country experiences three consecutive years of positive credit growth (as a fraction of GDP) averaging more than 5%. The boom ends when the country experiences at least two years of credit growth (also as a fraction of GDP) not higher than 0%. Given their country/time sample and these norms, they identify 87 booms. In their sample there are 47 crises also identified by Laeven and Valencia (2012). It turns out that 34 of those crises happened at the end of one of the 87 booms. As a result, they conclude that there are 34 bad booms and 53 good booms in the sample. On the other hand, there were eight crises that occurred not at the end of a boom but *during* a boom, and there were five crises that were not associated with any boom. So, whilst there are both good and bad booms in their data set, there are also crises that do not occur at the end of booms, and some in fact that are unrelated to booms.

Boom periods have certain statistical regularities in the Gorton and Ordoñez data. First, investment growth is significantly higher during booms compared to non-booms (suggesting that investment booms typically coincide with credit booms). Similarly, credit extended both to the corporate and household sectors is higher during booms, as is real GDP growth (the latter higher in good as compared to bad booms). Importantly, average growth in both total factor and labour productivity is significantly higher in good booms compared to bad booms, a feature consistent across both developed and developing countries. Thus, whilst credit growth is a predictor of financial crises in their data set, as for Schular-

[19]Credit is defined as financial resources provided to the private sector, including loans, acquisitions of non-equity securities, trade credit and other receivables. It thus appears to be a mix of secured and unsecured credit.

[20]Auxiliary criteria employed by Laeven and Valencia (2012) are (1) extensive liquidity support (when central bank claims on the financial sector to deposits exceeds five percent and more than double relative to the pre-crisis level); (2) bank restructuring gross costs are at least three percent of GDP; (3) significant bank nationalizations; (4) significant guarantees are put in place; (5) there are significant asset purchases (at least five percent of GDP); and (6) there are deposit freezes and/or bank holidays.

ick, and Taylor (2012), the likelihood of a crisis is reduced by the occurrence of productivity growth.

The authors show that a credit boom starts with a positive innovation to productivity, but that the growth trajectories subsequently differ across good and bad booms. In bad booms, productivity, real GDP and investment growth rates tail off. In good booms, labour productivity growth is high and sustained, while in bad booms it collapses sharply by the fourth year of the boom.[21]

The important lessons that seems to emerge from this literature is that banking crises appear to be linked quite strongly to prior (often secured) credit growth. That lesson has been reflected in a number of macroprudential policy innovations in some countries. However, the lessons from the historical record, some argue, are not quite so clear. We turn now to sketch some of those arguments.

5. Facts and features of financial crises: some issues

5.1. Dating and definitions

Bordo and Meissner (2016) provide an interesting comparison of leading data sets concerning the definition of crises. They argue that there are substantial discrepancies across researchers over what constitutes a crisis and ultimately that leads to different conclusions about the number, impact and possibly the causes of crises. From the perspective of policymakers and model builders, those disagreements may lead to uncertainty about which facts and leading indicators to focus on. Of particular interest to Bordo and Meissner (2016) are longer run data sets (covering more than just banking crises[22]). They emphasize three in particular: Bordo et al. (2001) document banking, currency, and twin (banking plus currency) crises for all years between 1880 and 1997. For the years 1880–1945 their sample includes 21 now mostly advanced countries and from 1945 data from 56 countries is available. Next is the celebrated work of Reinhart and Rogoff (2009) providing data on banking, currency, and (sovereign) debt crises for over 70 countries, and with some data going as far back as the medieval period. Finally, Taylor (2015) provides the dates for systemic financial crises (mainly banking crises) for 17 countries

[21]The authors test, and verify, that their results are not skewed by the recent financial crisis. They go on to build a model to capture the salient features in their dataset. This interesting contribution is not a DSGE macro model and so we do not include it in the present survey.

[22]That is, including banking, currency and sovereign debt crises, as well as twin (banking plus currency) and triple (banking plus currency plus sovereign debt) crises.

1870–2010[23]. Bordo and Meissner (2016) also consider Laeven and Valencia (2008, 2012) who compile a comprehensive data set covering banking, currency, and debt crises for the period 1970–2011. Their data include 162 advanced, emerging, and less developed economies.

Table 1 in Bordo and Meissner (2016) gives the definitions for dating the various types of crises in each of the leading data sets: Bordo et al. (2001), Laeven and Valencia (2008, 2012), Reinhart and Rogoff (2009), and Jordà et al. (2016). They note that

> "...for banking crises, authors disagree about how many banks must be closed or what percentage of the financial system's capital must be impaired for a crisis to be classified as systemic. Laeven and Valencia require that major policy interventions take place. Reinhart and Rogoff classify more crises than other authors likely because they only require bank runs to lead to the "closing of one or more financial institutions".

Data sets may differ in what constitutes a crisis, as noted. Related to that, they may also differ as to whether they document a crisis as a twin crisis (data sets perhaps agreeing on one but not the second crisis). Data sets can also disagree about the precise timing of a crisis–what Bordo and Meissner (2016) call "near misses". Bordo and Meissner (2016) argue that the correlation between dating methodologies "is not extremely high even within constant country samples." It is difficult to tell how serious the differences are for the dating specifically of banking crises (our main interest here). It appears that Taylor's (2015) dating of banking crises is closer to that of both Laeven and Valencia (2008, 2012) and Reinhart and Rogoff (2009), compared to that of Bordo et al. (2001).[24]

Romer and Romer (2016) have also emphasized definitional issues in the dating of crises as well as the binary nature of these and other researchers' classification scheme. They propose an index of financial crisis which is somewhat more contin-

[23]This data, as noted above, expands on the 14 countries covered in Schularick and Taylor (2012) on which they based their influential argument that banking crises are 'credit booms gone bust', reviewed above. That is, that credit extended by the banking sector has been the main predictor of financial crises in the twentieth century (in advanced economies). Bordo and Meissner (2016) appear to question some of Schularick's and Taylor's conclusions.

[24]Bordo and Meissner (2016) report some dissimilarities in the cases of sovereign debt crises and currency crises that identify some significant differences but these are not as relevant for our interests here.

uous in nature, thus moving away from what they regard as the overly simplistic crisis/no crisis distinction. We review their contribution in more detail below.

5.2. Output and fiscal costs of financial crises

If researchers come to different judgments about the timing and nature of financial crises, it seems likely that they may also come to different judgments about the costs of those crises. In addition to that issue, different researchers use different methodologies for measuring the lost output as a consequence of a financial crisis. Typically, most authors try to define output losses as deviations from a pre-crisis peak in output or a pre-crisis output trend; some emphasize how long it takes to return to the pre-crisis 'norm'; and others measure cumulative output losses over the period of the acute phase of the crisis.

Bordo et al. (2001) find that financial crises are typically associated with higher output losses compared with recessions without financial crises, as do Gourinchas and Obstfeld (2012) and Jordà et al. (2013) amongst others. Reinhart and Rogoff (2009, 2014) find that recessions with financial crises are typically followed by slower-than-usual recoveries. A number of researchers have confirmed that finding with different data samples. More significant, perhaps, is that Jordà et al. (2011) find that output losses in financial recessions are positively associated with the size of the pre-crisis increase in the credit-to-GDP ratio. That suggests that the financial crisis is indeed a significant factor in causing output losses. However, it may be that selection bias in constructing databases of financial crises pairs large recessions with episodes of financial frictions in a way that exaggerates the apparent effect of crises on output losses. Or, it may be that in anticipation of a large recessions agents try to reduce leverage in anticipation of future credit supply difficulties, making causality difficult to disentangle. More work in this area would be useful.

Despite numerous differences in calculating trends, crisis dating methodologies and samples (time periods and countries), most researchers appear to agree that financial crises are typically associated with economically significant downturns in output and output growth. Indeed, there is evidence that output losses may even be larger in the post Bretton Woods era compared to the pre-World War I period. Whether that reflects that the earlier period was able to recover from crises because economies were more flexible, as Bordo and Meissner (2016) hypothesize, and/or because the financial sector and leverage was smaller, is an open question[25].

[25]We return to this below under our section Directions for future research.

On the other hand, Bordo and Haubrich (2012) compare recovery from recessions with and without crises across 22 business cycles in the US over the period 1880–2010. They find that recessions with financial crises were indeed deeper than non-financial recessions but that recoveries were stronger than those from non-financial recessions. Looking across the OECD economies post-1967, Romer and Romer (2016) come to a similar conclusion as to the speed of recovery.

The work of Reinhart and Rogoff (2009) has emphasized the possible impact of banking crises on the probability of a debt crisis; if sovereign debt is called into question in advanced countries it seems likely, wars aside, that will be due to banking crises. However, the fiscal costs of crises may be due both to the direct cost of the bailout as well as the indirect cost as the economy slows, tax revenues grow more slowly and government expenditure on welfare rises.

Schularick (2012) shows that the (systemic) crises of the late 20th century are associated with large rises in the debt-to-GDP ratio, but that, in the same 14 advanced countries sample as Schularick and Taylor (2012), crises prior to the 1970s were not associated with significant rises in this ratio.

Laeven and Valencia (2012) analyze the rise in debt-to-GDP ratios for all of the systemic banking crises in their data set. They find that the median rise in the debt-to-GDP ratio across all such crises is 12% of GDP while in advanced economies the figure is somewhat higher, at 21.4% of GDP. Fiscal costs, measured as the rise in outlays due to restructuring the financial sector, had a median of 6.8% of GDP. Deducting the rise in fiscal outlays from restructuring from the rise in total debt provides a simple measure of the degree of discretionary fiscal policy. The median for this variable is 7% of GDP. Furthermore, Laeven and Valencia (2012) also suggest that countries with large financial sectors and/or large credit booms also face the largest fiscal costs.

5.3. Crisis? What crisis?

Romer and Romer (2016)[26] create a new semiannual series of financial distress in 24 advanced countries for the period 1967 to 2012. The measure is derived from contemporaneous narrative accounts of country conditions given in the Organization for Economic Co-operation and Development (OECD) publication, *OECD Economic Outlook*. They classify financial distress on a scale (0 through 15), rather than treating it as a 0-1 variable, with a 7 correlating, they claim, with a moder-

[26]The (2016) version of their paper appears to update the March 2015 NBER Working Paper 2102, of the same name.

ate or systemic crisis.[27] Motivated by Bernanke (1983), the definition of financial distress centres, not on banking crises or measures of excess credit growth, but on increases in the cost of credit intermediation identified in the OECD Economic Outlook. Overall, the Romer and Romer index appears to pick up many of the same episodes as other crisis indicators (their main comparators are Reinhart's and Rogoff's crises and Laeven's and Valencia's). That said, some episodes of crises included in alternative chronologies do not show up in their measure[28] and the timing of financial distress is often quite different. For example, Reinhart and Rogoff (2009) sometimes appear to date crises somewhat earlier than do Romer and Romer, whilst these three chronologies quite often come to different views as to how long-lasting a crisis was and sometimes how severe.

Romer and Romer (2016) also study the aftermath of financial crises. They find, as do other researchers, that real GDP falls significantly and persistently. However, overall for the advanced countries in their 1967-2012 sample, that fall in output following 'a typical crisis' is, they argue, moderate. The peak decline in real GDP is approximately 6 percent, whilst the falls in industrial production and the rise in the unemployment are more modest. Moreover, their characterization of the typical aftermath of financial crises is not substantially different from that derived using existing crisis chronologies (conditional on using the same time period and sample of countries).

Romer and Romer (2016) argue that particular episodes are important outliers, showing that including the 2008 crisis and the fall in Greek national output influences strongly the results; excluding Greece from the sample lowers the estimated average output decline following a crisis by more than a percentage point.

Romer and Romer identify 19 episodes in their sample when distress reached at least a 7 (a 'moderate/systemic' crisis). They examined the path of output in the wake of these crises, concluding that even here the evidence does not support the

[27]So, for the Romer and Romer index, rather than a time period being a period of no crisis or a period of crisis, they define things as follows: 0 corresponds to no financial distress; 1, 2, and 3 correspond to gradations of credit disruptions; 4, 5, and 6 to gradations of minor crises; 7, 8, and 9 to gradations of moderate crises; 10, 11, and 12 to gradations of major crises; and 13, 14, and 15 to gradations of extreme crises.

[28]As noted, for Romer's and Romer's measure of financial distress, 7 indicates a systemic crisis. There are six such episodes before 2007: Finland, Norway, and Sweden in the early 1990s; Japan in the 1990s and early 2000s; Turkey in the early 2000s; and the United States around 1990. The same six episodes show up in the Reinhart and Rogoff (2009) and Laeven and Valencia (2008,2012) chronologies, though Reinhart and Rogoff do not classify the U.S. episode around 1990 as systemic. Romer and Romer also do not classify Spain in the late 1970s and early 1980s and Turkey in 1980s as systemic crises, although other researchers' chronologies do.

view that the impact of crises are exceptionally damaging. They also argue that there is little evidence of nonlinearities in the aftermaths of crises; more severe crises do not appear to have disproportionately negative aftermaths. They do find, however, that the size and persistence of their measure of financial distress helps explain the variation in aftermaths; it may be that financial distress that persists at elevated level is more likely to lead to more damaging contractions in output. And in six cases of extremely adverse aftermaths, including the actual behavior of financial distress explains a substantial portion of the shortfall of output from a forecast of what output would have been (based solely on output).

5.4. Conclusions from empirical literature

Systemic banking crises and financial recessions appear to be relatively infrequent in advanced economies. Hence, the historical data required to build up a picture of these events covers long periods of time and diverse countries with somewhat differing financial sectors. It is therefore not surprising that uncertainties exist on some issues, quite apart the dating and definitional discrepancies. For Bordo and Meissner (2016) an over-emphasis on credit growth may lead policymakers to ignore other relevant indicators of impending crisis. For Romer and Romer (2016) crises, of late, in advanced economies just don't seem that bad, most of the time.

However, the historical record also suggests that banking crises *can* be very costly, possibly the more so the larger is the financial sector. Broad trends in the post-WW2 era suggest the financial sector has become highly inter-connected and highly leveraged. Moreover, it is also clear that financial regulation has not ended systemic bank crises. The impact of widespread bailouts on incentives would appear to be significant, although the historical research has not for the most part studied the impact of regulation[29]. Some quantitative theorists have therefore focused on modeling explicitly the credit intermediation process in DSGE environments and the size of the financial sector, the potential costliness of financial recessions and the relative infrequency of crises. Less effort has been directed at understanding the quantitative significance in these models of financial regulation.[30] We now turn to the recent research extending the core models.

[29] Although, see Jordà et al. (2017).

[30] There is an important empirical literature, however, seeking to understanding the macroeconomic effects of financial regulation. For example, see Meeks (2017) and the references therein.

6. Financial frictions in DSGE models: New directions

As noted above, Bernanke and Gertler (1989), Kiyotaki and Moore (1997) and others[31] focus on credit constraints faced by non-financial borrowers. For instance, in the Bernanke et al. (1999) model the size of the external finance premium depends on the health of the borrower's balance sheet. In essence, as the borrower's interests become more aligned with the lender's, that is, as the borrowers own funds invested in the outcome of an investment project increases, the incentives to deviate from the interests of the lender decline. The external finance premium goes down in consequence. The upshot of this process is that a "financial accelerator" mechanism emerges. As wider economic conditions improve, balance sheets strengthen and the external finance premium declines. That results in a boost to the borrower's spending, further bolstering economic activity. And the process works in reverse too; worsening economic conditions are exacerbated by the external finance premium increasing and asset prices declining.

During the recent financial crisis many commentators pointed to widespread evidence that there was disruption in the process of financial intermediation. Consistent with some of the findings of Giesecke et al. (2014), Adrian et al. (2012) conclude that disruptions in the supply of credit intermediated by banks and other financial intermediaries was a central driver in the recent financial crisis; there is evidence that firms that could, resorted to direct (i.e., bond) financing[32]. That disruption in credit intermediation appeared to impinge on the supply of credit to non-financial firms–reminiscent of the properties of the two workhorse models above–but also on bank leverage and interbank lending. Adrian et al. (2012) argue that:

> The leverage of the banking sector emerges as being a key determinant (and reflection) of financial conditions. As such, understanding how the leverage of financial intermediaries fluctuates over the cycle emerges as perhaps the most pressing question in the study of macroeconomic fluctuations.

6.1. The interbank market in DSGE models: Part I

Gertler and Kiyotaki (2010) developed a model to begin to address these issues. In effect, these authors introduce a financial accelerator mechanism into the process

[31] For example, Holmstrm and Tirole (2011).

[32] See also the evidence presented in Ivashina and Scharfstein (2010).

of financial intermediation itself: the emphasis shifted from how much were final producers able to borrow, to how much banks were able and willing to lend.

In the model of Gertler and Kiyotaki (2010) financial intermediaries exist because they are assumed to possess some specialized skills, for example in evaluating and monitoring borrowers and enforcing contracts. That assumption motivates why credit flows from lenders (households) to non-financial borrowers (firms) via financial intermediaries. The bank takes an equity stake in the firm to which it lends (i.e., it makes a loan and absorbs the resultant risk). However, the use of the bank is not without problems. In the background there is also assumed to be an agency problem. Specifically, bank managers face the temptation to abscond with a proportion of the bank's assets; call that proportion θ. That means that households' deposits (and deposits from other banks) may not be repaid in full. If the managers do abscond with any assets, this is observed by all and the bank is deemed to have defaulted. The bank is then wound up and the remaining proportion of the bank's asset, $1 - \theta$, are allotted to the depositors.

The risk of losing their funds means that depositors require some assurance that the intermediaries will be able to honour their commitments. The upshot is that lending banks need to hold sufficient own funds to counter the agency risk. That assurance is reflected in the following incentive compatibility condition:

$$V_t(s_t, b_t, d_t) \geq \theta(Q_t s_t - \omega b_t).$$

Here, $V_t(s_t, b_t, d_t)$ is the value of the banking firm. $Q_t s_t$ is the value of the bank's loan book, Q_t being the price of the loan and the volume is denoted by s_t. θ, as noted, is the proportion of assets that the banker is able to steal, b_t is the volume of interbank deposits and $\omega \in [0, 1]$. The higher is ω, the harder it is for the bank to divert assets funded by interbank deposits. Therefore, $\omega = 1$ implies frictionless interbank markets. Moreover, when the constraint is binding, or expected to bind, the intermediary's balance sheet limits its ability to obtain deposits and lend. When adverse shocks are experienced, the spread widens and that raises the cost of credit to non-financial borrowers. Thus, a decline in intermediary net worth induces a fall in the value of assets that the intermediary can hold, given the constraint on its leverage ratio–the latter due to the principal-agent problem.

The modeling of the interbank market in Gertler and Kiyotaki (2010) is relatively simple. It is assumed that financial institutions experience idiosyncratic liquidity shocks; some institutions experience a surplus of funds, others a deficit. However it is costly to reallocate funds from surplus to deficit institutions. That is because first, the agency problem constraining an intermediary's ability to obtain

funds from depositors may also constrain its ability to obtain funds from other financial institutions. And second, non-financial firms may only be able to raise deposits from a subset of financial intermediaries. The upshot is that such frictions in the inter-bank markets distort real activity, relative to the no-frictions benchmark case.

Thus the friction between depositors and banks is exacerbated when the interbank market is compromised. Moreover, there is no friction distorting the interaction between banks and non-financial debtors, as in the two core (pre-crisis) work-horse models.

A "crisis" in this set up is sparked by an exogenous decline in the "quality of capital"; that is, a decline in the sequence of dividend payouts expected to be remitted to the bank. Intuitively, the nonfinancial companies in which banks own equity stakes experience a (persistent) decline in their productive potential, and hence their dividend payouts. This causes the bank, due to its leveraged position, to have to reduce its borrowings by proportionally more than the initial drop in net worth. In doing so, this 'firesale' reduces further the value of nonfinancial equity, tightening still further the bank's borrowing constraint. This decline in asset values depresses real investment. How damaging the ensuing downturn is depends on the size of the negative shock, the efficiency of the interbank markets and government intervention.

If interbank markets are frictionless, bankers cannot divert assets funded by interbank borrowing and the impact of a quality of capital shock is more limited; the incentive compatibility constraint tightens less than it otherwise would. The contraction in the capital stock drives up the return to capital, encouraging a return to investment activities. In their baseline model, Gertler and Kiyotaki (2010) show that compared to a real business cycle model benchmark, the model with no interbank financial frictions experiences a deeper contraction in aggregate economic activity and endures a slower recovery following the initial negative shock. On the other hand, with frictions in the interbank market, the contraction in the economy is even more severe. The efficiency of the interbank market in this set up works to ameliorate the severity of the contraction in economic activity; the interbank market, if efficient, is in effect a partial solution to the underlying agency problem faced by households in placing their deposits with banks.

However, if banks are no better than households in monitoring bank activity (that is, the agency problem faced by households is as severe for banks in their lending), then the downturn in economic activity consequent on a quality of capital shock to nonfinancial borrowers is more pronounced. The leverage and firesale

effects just noted are somewhat more severe under inefficient interbank markets, as the spread between the expected return on equity and the risk free rate rises further (as a result of the decline in bank net worth). Regardless of how efficient the interbank market is, it takes time for banks in the model to rebuild their capital base (net worth)–the model's version of deleveraging–during which time the spread between the expected return on equity and the risk free rate (the credit spread) remains elevated. And that spread is wider the less efficient is the interbank market.

Gertler and Kiyotaki (2010) also examine whether direct lending by the central bank may alleviate financial recessions in their model. They assume a simple rule for the central bank whereby private credit is intermediated by the central bank in proportion to the rise in the credit spread; the higher the credit spread relative to its long run (steady state) value, the more the central bank lends to private borrowers. This policy significantly reduces the rise in the spread, which in turn ameliorates the drop in investment. The overall decline in output is significantly reduced.

Again, there appears to be a significant difference between how important this intervention is with frictionless interbank markets compared to case with frictions. When interbank markets are compromised, and the central bank is able to identify good lending opportunities, central bank intervention is even more effective.

Gertler and Kiyotaki (2010) is an important contribution as it maps out a way to model financial intermediaries in a quantitative, mainstream DSGE environment usable in principle for policy purposes. Moreover, in introducing an interbank market it moves the DSGE model environment in a realistic direction given the increasing importance, and possible fragility, of interbank funding[33]. However, there are some shortcomings. For example, there is no role for outside equity for banks. The only funds that banks in the model obtain from investors are one-period deposits, whilst the own-funds are underpinned by the incentive compatibility constraint. In practice, retail deposits are typically covered by deposit protection schemes and capital is regulated by prudential authorities. In addition, some firms, especially larger firms, are able to substitute direct financing for bank loans, as noted earlier. Finally, the Gertler and Kiyotaki (2010) model is analyzed in approximate linear form, with the incentive compatibility constraint always binding, missing key aspects of crisis dynamics. We turn now

[33]See Gorton and Metrick (2012) for a description of the role of the interbank market in the recent crisis. They emphasize the role of securitization in the repo market. Such features have not yet been explicitly worked in to DSGE models. See Gorton and Ordoñez (2014).

to that latter issue.

6.2. Financial frictions and financial crises

For some researchers the sharp contraction and slow recovery in some countries following the recent crisis are important features to be explained. Brunnermeier and Sannikov (2014) develop a stochastic, continuous-time model to study full equilibrium dynamics (as opposed to local analysis based on linear approximations).

In their model, they distinguish between 'experts' who are more efficient than are households at turning capital into output. Experts, however, are limited in how much equity they may issue–a reflection of an underlying agency problem– but they are in principle not constrained in the issuing of debt. Their model features occasionally binding borrowing constraints which are the central element in producing highly nonlinear dynamics of a sort that is intended to reflect crisis periods[34]. Indeed, the effects are asymmetric arising only in downturns. Broadly speaking, in times of relative stability the borrowing constraint is not binding and the economy is stable, not deviating much from its long run (stochastic) steady state. However, following a large enough negative disturbance (or a sequence of smaller, negative disturbances) the economy may shift into a region where the constraint is binding, amplifying the effect of the shock on the downturn.

In the aggregate, 'experts' act in a risk-averse manner: they anticipate possible adverse shocks and optimally determine a level of net worth able to handle a range of shocks whilst still meeting their debt obligations. Thus, in 'normal' times, near the stochastic steady state, amplification effects are subdued. However, when faced with rare, large negative shocks, they delever. As in Gertler et al. (2016) (see below), during a period of deleveraging, capital is used less efficiently (aggregate production falls), asset prices are negatively affected and are volatile and financial amplification is substantial and long lasting. Brunnermeier and Sannikov (2014) emphasize that this process leads to high levels of asset price volatility and wider economic volatility due to endogenous risk formation. In addition to being able to study the global solution of the model, the stochastic continuous time framework

[34] As we note below, international macroeconomists have been building models for some time of small open economies with similar features (occasionally binding constraints) in order to analyze so-called 'sudden stops' and related issues in developing economies. The methodology and model developed by Brunnermeier and Sannikov (2014) are, however, distinct along a number of important dimensions.

also connects with the asset pricing literature[35].

Unlike in Gertler and Kiyotaki (2010), there is no role for an interbank market in the Brunnermeier and Sannikov (2014) model. In the recent crisis, many analysts point to that market as being central to the worsening of the crisis. We now examine new models that can combine nonlinear dynamics, as in Brunnermeier and Sannikov (2014), along with simple models of the interbank market.

7. The interbank market in DSGE models: Part II

This section focuses on two recent contributions introducing a non-trivial interbank market into a DSGE environment. The first is that of Boissay, Collard and Smets (2016). The role of the interbank market, which is subject to a 'lemons' problem, is central to their model. The explicit motivation behind their model is the infrequent nature of financial crises, the interbank market and the 'credit booms gone bust' characterization of banking/credit crises of Schularick and Taylor (2012) reviewed above.

In the model of Boissay et al. (2016), banks are heterogeneous in how efficient they are at intermediation. One may think of there being costs to finding good loan opportunities with some banks more proficient than others and the better banks incurring lower search costs. Banks, as in Gertler and Kiyotaki (2010), have an incentive to divert borrowed funds and that incentive limits how much they can borrow. Importantly, a bank's type is also private information. If information on type were publicly known, and with no diversion risk, it would be optimal to channel all lending via the most efficient bank. When type is private information, that is not possible; lenders cannot factor bank type into their assessment as to how likely a bank is to divert resources. Therefore, the interbank loan contract is the same for all banks. Let ρ_t be the gross interbank loan rate and γ be the gross return on diverted funds. A bank may divert its own funds and any borrowed funds, ϕ_t, although such diversion is costly. Let $0 \leq \theta \leq 1$ reflect that cost so that, per unit of deposit, the requirement for banks not to divert funds is the gross interbank rate be high enough:

$$\gamma(1 + \theta\phi_t) \leq \rho_t.$$

This is an incentive compatibility constraint and it potentially limits the amount of interbank lending that can take place in equilibrium. Notice, that as the gross interest (ρ_t) rate goes down, so too might the amount of interbank borrowing (ϕ_t).

[35]See also He and Krishnamurthy (2012, 2014) and Di Tella (2017).

This model features a more-or-less familiar financial accelerator effect. However, on top of that, and similar to the model of Brunnermeier and Sannikov (2014), it features highly nonlinear dynamics as periods of strong economic growth give birth to strong credit growth and subsequent slumps as the economy deleverages. That is, as the economy grows and productivity rises, the banking system expands credit to final borrowers. The more efficient banks naturally expand their firm lending activities by borrowing from less efficient banks. However, as the economy slows (as the underlying elevated level of productivity comes to an end) agents in both the household sector and the corporate sector naturally respond. Households increase their savings to smooth consumption and firms borrow less anticipating lower future demand. This rise in net savings depresses economy-wide interest rates, including in the interbank market. As the interbank rate falls, less efficient banks are more tempted to borrow and divert funds. And since bank type is private information, the interbank market becomes very risky and interbank lending declines. This reflects the so-called lemons problem.[36] Boissay et al., (2016) show that there is a threshold level of interest rates below which the interbank market freezes entirely. The result is a credit crunch and a very deep recession. In this way, the interbank market plays a critical role in both the credit boom and the credit bust.

In this model, all crises would appear to follow 'good' booms, in the terminology of Gorton and Ordoñez (2016). Indeed, all good booms run the risk of precipitating a crisis. The interbank market, and its lack of transparency, is the ultimate source of any serious instability. There is no role in the model for bank equity or secured lending. And since bank type is not verifiable, the model's implications for financial regulation are unclear. Nevertheless, the model is a significant step forward in modeling the role of credit intermediation.

The second contribution we focus on is Gertler, Kiyotaki and Prestipino, (2016). Building on the earlier contribution of Gertler and Kiyotaki (2010), the authors suggest that it is not the interbank market as such that is the problem. They argue that a combination of financial innovation and regulatory constraints on traditional banks has created a network of financial intermediaries that has increased the equilibrium level of leverage in the economy. Specifically, financial innovation has created specialist institutions with comparative advantages over traditional banks in certain forms of loan origination, securitization and funding. Given these skills, and the distortive impact of capital and other regulation on traditional banks (although none of these factors are modeled explicitly), an

[36] See Akerlof (1970)

increasing proportion of lending has migrated to the shadow banking/wholesale sector. And it was this sector that played a key role in the recent financial crisis. They argue that the freezing up of the interbank market was a defining characteristic of the crisis since, as in Boissay et al. (2016) and Brunnermeier and Sannikov (2014), it results in the economy operating in a highly inefficient way, unable to direct capital to its most efficient uses.

The model builds on the frameworks of Gertler and Kiyotaki (2010) and Gertler and Kiyotaki (2015)[37]. Private households may invest directly in nonfinancial firms or in retail or wholesale banks. It is costly to make such investments for all agents, but regulations applied to retail banks and not applied to wholesale banks, provide the latter with a competitive advantage at the margin. Similarly, retail banks have expertise not available to households, giving the latter an advantage over the former at the margin. The wholesale banks are set out such that they fund themselves optimally largely via the interbank market (that is, they hold few retail deposits). Consequently, the size of the wholesale banking market arises endogenously depending on two factors. First is the advantage that wholesale banks have over retail banks in managing assets and, second, the advantage of retail banks over households in overcoming an agency friction that impedes lending to wholesale banks. We first describe this model setting to one side the issue of bank runs, to which we return later.

The model is an endowment economy with a fixed amount of non-depreciating capital and a single non-durable good. There are three classes of agents: households, retail banks and wholesale banks. In principal, all agents may hold capital directly and invest their wealth in each of the other agents. The capital held is used to produce the non-durable good and to be carried over into next period to be used in goods production. The quantity of goods produced is stochastic as it depends on an aggregate technology (productivity) shock. The productivity of capital will also depend on which agent operates that capital.

Households consume and save. Their savings are in the form of bank deposits and direct capital holdings. If they hold capital directly, they need to pay an operating or "absorption" cost; it is costly for agents directly to hold capital, and increasingly so at the margin. In the absence of bank runs, bank deposits are one-period debt instruments, paying a non-contingent return. Each period households receive income from their capital holdings, their bank deposit portfolio, and they receive an endowment (attended by the aforementioned productivity shock).

[37]Gertler and Kiyotaki (2015) is a macroeconomic model of bank runs. See the discussion below.

As noted, there are two types of banks, retail and wholesale. They are identical but for their ability to absorb capital at the margin; wholesale banks face a zero marginal cost, whilst retail banks face a positive cost (that is nevertheless lower than households' cost). Both types of bank may raise funding from households and other banks and both may hold capital directly. Retail banks combine their own funds (retained earnings plus an initial endowment; there is no outside equity) with deposits from households and other banks.

As in Gertler and Kiyotaki (2010), there is an assumed moral hazard problem that limits banks' ability to raise funds. The banker may divert a fraction, θ, $(0 < \theta < 1)$ of nonfinancial loans funded via retail deposit or own funds. However, the banker is able to divert only $\theta\omega$ $(0 < \omega < 1)$ proportion of loans funded by interbank deposits. As before, bankers are assumed to possess superior monitoring skills, compared with households. There are also retail and wholesale funding markets. On the other hand, if the bank lends to other banks, the assumption is that such loans are easier to monitor and, as such, more difficult to divert. Given the incentives to divert and the ability and constraints on the lenders to the banks, the banks will choose to act honestly only if the following incentive constraints are respected:

$$V_t(\cdot) \geq \theta((Q_t + f^j)k_t^j - b_t^j + \omega b_t^j), \text{ for } b_t^j > 0;$$
$$V_t(\cdot) \geq \theta((Q_t + f^j)k_t^j + \gamma(-b_t^j)), \text{ for } b_t^j < 0.$$

Here, the value of the banking firm j $(j = r, w,\ r$ for retail bank, w for wholesale bank) is denoted by $V_t(\cdot)$. The non-financial loan book is funded in the amount $(Q_t + f^j)k_t^j - b_t^j$ by retail deposits and the bank's own net worth and by $b_t^j > 0$ in interbank borrowed funds. The first constraint is relevant to banks who borrow on the interbank market and the second to those who lend (in which case, $b_t^j < 0$). Q_t denotes the price of capital and f^j is the marginal cost of managing the loan book. For retail banks, $f^r > 0$, whilst for wholesale banks, $f^w = 0$. Finally, $0 < \gamma < 1$ so that $\theta\gamma$ reflects an assumption that bankers can divert only a fraction of its loans to other banks. Thus, whilst low monitoring costs $(f^w = 0)$ may encourage expansion of the wholesale banking sector at the expense of the retail sector, retail banks have a superior ability over households to monitor wholesale banks, who also face incentives to behave dishonestly. By appropriate choice of ω and γ Gertler et al. (2016) are able to generate what they argue is an empirically plausible amount of interbank lending whilst still having retail banks making non-financial loans.[38] In fact they are able to analyze equilibria where

[38]If there are multiple types of loans, and retail banks have a comparative advantage in

wholesale banks raise no funds from households, instead relying on own funds and interbank loans and where retail banks are able to increase their leverage by making interbank loans[39].

Figure 4 is a visual characterization of these new models, which attempts to relate them to the earlier core models in Figure 1. The idea is to show that interbank lending may complicate the process of deleveraging when that market also suffers from frictions as in Boissay et al. (2016) and Gertler et al. (2016). In the top section the banking sector acts to stabilise the economy; it channels funds towards profitable opportunities. However, when there are financial frictions (lower section) the fall in prices tightens constraints that banks face. That tightening can exacerbate the initial shock and jointly banks' creditworthiness suffers, impacting the wider economy.

[Figure 4 about here]

7.1. Equilibrium with bank runs

The possibility of non-linear dynamics in the Gertler et al. (2016) model comes from the possibility of bank runs in the model (either anticipated or unanticipated)[40]. The condition for a bank run is when the wholesale sector may not be able to repay its interbank creditors–more likely the higher is wholesale bank leverage (and so the lower is the resale value of capital); the higher the interbank borrowing rate; and the lower is aggregate productivity. If there is a run on the wholesale banking sector, there is in effect a firesale; wholesale banks liquidate

booking some of the these alternatives types, then it need not be the case that retail banks make loans solely because the wholesale sector has reached loan capacity.

[39]That is, whilst retail funding may be cheaper for wholesale banks, it is more heavily rationed than interbank funding. Wholesale banks are able to increase leverage by relying solely on interbank deposits. Nevertheless, interbank funding too is limited by the banks incentive to divert funds. Similarly, by making interbank loans, retail banks are able to attract more deposits and further increase leverage per unit of net wealth.

[40]For example anticipated runs unfold as follows: The authors assume that the conditional probability of a run is exogenously linked to the ratio of net assets to liabilities; the closer the wholesale bank is to not being able to meet its liabilities, the higher the perceived probability of a run. This assumption in effect attaches risk premia on loan rates to wholesale banks and can lead to a so-called 'slow run' where credit extended to the wholesale sector is incrementally tightened as the sector's solvency is increasingly called into question.

their portfolio which has to be absorbed by the retail banks and private agents, both of whom are less efficient at managing capital, as in Brunnermeier and Sannikov (2014). The wholesale sector then has slowly to rebuild itself as new banks enter the market.

The economy thus finds it difficult to re-equilibrate following a negative shock to productivity as retail banks and households face costs absorbing additional capital. These assumed costs make it increasingly costly at the margin for retail banks and households to absorb capital directly. In this way, agents with wealth but lack of expertise are constrained in their purchases of assets during a resale.

The lower the agency friction, ω, between retail banks and wholesale banks, the larger is equilibrium leverage. On the one hand, the lower is ω (the higher is financial innovation as Gertler et al. interpret it), the more stable is the economy, other things constant. That is because retail banks are in a better position to absorb asset sales of wholesale banks, stabilizing asset prices and reducing the financial accelerator effects. On the other hand, the lower is ω, the more likely are bank runs; financial efficiency entails higher equilibrium leverage and asset liquidation values are lower than they would be otherwise.

The financial accelerator mechanism is present here as in Gertler and Kiyotaki (2010) although the wholesale sector plays an especially significant part. Leverage amplifies the impact of the drop in aggregate productivity on bankers' net worth, resulting in a tightening of financial constraints, as credit spreads increase. As a result, wholesale banks sell off loans, pushing down on asset prices and pushing down bank net worth. The higher is wholesale bank leverage, the stronger this feedback typically is, forcing large scale liquidations of their assets and reducing their demand for interbank loans. As a result of this firesale, retail bankers increase their asset holdings and absorb, along with households, the capital which the wholesale banks place on the market. However, as retail banks and households are less efficient in intermediation, the firesale is costly; the cost of bank credit to nonfinancial borrowers rises and the drop in aggregate output is amplified.

As with Boissay et al. (2016), Gertler et al. (2016) is an innovative way to extend the core DSGE framework to incorporate credit intermediation. However, the policy implications of these models are, as yet, tentative. On the one hand, it remains the case that banks in these models have no equity capital, a major lever that, in practice, regulators may adjust to address the robustness of the banking sector. Also, the moral hazard due to bailouts and other banking support operations are difficult to assess. For example, Gertler et al. (2016) emphasize the excessive costs on the economy of wholesale banks liquidating their assets,

and which is especially costly in the presence of a bank run. They argue that the anticipation of ex post intervention by the central bank may help stabilize asset prices and reduce the risk of a bank run. Indeed leverage could actually decrease as anticipated intervention puts a floor under asset prices. However, the moral hazard implications of such actions, actual or anticipated, are unclear as it would seem that anticipated bailouts run the risk of increasing leverage and the frequency of bailouts. This is not studied in their model. Kareken and Wallace (1978) is a discussion of the potential risks.

8. Financial frictions: International dimensions

The notion that financial frictions may only bind periodically, has been an important theme in the international macroeconomics literature, particularly in the context of developing countries. Financial frictions are also prevalent in the international macro literature that focuses on sudden stops to capital inflows. Mendoza (2010) studies a small open economy with an exogenous interest rate and price of foreign input goods. There exists a collateral constraint limiting the value of outstanding intertemporal debt and intratemporal loans to cover working capital requirements (labour and intermediate inputs). Mendoza (2010) shows that for his model of an emerging economy, the collateral constraint is only occasionally binding. Similar to Brunnermeier and Sannikov (2014), most of the time, following shocks, it has little impact on the economy's dynamics. In part the constraints bind infrequently because of precautionary savings behaviour (as agents seek to avoid the effects of precipitous falls in consumption). Leverage build-ups are preceded by a period of strong growth. When the leverage constraint binds, there is a cessation of lending to the economy (a 'sudden stop') and a sharp contraction in the economy as the cost of borrowing rises and fire sales of capital tighten further the collateral constraint. The build up of risk in the economy is, in a sense, endogenous. That is, a crisis may be sparked by shocks that at lower leverage levels would be absorbed by agents, rather than by a sharp contraction in activity at a higher level of leverage. The role of financial frictions in the developing economy context is surveyed in more detail in Uribe and Schmitt-Grohé (2017).

9. Directions for future research

The literature on financial frictions remains an active and important area of research. There has been a great deal of progress since the financial crisis, both in

understanding the properties of that, and earlier, crises and in how to go about modeling crises in a DSGE environment.

However, there remains much that needs to be better understood around the historical record and the materiality of any inconsistencies across data sets and studies. And although much progress has been made in incorporating financial intermediation into workhorse DSGE models, some important features of the landscape are missing making policy prescriptions based on these models challenging.

For instance, an important omission in all models of banks and financial intermediaries in DSGE models is a theory of how easy it is for classes of final borrowers to switch sources of external finance during difficult economic times. The models reviewed above characterize a crisis as a period when the economy finds it hard to reallocate capital across agents and operate it efficiently. That behavior, however plausible, is essentially hardwired into these models. Clarifying the microfoundations of these difficulties seems important.

The models emerging of the banking sector in DSGE environments have not yet incorporated the outside equity of banks. The level of bank capital has been at the forefront of supervisory concern for many decades and capital regulation has now come under the purview of so-called macroprudential policymakers[41]. The efficiency and welfare implications of such policies, including the optimal form of these regulations, are as yet far from clear when viewed from the perspective of DSGE models.[42] Gertler et al. (2016) argue that the shadow banking sector is, in part, a response to other financial regulations. Understanding the interplay between financial intermediaries' corporate structures also appears to be an underexplored area.[43]

Finally, building and econometrically estimating medium-scale, non-linear DSGE models with financial intermediaries and incorporating the possibility of crisis events (e.g., bank runs, collapses in the interbank market) is a desirable goal for applied work. As things stand, the technical challenges appear substantial and such models may be some way off.

[41]See Duncan and Nolan (2015) for an analysis and critique of macroprudential policies. They analyze the UK macroprudential framework including the time-varying capital requirement powers.

[42]Jordà et al. (2017) is an historical study of bank capital and liquidity since the end of the nineteenth century across 17 advanced economies.

[43]Damjanovic et al. (2017) build a macroeconomic model with retail and investment banks to study the macroeconomic effects of rules such as Vickers and Volker have proposed.

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A. Figures

Figure A.1: Pecuniary externalities in financial frictions models

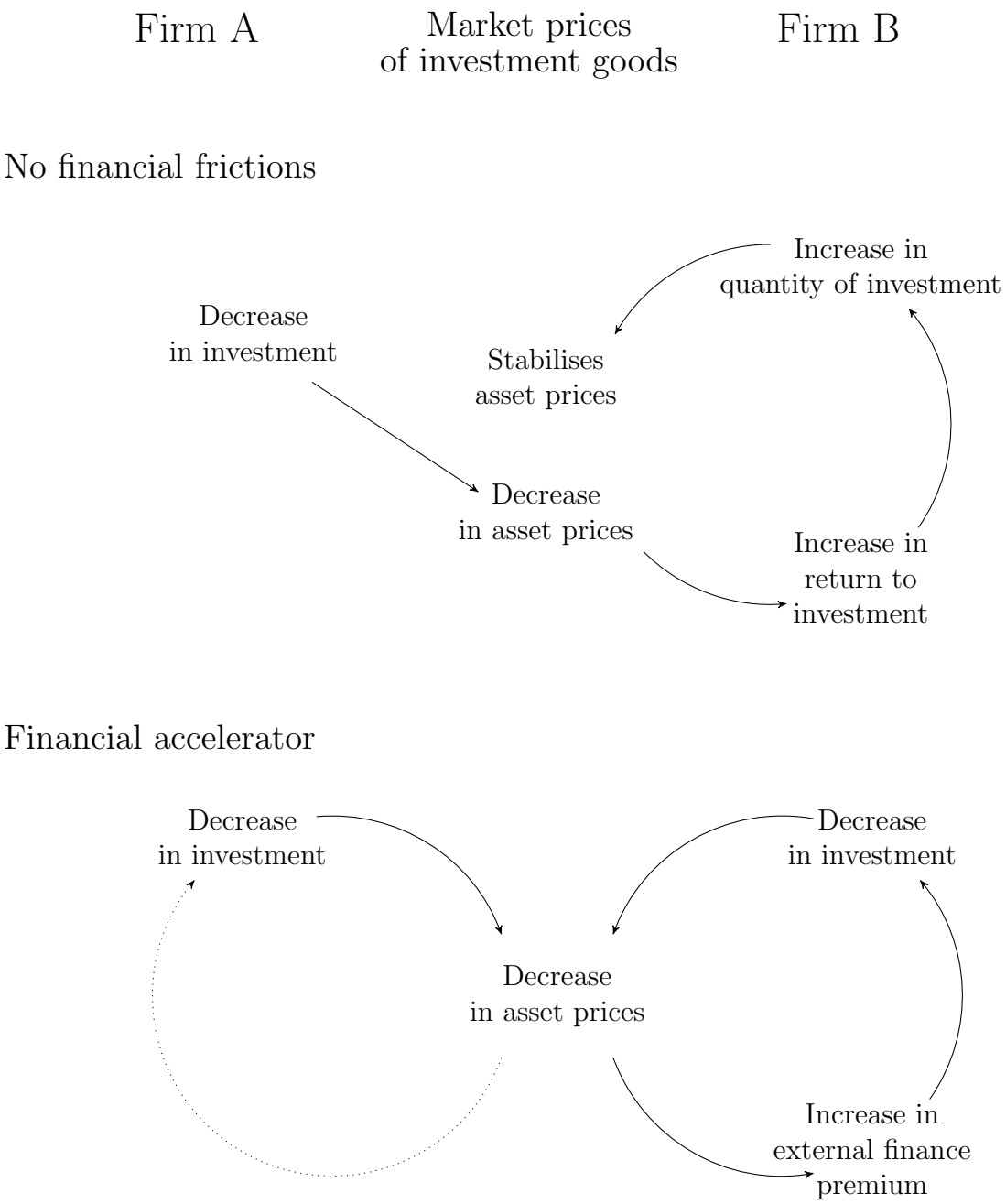
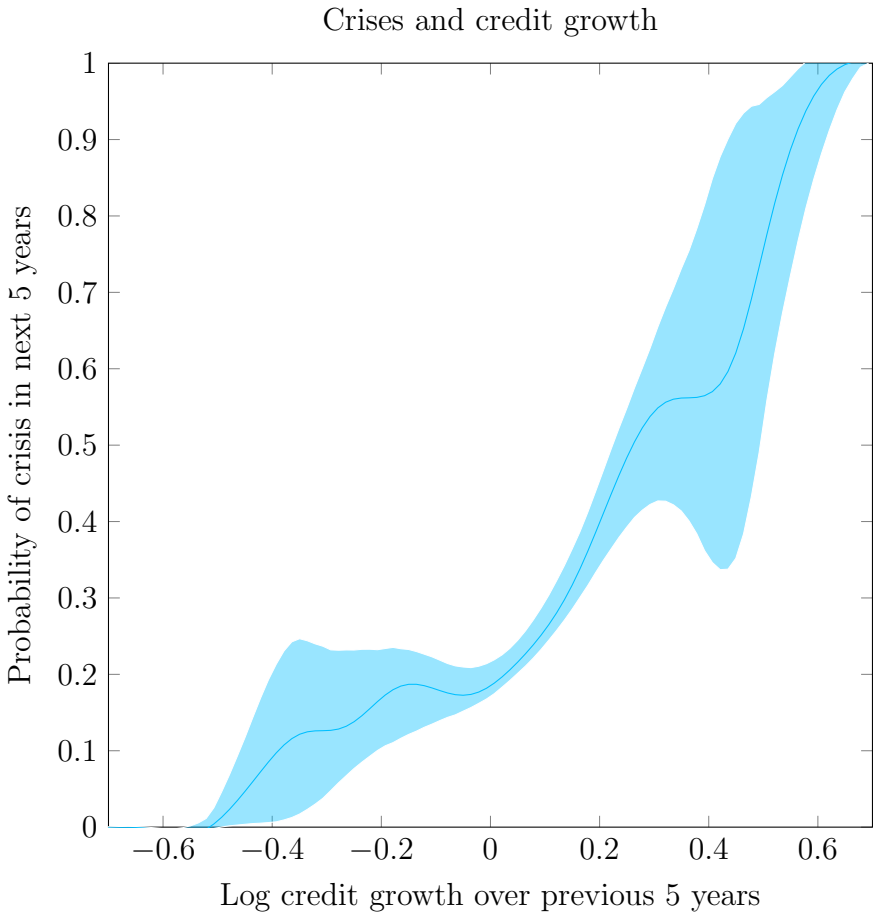
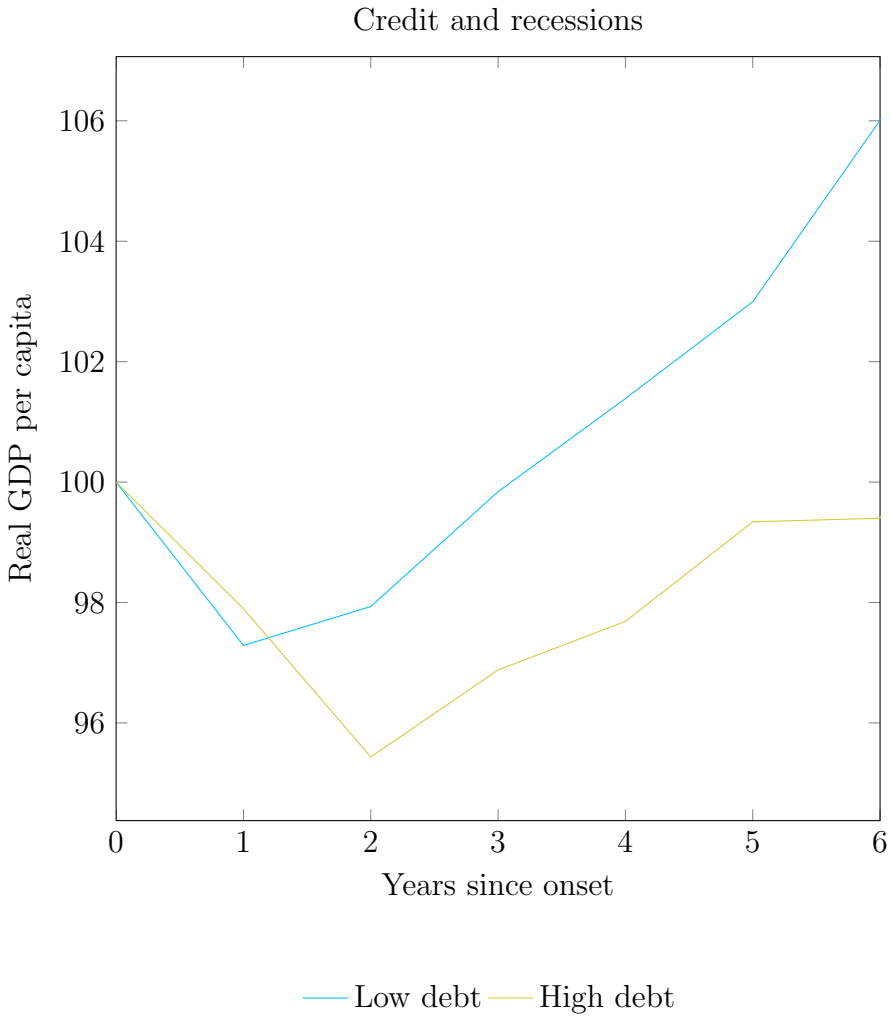


Figure A.2:



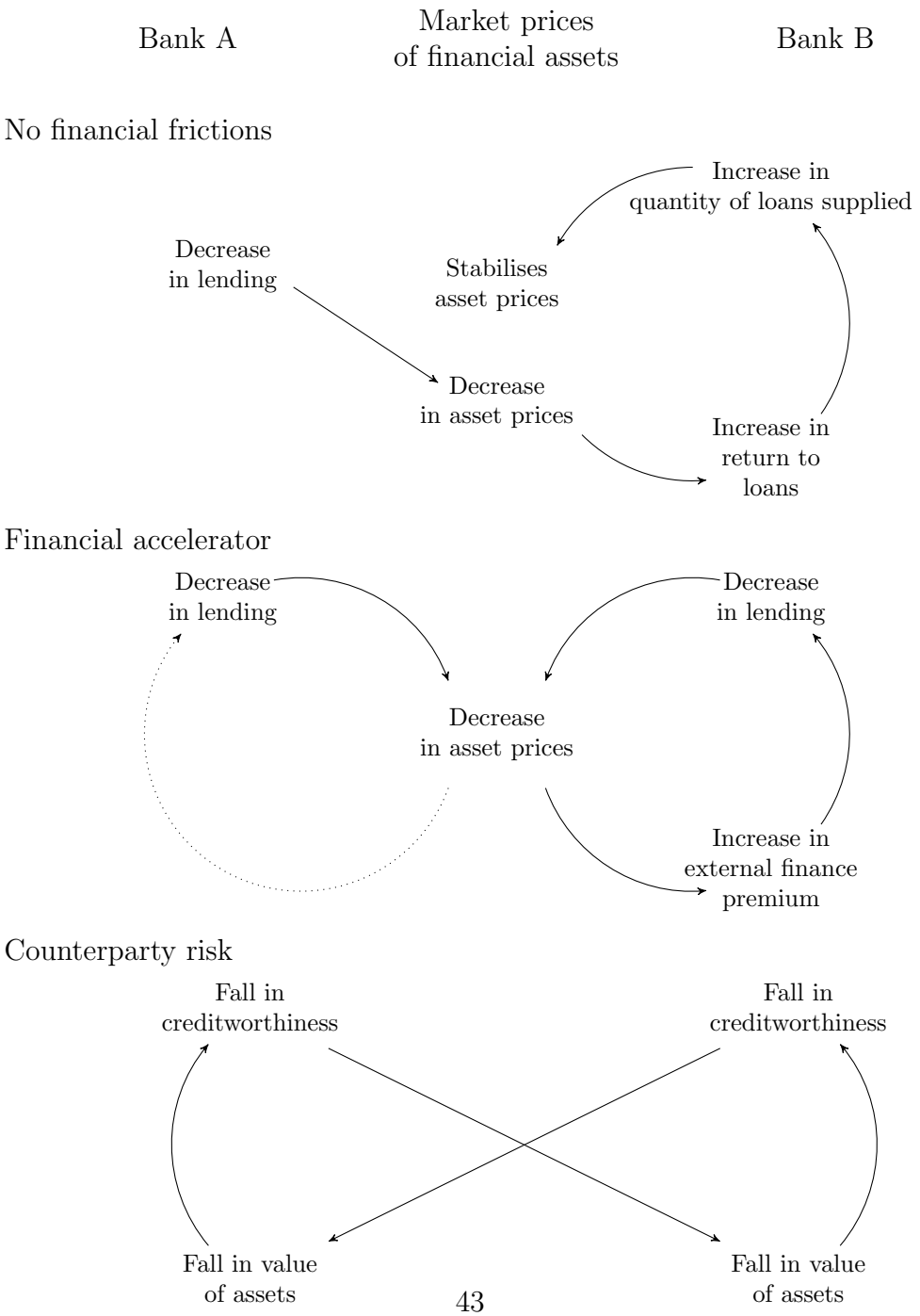
Source: This plot is constructed from the Jordà, Schularick, and Taylor (2016b) dataset of 17 countries with first observations in 1870, combined with authors' calculations. There are 90 crisis episodes identified by Jordà, Schularick, and Taylor (2016b) in the sample. Probabilities are estimated by unweighted local linear regression with shaded areas representing bootstrapped confidence intervals.

Figure A.3:



Source: This plot is constructed from the Jordà, Schularick, and Taylor (2016b) dataset of 17 countries with first observations in 1870, combined with authors' calculations. Series represent unweighted arithmetic averages over individual recession events, where for each event, Real GDP per capita has been normalised to 100 at the onset of the recession. Recessions represent any period of negative growth in real GDP per capita. Recessions are denoted as "High debt" when the ratio of credit to private sector nonfinancial firms over GDP exceeds 1 at the onset of the recession (n=16). All other recessions are denoted as "Low debt" (n=63).

Figure A.4: Extending financial frictions models to the banking sector



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