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Shadow banks and macroeconomic instability

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Roland Meeks
University of Essex and
Centre for Applied Macroeconomics Analysis

Benjamin Nelson
Monetary Assessment & Strategy Division
Bank of England

Piergiorgio Alessandri
Banca d'Italia

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Keywords

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Address for correspondence:

(E) cama.admin@anu.edu.au

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Roland Meeks*
University of Essex and
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*Corresponding author (email: rmeeks@essex.ac.uk; Nelson: benjamin.nelson@bankofengland.co.uk; Alessandri: piergiorgio.alessandri@bancaditalia.it). We would like to acknowledge helpful feedback received from Marnoch Aston, Arnoud Boot, Luca Dedola, Francesco Furlanetto, Liam Graham, Wouter den Haan, Richard Harrison, Bart Hobijn, Thomas Laubach, Stefan Niemann, Matthias Paustian, Lavan Mahedeva and seminar participants at the winter 2011 Bank of England-LSE macro workshop, Banque de France, Banca d'Italia, European Economic Association Meeting in Malaga, North American Summer Meeting of the Econometric Society at Northwestern University, the May 2012 meeting of the ESCB Macro-Prudential Research Network (MaRs) at the ECB, University of Essex, Norges Bank and Western University. We are particularly grateful to Niki Anderson for her feedback. The views expressed in this paper are those of the authors, and not necessarily those of the Bank of England or the Banca d'Italia.

1 Introduction

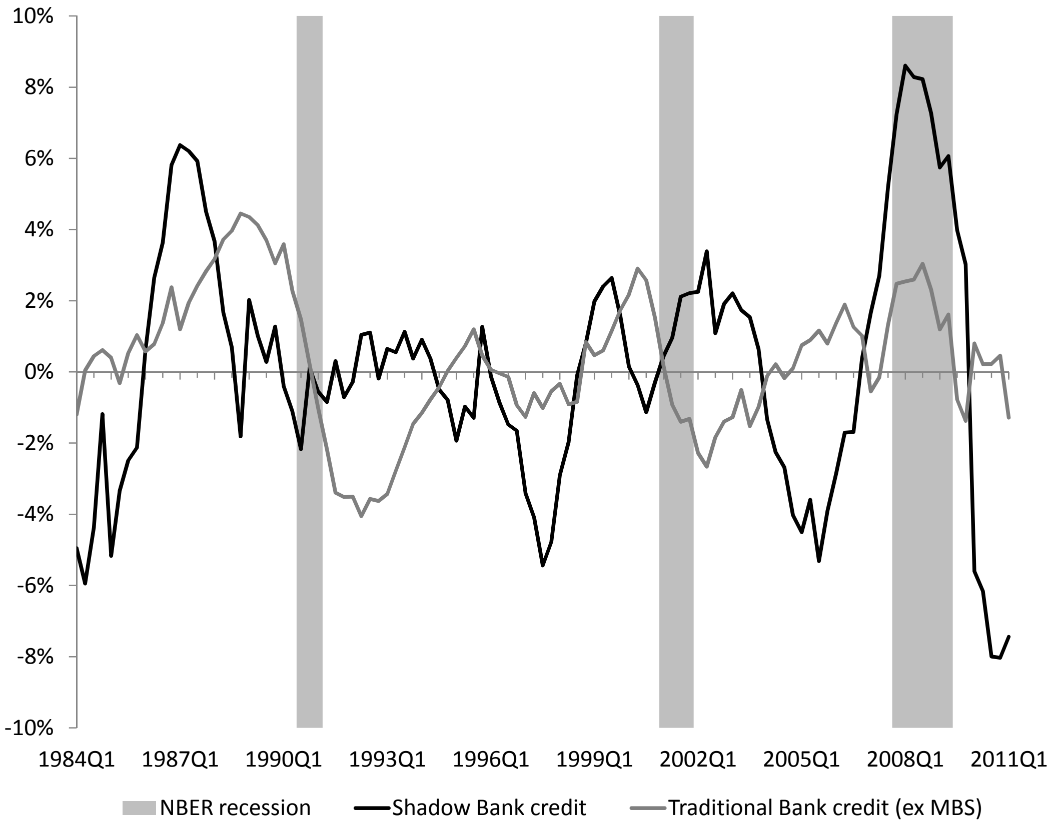
Between the early 1990s and the onset of the 2007-2009 subprime crisis, the financial system in the United States and elsewhere underwent a remarkable period of growth and evolution. Banking underwent a shift, away from the traditional 'commercial' activities of loan origination and deposit issuing towards a 'securitized banking' business model, in which loans were distributed to entities that came to be known as 'shadow' banks (Gorton and Metrick, 2012a).[1] As shadow banks came to replicate core functions of the traditional banking system, in particular those of credit and maturity transformation, they took on many of the same risks but with far less capital. An over-reliance on securitization, and the increased leverage of the financial system as a whole, ultimately contributed to financial instability, recession, and a substantial contraction in shadow banking activity.

The aggravating role played by flaws in the securitized banking model have been rightly emphasized in many accounts of the subprime crisis and ensuing great recession (Blinder, 2013). But there is also a need to understand the increasingly central role of securitization in credit provision over the decades prior to the crisis. To illustrate why, figure 1 shows the cyclical component of aggregate credit extended by banks and shadow banks from 1984 to 2011 in the United States. A striking pattern is that, especially between 1990 and 2007, periods when traditional bank credit underwent cyclical contraction were often periods when shadow bank credit expanded. In the same vein, den Haan and Sterk (2010, Table 1) documented that over the post-1984 period, consumer credit and mortgage assets held by commercial banks were positively correlated with GDP, while holdings outside the banking system were negatively correlated. Further, they showed that the two aggregates move in different directions following a monetary tightening. Similar evidence has been found in bank level data (Altunbas, Gambacorta and Marquez-Ibanez, 2009; Loutskina and Strahan, 2009). Figure 1 also shows the extent of the decline in shadow bank credit at the onset of the recession, and how, in contrast to the pre-2007 pattern, commercial bank credit contracted roughly in tandem with it.

The preceding observations suggest that macroeconomic models in which intermedi-

[1] The term 'shadow' banking has been used to refer to a diverse array of non-bank financial activities. For a comprehensive survey of shadow banking activities (some of which have by now disappeared), and the government programs that backstopped them during the financial crisis of 2007-2009, see Pozsar, Adrian, Ashcraft and Boesky (2010). Our focus will be on shadow banks engaged in the bank-like activities of credit transformation (issuing fixed obligations against risky assets) and maturity transformation (issuing short maturity obligations against long maturity assets) emphasized by Tucker (2010). By securitization we mean the issuance of tradeable securities against the collateral of an underlying pool of assets, including mortgages, consumer credit or business loans. The financial system we describe later in this paper resembles the securitized banking model in Gorton and Metrick.

Figure 1: Credit cycles in traditional and shadow banking



Note: Figure shows the percentage deviation from the HP trend for commercial and shadow bank credit aggregates taken from the United States Flow of Funds. We group U.S.-Chartered Commercial Banks, Savings Institutions and Credit Unions in the 'traditional bank' sector, and Security Brokers and Dealers, Issuers of Asset-Backed Securities, Agency- and GSE-Backed Mortgage Pools, and Government-Sponsored Enterprises in the 'shadow bank' sector. Between 1990Q1 and 2007Q2, the correlation between the series is -0.25. For complete details of data construction and sources, see Appendix D.

ated credit has a prominent role might provide an improved account of the behavior of credit in pre-2007 business cycles by explicitly allowing for heterogeneity and specialization in the functions of financial intermediaries. Furthermore, if an important impulse for the 2007-9 recession was a shock originating from within the financial system, as most observers believe, modeling the financial system in a more granular way is vital (Gertler, 2010).

In this paper, our main purpose is to construct a simple model that captures some of the key features of an economy in which traditional and shadow banks interact. We claim the following contributions. We develop a dynamic general equilibrium model featuring securitization and shadow banking, which aside from its treatment of the financial sector, closely resembles a standard macroeconomic model. We show that the ability of commercial banks to securitize can stabilize the overall supply of credit in the face of aggregate disturbances, but that risk-taking by the shadow banking system leads to an increase in macroeconomic volatility. We then give conditions under which the negative correlation between traditional and shadow bank credit seen in figure 1 come about, and quantify the additional credit dynamics resulting from the interaction between banks and shadow banks. Last, we argue that, in a securitization crisis, government policies targeted at the shadow banking system, such as purchases of asset backed securities (ABS), can have spillover effects on the rest of the financial system which weaken the effectiveness of interventions.[2] Together, these points are a first step towards addressing what are widely thought to be some important shortcomings of the generation of dynamic general equilibrium models used for research and policy analysis prior to the recent crisis (see for example the diagnosis in Woodford, 2010).

The main elements of the model we develop can be summarized as follows. There are two types of financial intermediary, each facing endogenous balance sheet constraints which depend on their net worth, as in standard models of the financial accelerator. Commercial banks purchase primary claims from firms ('loans'), the economy's ultimate borrowers. They optimally choose the amount of loans to retain on balance sheet, and the amount to sell to the shadow banking system. Shadow banks in turn fund their asset purchases by issuing claims against the pool of loans they acquire, in the form of asset-backed securities.

Securitization does not necessarily eliminate commercial banks' exposure to risk, however. Commercial banks actually have an incentive to invest in ABS, because securitized assets, which are tradeable and backed by pools of loans, are more pledgeable than the opaque and idiosyncratic loans they retain on balance sheet. By exchanging a direct exposure to the real economy for an intra-financial claim, commercial banks improve the quality of collateral on their balance sheets, which loosens their funding constraint, and enables them to increase their leverage and their profitability. In our economy, shadow banks can therefore be thought of as collateral manufacturers, who take the raw material of loans produced by commercial banks, and transform it into ABS.

[2]The term asset-backed security encompasses issues backed by pools of assets which can include residential or commercial mortgages, consumer loans, leases on major pieces of industrial equipment, and many other asset classes. As will become clear, in our model ABS is backed by claims on physical capital.

Although increased securitization activity expands the supply of real economy credit by broadening the available base of pledgeable assets, it also creates a vulnerability as the supply of ABS is itself governed by the strength of shadow bank balance sheets. In the face of an adverse aggregate shock, shadow bank net worth tends to contract in tandem with that of commercial banks, constraining the supply of collateral for the commercial banking system. The shortage of collateral leads to a tightening of commercial banks' financing constraint, causing them to delever, so further suppressing asset prices. The process by which constraints endogenously tighten on both banks and shadow banks can then lead real disturbances to be amplified.[3]

The reader should be aware of what we do not do in this paper. First, we do not attempt to model the process of financial innovation and regulatory change which lay behind the rapid expansion of shadow banking. Second, the crisis highlighted shortcomings both in the workings of key asset markets, and in regulation, which we largely ignore. For example, we do not model complex financial instruments based on securitized assets, such as collateralized debt obligations (CDOs), which the market badly mispriced (see Coval, Jurek and Stafford, 2009). Also, an important contributory factor behind the creation of some shadow banking entities, in particular structured investment vehicles (SIVs), was a desire by banks to reduce the amount of regulatory capital they held against credit exposures (see Brunnermeier, 2009; Pozsar et al., 2010). However, in our model there is no explicit regulatory motive behind the existence of shadow banks or the market for securitized assets. Allowing these factors to come into play would likely strengthen, rather than weaken, our main conclusions, but is beyond the scope of the current paper.

The remainder of this paper is organized as follows. We begin in section 2 with a brief review of related work. Section 3 outlines our baseline model, including the structure of the financial system, the behavior of commercial and shadow banks, and equilibrium in the asset backed securities market. Section 4 gives details on calibration, and the results of our main experiments. There, we discuss the responses of both macroeconomic aggregates, and of securitization activity, following aggregate and cross sectional shocks. In section 5 we go on to discuss the effects of a securitization crisis triggered by a decline in the liquidity of ABS, and the relative ineffectiveness of government intervention in the ABS market. Section 6 offers concluding comments.

[3] An equivalent story, which in our model is the flip side of the collateral supply story, is that shadow banks' reduced demand for the raw material of securitization makes it harder for commercial banks to move loans off balance sheet.

2 Related literature

The financial stability issues around shadow banking, and securitization in particular, have by now been widely discussed (Adrian and Shin, 2008). Until now, few papers have attempted to model shadow banking in a macroeconomic context. But there has been increasing concern with modeling the supply-side mechanisms governing credit growth, especially the role of financial intermediaries, rather than the borrower or demand-side mechanisms discussed in the classic Handbook contribution of Bernanke, Gertler and Gilchrist (1999).[4] Some recent examples include Gerali, Neri, Sessa and Signoretti (2010), Meh and Moran (2010) and Gertler and Karadi (2011). In these papers, the presence of a bank balance sheet channel is shown to improve the ability of a DSGE model to match the size and shape of the economy's response to shocks seen in the data. However, 'banks' are taken to represent the entire financial system. This paper allows for heterogeneity and specialization in the functions of intermediaries, generating an additional source of dynamics.

The most important point of comparison for our model is found in Gertler and Kiyotaki (2011). Gertler and Kiyotaki study the interbank lending market. In their model, banks are subject to idiosyncratic (locale-specific) liquidity shocks, but the interbank market allows for some (in the limit, perfect) sharing of cross-sectional risk. In the absence of a perfectly functioning interbank market, asset prices are not equalized across locales, and as a consequence the marginal supplier of real economy credit becomes more levered than average. This excess leverage amplifies the effect of shocks on real investment. A similar effect is present in our model, in that the high leverage of shadow banks magnifies the effect of shocks on their demand for loans from, and their supply of ABS collateral to, commercial banks.

In an extension, Gertler and Kiyotaki discuss the case where banks consists of a commercial branch, which faces a regulatory capital requirement, and an unregulated investment branch, which is subject to market discipline. Under the assumption of unified ownership, leverage is determined by a single financing constraint operating at the consolidated level. The authors note that the consolidated entity then behaves exactly like the commercial bank in their baseline model, resulting in no new macroeconomic implications. In this paper we dispense with the consolidated ownership assumption which, as anticipated by Gertler and Kiyotaki (p. 586), results in a rich set of novel

[4] A prominent approach, due to Holmström and Tirole (1997), allows both borrower and intermediary balance sheet condition to affect the aggregate amount of credit extended. The present paper focuses on intermediary balance sheets alone.

implications.

In common with the present paper, Shin (2009) emphasizes that credit supply is endogenous and depends, in particular, on the amount of equity in the intermediary sector as a whole. Shin, and Adrian and Shin (2008), employ a value-at-risk (VaR) constraint to induce intermediaries to use up slack balance sheet capacity in upswings. In their model, changes in risk have first order effects on intermediary behavior. The approximation methods we employ when we solve the model do not take account of the consequences of changes in risk or in risk premiums explicitly, although we recognize the potential importance of both.[5]

Our model shares with Gennaioli, Shleifer and Vishny (forthcoming) the feature that it is demand by outside investors for good collateral that drives banks to securitize. In their model, demand for safe assets is a consequence of investor risk intolerance (utility depends on worst-case consumption levels). Banks securitize their low-quality assets because, by appropriate tranching, they can pledge a portion of the otherwise risky cash flows to investors. In our model and theirs, securitization allows the financial system to pledge a greater proportion of the cash flows from underlying assets to investors, and facilitates increased credit supply to the economy's ultimate borrowers. And in both cases, securitization allows gross financial-sector leverage to increase. However, our treatment rests on fewer special assumptions than does theirs, and as such arguably makes cross-model comparisons more transparent.

There are a small number of papers which, like ours, seek to examine the effects of either securitization or shadow banking in a general equilibrium setting. Verona, Martins and Drumond (2011) introduce a distinct class of financial intermediary labeled shadow banks into a sticky price DSGE model to study the effect of low interest rates on the financial sector. However, there are few similarities between their treatment of shadow banking and ours. Their model does not feature securitization, and shadow banks have no direct interaction with the commercial banking system. Goodhart, Kashyap, Tsomocos and Vardoulakis (2012) study a variety of regulatory policies in a two period general equilibrium model with heterogeneous households, banks and shadow banks. The authors generate a role for shadow banking by assuming lower risk aversion amongst non-banks than amongst banks, and financial constraints bind when default costs erode institutions' exogenous endowments of equity capital. The paper shows how a fire sale dynamic can arise with knock-on effects that further tighten financial constraints. Later, we discuss

[5]Gertler, Kiyotaki and Queralto (2012) employ higher order perturbation methods around their model's stochastic steady state to generate a role for risk in determining balance sheet structure.

how very similar effects arise in our model. Finally, in Hobijn and Ravenna (2010) an adverse selection problem is introduced into a New Keynesian monetary policy model. The asymmetric information held by borrowers leads to an endogenous sorting of loans into those directly held by originators, and those sold into securitization pools of differing qualities. Although their model gives a relatively detailed account of securitization, the health of intermediary balance sheets plays no particular role.

3 The baseline model

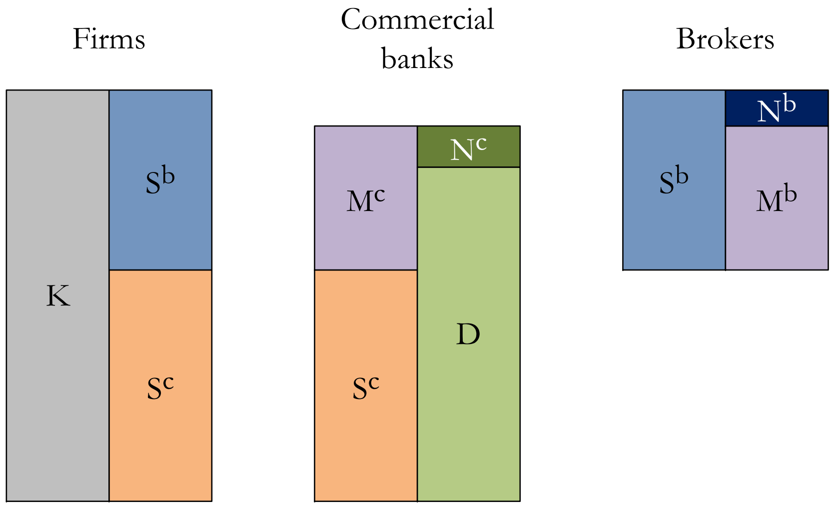
The model we employ is a basic real business cycle model, augmented with a set of real frictions intended to aid comparability with recent quantitative macroeconomic models. Our analysis rests on four key assumptions. The first two are familiar from other recent work on financial intermediation, such as Gertler and Kiyotaki (2011). The third and fourth are specific to our model of shadow banking.

First, because of an inability to enforce contracts, or an inability to verify cash flows, households do not lend directly to firms, the economy's ultimate borrowers. As a consequence financial institutions, which are able to perfectly enforce payment from firms, have a vital role in intermediating funds from the economy's ultimate lenders to ultimate borrowers. Second, financial institutions are unable to completely pledge the assets they hold on their balance sheets as collateral to raise funds from outside investors. This means that creditors limit the extent of their funding for banks, and bankers are able to extract rents, in the form of incentive payments, which drive a wedge between the returns earned by savers, and the costs incurred by borrowers. Third, we assume that the shadow banking system is economically valuable because, by transforming illiquid loans into tradeable assets, securitization allows collateral to be used more efficiently.[6] Finally, and in line with much actual experience, we assume that commercial banks transfer aggregate risk to the shadow banking system (such transfers may be complete or partial), but risk is not transferred to unlevered investors outside of the intermediary sector. Shin's 'hot potato' remains inside the financial system (Shin, 2009).[7]

[6] By assumption, securitization augments net aggregate liquidity, since all proceeds are effectively recycled into real investments, see Holmström and Tirole (2011). Pozsar et al. (2010) detail economic drivers, such as gains from specialization and comparative cost advantages over traditional banks, behind growth in shadow banking. They also identify forms of shadow banking that had little economic value and which were driven primarily by regulatory arbitrage.

[7] Our characterization of systematic risk being retained in the financial system was more true for some types of shadow banking activity than others. For example, Acharya, Schnabl and Suarez (forthcoming) present evidence that risk from conduits funded by asset-backed commercial paper remained with banks, rather than being borne by outside investors, during the 2007-2009 crisis. But as is well known, many 'real money' investors also lost money on securitization-related securities.

Figure 2: Aggregate balance sheet positions of firms, banks and brokers



Note: A stylized representation of sectoral balance sheets in the steady state equilibrium. For each sector: height of LH column represents assets; height of RH column represents liabilities. Shaded areas are of equal height. Key: K - aggregate physical capital; S - primary securities (bank loans); N - aggregate net worth; M - aggregate asset-backed securities; D - aggregate commercial bank deposits. A superscript c denotes commercial bank; a superscript b denotes a broker, or shadow bank.

The remainder of this section details the behavior of each of the five types of agent in our model: banks and shadow banks, which we will also refer to as 'brokers' for short, households, good-producing firms and capital-producing firms.

3.1 The financial system

The financial system is comprised of two types of financial intermediary, commercial banks and shadow banks. As is explained in this section, the distinction between a bank and a shadow bank lies in the separate economic roles that each play in the model. Whereas banks specialize in originating loans, brokers have a comparative advantage in holding them. To fund itself, the shadow banking system produces ABS, which in turn find a market amongst commercial banks eager to expand their balance sheets by acquiring high quality collateral. Crucially, both banks and brokers face financial constraints. The economic separation we introduce between banks and brokers mirrors institutional arrangements that restrict transactions between depository institutions and affiliates, such as brokerage firms, under the Federal Reserve Act in the United States.[8]

[8] In particular, that depository institutions may not use deposits to fund broker subsidiaries, see Section 23A and 23B of the Act.

A stylized picture of the aggregate steady state balance sheets of the principal actors in the financial system is given in figure 2. Firms are the economy's ultimate borrowers. They are able to finance their holdings of capital K by selling a single type of primary claim S, which we think of as a loan, to the commercial banking system. Commercial banks hold a portion of the total loan stock S^c on their balance sheet. As in the traditional commercial banking model, they finance themselves through a combination of inside equity N^c, and a single class of debt D held by households. However, in our economy commercial banks are able to use a secondary loan market to move some of the loans that they originate off their balance sheets. The loan pools S^b that result from loan sales by commercial banks are held by brokers. Brokers finance themselves with inside equity N^b and through issuing asset backed securities M^b, which in turn are held by commercial banks. The balance sheet relations hold as identities for each sector, and in equilibrium, the value of each sector's assets is matched exactly by the value of the other sectors' liabilities.[9]

3.1.1 Risk sharing and risk taking securitization

Shadow banks in our model retain the 'equity' or 'first loss' tranche of securitizations (the net worth component of shadow bank liabilities in figure 2). But the distribution of the remaining aggregate risk amongst shadow banks and investors in ABS depends crucially on the type of liabilities that shadow banks issue. We allow for two possibilities. First, asset backed securities may offer 'pass-through' exposure to an underlying collateral pool.[10] As well as being the simplest form of securitization, pass-through has historically been the predominant mode of financing for large classes of securitized assets, such as mortgages, in the United States. In the pass-through case, the returns on ABS are contingent on the cash flows on the underlying loan pools, and aggregate risk is shared between investors in ABS and shadow banks. We refer to this as the 'risk sharing' model of shadow banking.

The second possibility is that ABS represent fixed (non-contingent) claims. Some argue that the financial sector's drive to produce apparently safe debt-like securities in the run-up to the subprime crisis hinged on strong portfolio preferences for such assets by large institutional cash pools (Pozsar, 2011; Gorton and Metrick, 2012b) and by foreign creditors (Bernanke, 2011). Others argue that regulation provided the incentive

[9]Ours is a simplified version of the financial sector accounting framework presented by Shin (2009).

[10]The key features of pass-through securitization are that the underlying assets are transferred off the balance sheet of the originator, and investors have a claim on the cash flows from the pool, after servicing fees.

for commercial banks to hold highly-rated securitized assets rather than loans by offering capital relief on the former, so-called regulatory arbitrage (Acharya and Richardson, 2009). The idea of shadow banks taking on 'bank like' risk, in the sense that they perform both credit and maturity transformation, is formalized by having brokers issue one-period discount bonds that promise a fixed return. We refer to this as the 'risk taking' model of shadow banking.

In what follows, we allow shadow banks to issue both pass-through and debt-like ABS, and study how their relative portfolio weight affects the behaviour of the economy. The composition of the ABS portfolio turns out to be a crucial determinant of both the relative volatility of bank and shadow bank credit, and the comovement between them.

3.1.2 Commercial banks

The economy is populated by many competitive commercial banks, which are owned and managed by household members called bankers. By virtue of their ability to costlessly enforce repayments by borrowers, bankers alone originate loans. However, banks also face an agency problem that means they cannot pledge the entire value of their investments to creditors. As a result, the amount of external funding that a bank is able to raise is limited. A shortage of pledgeable income is the source of financial frictions in the economy. Following Gertler and Karadi (2011), and Gertler and Kiyotaki (2011), we make a set of assumptions to ensure financial constraints bind in equilibrium, and to facilitate aggregation.

As well as originating loans, banks can bundle loans together and sell them in a secondary market. Bundling is valuable because it helps banks to overcome an adverse selection problem when they come to sell the loans. Suppose the relationship between the primary lender and the borrower is such that private information on loan quality is unavoidably produced. This private information cannot be credibly communicated to outsiders. In such a case, no secondary creditor is willing to purchase an individual claim in the secondary market, as they will suspect that only the least sound claims will be sold. By destroying private information, bundling assures a secondary creditor that the loans she is purchasing are a 'fair mix, not just lemons'.[11] In our case, secondary creditors are shadow banks; their loan purchase decisions are discussed below.

[11]See Kiyotaki and Moore, 2005, p. 705; the idea that the purpose of bundling is to destroy private information is also found in DeMarzo (2005). In general, private information may exist on either the side of the seller or of the buyer. DeMarzo considers the case of sellers who specialize in originating and marketing assets, but do not have a comparative advantage in valuing or holding them. Pooling reduces the ability of sophisticated buyers, such as specialist brokers, to cherry-pick assets. As we abstract from idiosyncratic risk, the bundling technology itself is trivial.

Commercial banks use the cash raised from loan sales to acquire ABS issued by shadow banks. Their asset portfolio therefore consists of a mix of loans and ABS, and is financed by one period external debt ('deposits') and inside equity.[12] The balance sheet identity of an individual commercial bank (mnemonic c) at the end of period t is given by:

$$Q_t s_t^c + m_t^c = d_t + n_t^c \tag{1}$$

where

$$m_t^c := q_t m_t^{\mathrm{PT},c} + m_t^{\mathrm{D},c}$$

is the total value of the portfolio of pass-through (PT) and debt-like (D) ABS held by the bank; q_t is the market price of pass-through ABS; Q_t is the price of a primary claim on a firm; and other lower-case symbols represent the individual-level counterparts to the aggregate amounts described above.[13] Note that in general, q_t is different from Q_t, since ABS investors are partly protected by shadow bank equity.

A bank's end of period net worth is determined by the accumulation of its retained earnings.[14] Its earnings are generated from the interest rate spread it can earn on its assets, compared to its liabilities (equity is held internally, so carries no charge):

$$\begin{aligned} n_t^c &= R_{st} Q_{t-1} s_{t-1}^c + R_{mt}^{\mathrm{PT}} q_{t-1} m_{t-1}^{\mathrm{PT},c} + R_{mt}^{\mathrm{D}} m_{t-1}^{\mathrm{D},c} - R_t d_{t-1} \\ &= R_{st} Q_{t-1} s_{t-1}^c + \left[\eta_{t-1}^c R_{mt}^{\mathrm{PT}} + (1-\eta_{t-1}^c) R_{mt}^{\mathrm{D}}\right] m_{t-1}^c - R_t d_{t-1} \end{aligned}$$

where $\eta_t^c := q_t m_t^{\mathrm{PT},c} / m_t^c$ is defined as the share of pass-through ABS in the bank's portfolio, the returns on loans is R_{st}, the deposit rate is R_t, $R_{m,t+1}^{\mathrm{PT}}$ is the return on pass-through ABS and $R_{m,t+1}^{\mathrm{D}}$ is the return on debt-like ABS. It follows that the return on the bank's portfolio of asset-backed securities is:[15]

$$R_{mt} = \eta_t^c R_{mt}^{\mathrm{PT}} + (1-\eta_t^c) R_{mt}^{\mathrm{D}} \tag{2}$$

and so using this, along with the balance sheet identity (1) to substitute out ABS holdings, the law of motion for the net worth of a commercial bank becomes:

$$n_t^c = (R_{st} - R_{mt}) Q_{t-1} s_{t-1}^c + (R_{mt} - R_t)\, d_{t-1} + R_{mt} n_{t-1}^c. \tag{3}$$

[12] It is best to think of banks issuing deposits to households other than their home household, and purchasing ABS from shadow banks other than those owned by their home household.

[13] Note that balance sheets are always valued at market prices, or 'marked to market'.

[14] As the bank does not raise new equity or make payouts except upon entry and exit (respectively), its net worth moves only sluggishly. This is in line with evidence presented by Adrian and Shin (2010) that growth in the balance sheets of large market-based banks in particular has historically been associated with growth in leverage.

[15] In a slight abuse of notation, we omit the c superscript from R_{mt}; it is plain enough that the returns earned by commercial banks on ABS assets, and those paid by shadow banks on ABS liabilities, must be equated.

A commercial bank's going concern value is the present discounted value of its net worth. Because bankers are members of households, and households are symmetric, risky cash flows to be received between any future dates $\{\tau_1, \tau_2\}$ are discounted by the representative household's stochastic discount factor Λ_{τ_1,τ_2}. We employ a standard device to ensure that banks remain credit constrained. Each period, bankers are replaced by new management with exogenous probability $1-\sigma$, and remain in place with probability σ. Since banks face credit constraints, it is optimal for bankers to defer payouts for as long as possible, that is, until they receive an exit signal. If bankers receive an exit signal, it is at the start of the period, after any aggregate shocks are realized. Upon exit they repay depositors, and pay out the residual net worth of the bank to the home household. The value of the bank at the end of period $t-1$ is then given by:

$$V_{t-1}^c = \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n_t^c + \sigma V_t^c\right]. \tag{4}$$

Bankers face an endogenous limit on the amount of external finance made available by creditors. As in Gertler and Karadi (2011), and Gertler and Kiyotaki (2011), we assume that between adjacent time periods the banker has an opportunity to transfer (synonymously, 'divert') a fraction of the assets under his or her control to the home household.[16] Incentive compatibility requires that the going concern value of the enterprise should exceed the value of divertible assets, which we take to be a weighted fraction of the bank's end of period balance sheet value. Our key assumption is that creditors regard on balance sheet loans as less good collateral than asset backed securities. To formally capture this idea, we allow portfolios of asset-backed securities to carry a lower weight in the incentive constraint than loans:

$$V_t^c \geq \theta_c(Q_t s_t^c + [1-\omega_c]m_t^c) \tag{5}$$

where $\{\theta_c, \omega_c\} \in [0,1]$, and ABS becomes perfectly pledgeable as $\omega_c \to 1$. The effect of switching a marginal unit of funds from loans into ABS is to reduce divertible assets by $\theta_c\omega_c$, loosening the bank's external finance constraint. In the absence of strong reasons to think otherwise, we take pass-through and debt-like ABS to be equally divertible, and so as they carry equal weight in (5), the mix between loans and total ABS pins down the amount of divertible assets.

The motivation behind (5) is that whereas loans held by banks are opaque and idiosyncratic, ABS are standardized, tradeable and backed by broad pools of collateral. A suggestive piece of supporting evidence for the proposition that banks demand ABS for

[16]This reduced form model can be derived from a variety of underlying micro-foundations, including the classic moral hazard problem of Holmström and Tirole (1997); see Holmström and Tirole (2011).

its collateral value comes from the change in bankruptcy provisions discussed in Perotti (2010). Between 1998 and 2005, a series of amendments to bankruptcy laws in the United States and European Union led to exemptions from bankruptcy stays for all secured financial credit used in repurchase agreements. This change greatly enhanced the value of such assets as collateral to banks wishing to raise short term secured funding, and banks' holdings of securitized assets boomed.[17]

The banker's objective is to maximize the value of the enterprise (4) subject to the incentive constraint (5) through choice of asset portfolio $\{Q_t s_t^c, m_t^c, \eta_t^c\}$. The commercial bank's value function is linear in $\{v_{st}^c, v_{mt}^{\mathrm{PT},c}, v_{mt}^{\mathrm{D},c}, v_t^c\}$, which give the marginal value of each balance sheet item at each point in time. Defining the excess value of loans over each type of ABS as $\mu_{st}^c := (v_{st}^c/Q_t - v_{mt}^{\mathrm{D},c})$ and $\mu_{mt}^c := (v_{mt}^{\mathrm{PT},c}/q_t - v_{mt}^{\mathrm{D},c})$ respectively, we may write the value function as:

$$V_t^c = \left[\mu_{st}^c - \eta_t^c \mu_{mt}^c\right] Q_t s_t^c + \left[(v_{mt}^{\mathrm{D},c} - v_t^c) + \eta_t^c \mu_{mt}^c\right] d_t + \left[\mu_{mt}^c \eta_t^c + v_{mt}^{\mathrm{D},c}\right] n_t^c \tag{6}$$

Let λ_t^c be the multiplier on the constraint (5). The first order necessary conditions for optimal $\{s_t^c, \eta_t^c, d_t, \lambda_t^c\}$ are:

$$\mu_{st}^c - \eta_t^c \mu_{mt}^c = \theta_c \omega_c \frac{\lambda_t^c}{1+\lambda_t^c} \tag{7a}$$

$$0 = \mu_{mt}^c (1+\lambda_t^c)(Q_t s_t^c + d_t + n_t^c) \tag{7b}$$

$$v_{mt}^{\mathrm{D},c} - v_t^c = \theta_c (1-\omega_c) \frac{\lambda_t^c}{1+\lambda_t^c} \tag{7c}$$

$$\begin{aligned} 0 = {} & (\mu_{st}^c - \eta_t^c \mu_{mt}^c - \theta_c \omega_c) Q_t s_t^c + (v_{mt}^{\mathrm{D},c} - v_t^c + \eta_t^c \mu_{mt}^c - \theta_c [1-\omega_c])\, d_t \\ & + (v_{mt}^{\mathrm{D},c} + \eta_t^c \mu_{mt}^c - \theta_c [1-\omega_c]) n_t^c \end{aligned} \tag{7d}$$

at an interior optima.

It is immediate from (7b) that $\mu_{mt}^c = 0$, as the terms in parentheses are strictly positive. Intuitively, as pass-though and debt-like ABS are equally liquid, their marginal values are also equal. With this in mind, we may then combine (1) and (7d), using (7a) and (7c) to eliminate terms, to yield the bank's ABS demand function:

$$m_t^c = \frac{1}{\omega_c} d_t - \left\{ \frac{v_{st}^c / Q_t - \theta_c}{\theta_c \omega_c - \mu_{st}^c} \right\} n_t^c \tag{8}$$

[17] According to the Flow of Funds of the United States, commercial bank holdings of all types of MBS (mortgage-backed securities) doubled from $600 billion in 1998 to more than $1.3 trillion in 2005. Note that the exemptions for Treasury and GSE securities predate the wider secured financial credit exemptions discussed here. A downside to these legal changes noted by Perotti is that strong creditor protection weakens monitoring incentives, and facilitates risk shifting.

Away from corners, the demand for ABS is decreasing in net worth and increasing in deposits. Dividing (8) through by total funding $d_t + n_t^c$, we see that a higher proportion of equity funding increases the capacity of the bank to hold loans on balance sheet, and so reduces its desire to hold ABS. On the other hand, a higher share of debt funding tightens the bank's incentive constraint, so it seeks out pledgeable collateral.

As the shadow value of net worth is of particular importance, let us provide some intuition for it. The Lagrange multiplier on the incentive constraint in the static maximization of (6) subject to (5) is

$$\lambda_t^c = \frac{\mu_{st}^c}{\theta_c \omega_c - \mu_{st}^c} \tag{9}$$

at interior optima. The multiplier indicates the effect of relaxing the constraint by a marginal unit. Every dollar can be leveraged into additional loans of $1/(\theta_c \omega_c - \mu_{st}^c) > 1$ dollars, which raises firm value by μ_{st}^c per unit. The multiplier therefore tells us the relative attractiveness of direct versus indirect asset holdings. When the multiplier is large, we are being told that on balance sheet loans are relatively much more valuable than securitized loans, but that the bank is unable to hold more loans without violating the incentive constraint.

To understand the shadow value of an additional unit of net worth, notice first that the marginal unit relaxes the incentive constraint of the bank by $v_{st}^c/Q_t - \theta_c$. (As net worth enters both the objective and constraint functions, a unit increase does not translate into a unit relaxation of the constraint). The banker will exit and consume her net worth with probability $(1-\sigma)$. She will continue with probability σ, in which case an additional dollar of net worth directly raises the value of the bank by v_{st}^c/Q_t (since internal equity carries no charge). By relaxing the constraint, the extra net worth also permits a leveraged increase in loans that raises the bank's going concern value by λ_t^c. The sum of these effects equals the expected value of a unit of bank net worth at the end of period t:

$$\Omega_t^c := (1 - \sigma) + \sigma\{v_{st}^c/Q_t + \lambda_t^c(v_{st}^c/Q_t - \theta_c)\}. \tag{10}$$

Finally, by substituting (7a)-(7d) into the commercial bank Bellman equation, the time-varying coefficients in (6) can be found to be discounted expected returns on loans, the two types of ABS and deposits:

$$\mu_{st}^c = \mathrm{E}_t \Lambda_{t,t+1} \Omega_{t+1}^c \left(R_{s,t+1} - R_{m,t+1}\right) \tag{11a}$$

$$\mu_{mt}^c = \mathrm{E}_t \Lambda_{t,t+1} \Omega_{t+1}^c (R_{m,t+1}^{\mathrm{PT}} - R_{m,t+1}^{\mathrm{D}}) \tag{11b}$$

$$v_t^c = \mathrm{E}_t \Lambda_{t,t+1} \Omega_{t+1}^c R_{t+1} \tag{11c}$$

$$v_{mt}^{\mathrm{D},c} = \mathrm{E}_t \Lambda_{t,t+1} \Omega_{t+1}^c R_{m,t+1}^{\mathrm{D}} \tag{11d}$$

where the discount factor is seen to depend on Ω^c_{t+1}, the tightness of the bank's incentive constraint (see Appendix A for a statement of the solution method).

3.1.3 Shadow Banks

There are many competitive shadow banks or 'brokerage' firms, each owned and managed by household members called brokers. They hold loan pools comprised of primary security bundles acquired from many originating commercial banks (other than the banks owned by their home household), financed by a combination of inside equity and ABS. In our model, securitized assets are held within the financial system, rather than being distributed to unlevered investors (households, in our model). As a result, aggregate risk is concentrated on the balance sheets of financial intermediaries. This idea is also present in the model of Gennaioli et al. (forthcoming), and the mechanisms by which financial institutions effected such concentration in the build up to the subprime crisis are discussed in Acharya and Schnabl (2009). However, we will also be interested in how risk is distributed between commercial and shadow banks, as discussed in section 3.1.1.

The balance sheet identity of an individual broker (mnemonic b) at the end of period t is given by:

$$Q_t s^b_t = m^b_t + n^b_t \tag{12}$$

where $m^b_t := q_t m^{\mathrm{PT},b}_t + m^{\mathrm{D},b}_t$ is the value of outstanding ABS in issue. A broker's internal equity is the accumulation of earnings retained from their securitization activities:

$$\begin{aligned} n^b_t &= R_{st} Q_{t-1} s^b_{t-1} - R^{\mathrm{PT}}_{mt} q_{t-1} m^{\mathrm{PT},b}_{t-1} - R^{\mathrm{D}}_{mt} m^{\mathrm{D},b}_{t-1} \\ &= (R_{st} - R_{mt}) m^b_{t-1} + R_{st} n^b_{t-1} \end{aligned} \tag{13}$$

with $R_m := \eta^b_t R^{\mathrm{PT}}_{mt} + (1-\eta^b_t) R^{\mathrm{D}}_{mt}$ analogous to equation (2). We take securitization to be 'frictionless' in the sense that loan bundles may move freely in and out of securitization pools. As a consequence, the prices of primary and secondary market loans are equalized.[18]

Brokers face the same random probability $1-\sigma$ of being replaced by new management as do banks. As banks and brokers have identical exit rates and ownership structure, there are no differences between institutions because of impatience or risk aversion. The going

[18] This assumption can be relaxed by introducing a bundling friction along the lines of Kiyotaki and Moore (2005). Formally, this is achieved by having a class of agents who purchase loans from banks, bundle them using a costly technology, and sell the bundles on to brokers in a competitive market. A wedge is then introduced between the price of an on balance sheet loan, and the price of a secondary market loan. However, the main dynamics of the model are little affected by introducing this friction so we omit it in the interests of parsimony.

concern value of the shadow bank is therefore:

$$V_{t-1}^b = \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n_t^b + \sigma V_t^b\right].$$

As with commercial banks, brokers are able to transfer a fraction of assets under their control to the home household, which gives rise to an endogenous financing constraint. The main point of departure is that whereas commercial bank creditors are households, broker creditors are themselves financial institutions. It is reasonable to suppose that banks possess superior ability to monitor the quality of collateral held by brokers, and that the diversification inherent in creating a securitization pool itself enhances the pledgeability of broker balance sheets.[19] Both considerations lead to the presumption that the fraction of divertible assets be no higher for brokers than it is for banks. Shadow banks may then be regarded as the natural holders of bundled assets.

The broker's incentive constraint says that the going concern value of the enterprise should exceed a fraction θ_b of the value of the balance sheet the broker can divert:

$$V_t^b \geq \theta_b(m_t^b + n_t^b) \tag{14}$$

and we will take it that $\theta_b < \theta_c$.

The broker's value function is linear in $\{v_{st}^b, v_{mt}^{\mathrm{PT},b}, v_{mt}^{\mathrm{D},b}\}$, which give the marginal value of each balance sheet item at each point in time. Define the excess values $\mu_{st}^b := v_{st}^b/Q_t - v_{mt}^{\mathrm{D},b}$ and $\mu_{mt}^b := v_{mt}^{\mathrm{PT},b}/q_t - v_{mt}^{\mathrm{D},b}$; then:

$$V_t^b = \left(\mu_{st}^b - \eta_t^b\mu_{mt}^b\right)m_t^b + (v_{st}^b/Q_t)\,n_t^b \tag{15}$$

Let λ_t^b be the multiplier on the constraint (14). The first order necessary conditions for $\{m_t^b, \eta_t^b, \lambda_t^b\}$ are:

$$\mu_{st}^b - \eta_t^b\mu_{mt}^b = \theta_b\frac{\lambda_t^b}{1+\lambda_t^b} \tag{16a}$$

$$0 = (1+\lambda_t^b)\,\mu_{mt}^b m_t^b \tag{16b}$$

$$0 = \left(\mu_{st}^b - \eta_t^b\mu_{mt}^b - \theta_b\right)m_t^b + (v_{st}^b/Q_t - \theta_b)n_t^b \tag{16c}$$

It is immediate from (16b) that whenever the shadow bank issues ABS, $\mu_{mt}^b = 0$, and as a consequence we have $v_{mt}^{\mathrm{PT},b}/q_t = v_{mt}^{\mathrm{D},b}$. With the condition $\mu_{mt}^b = 0$ in mind, we may rearrange (16c) to find the ABS supply function:

$$m_t^b = \frac{v_{st}^b/Q_t - \theta_b}{\theta_b - \mu_{st}^b}n_t^b \tag{17}$$

[19]The idea that diversification creates pledgeable income is explored in Tirole (2006, Chapter 4.2).

The expression shows that the supply of high quality collateral depends on the financial condition of brokers. The term multiplying n_t^b on the right hand side is the broker's leverage ratio minus unity. As their leverage is typically much larger than unity, ABS supply will be highly sensitive to changes in broker net worth.

The shadow value of broker net worth can be understood as follows. Whenever the broker is operational, $s_t^b > 0$, the Lagrange multiplier on the incentive constraint (14) is

$$\lambda_t^b = \frac{\mu_{st}^b}{\theta_b - \mu_{st}^b} \tag{18}$$

This tells us that the shadow value of a unit relaxation in the constraint is the leveraged increase in loans held $1/(\theta_b - \mu_{st}^b)$ multiplied by their value μ_{st}^b. To understand the expected value of a marginal unit of net worth at the end of period t, recall it is consumed with probability $(1-\sigma)$. Otherwise, with probability σ, the broker's constraint is relaxed by $v_{st}^b/Q_t - \theta_b$, which raises its value by λ_t^b times as much. There is a direct benefit of v_{st}^b/Q_t (since equity carries no charge), with the total increase in value being the sum of these effects:

$$\Omega_t^b := (1-\sigma) + \sigma\left\{v_{st}^b/Q_t + \lambda_t^b(v_{st}^b/Q_t - \theta_b)\right\}. \tag{19}$$

After plugging the first order conditions into the broker's Bellman equation, the coefficients of the value function are found to be equal to the discounted expected returns on loan pools and ABS:

$$v_{st}^b/Q_t = \mathrm{E}_t\Lambda_{t,t+1}\Omega_{t+1}^b R_{s,t+1} \tag{20a}$$

$$\mu_{st}^b = \mathrm{E}_t\Lambda_{t,t+1}\Omega_{t+1}^b\left(R_{s,t+1} - R_{m,t+1}\right) \tag{20b}$$

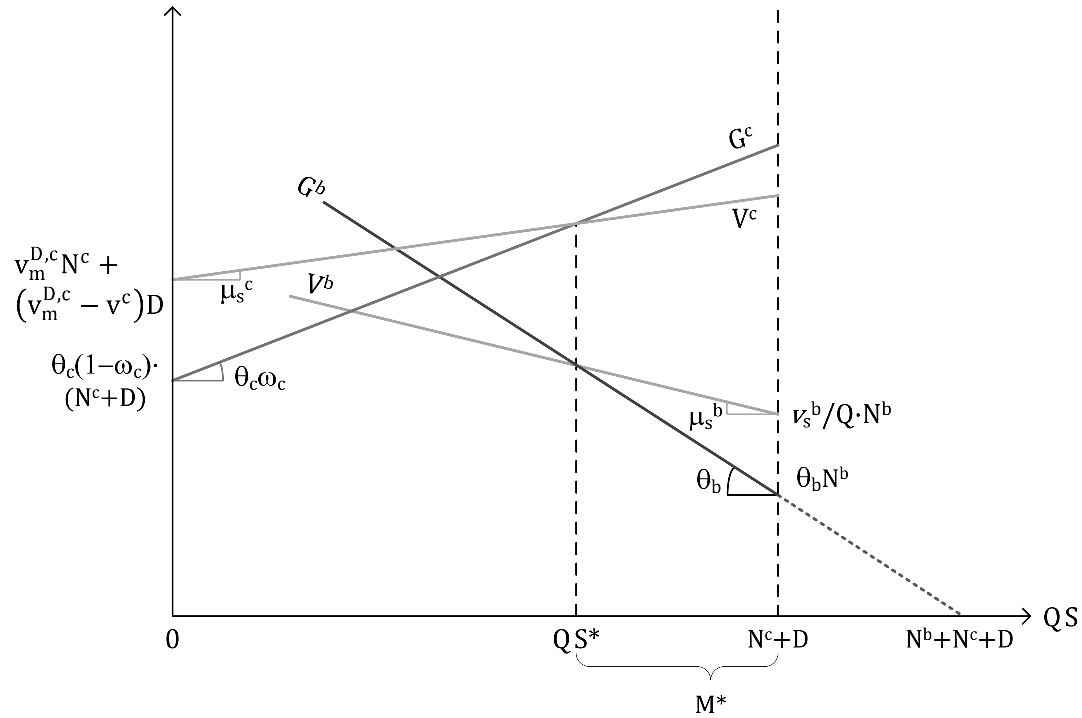
$$\mu_{mt}^b = \mathrm{E}_t\Lambda_{t,t+1}\Omega_{t+1}^b(R_{m,t+1}^{\mathrm{PT}} - R_{m,t+1}^{\mathrm{D}}) \tag{20c}$$

where similar to the commercial bank case, the effective discount factor depends on the tightness of the broker's incentive constraint through Ω_{t+1}^b.

3.2 Equilibrium in the asset backed security market

Commercial banks and brokers trade in secondary markets for loans and in the market for asset backed securities. We take it that securities markets always clear. In particular, the potential for an endogenous breakdown in the market for securitized assets, because of dynamic strategic complementarities or insufficient financial muscle, is not addressed in this paper (see, for example, the papers referenced in Tirole, 2011). As a prelude to the general equilibrium analysis of section 4, the current section analyzes the behavior of the ABS market in isolation.

Figure 3: ABS market partial equilibrium



Note: A stylized representation of partial equilibrium in the ABS market, assuming N^c, N^b and D are given. The vertical axis gives the going concern value V^τ and amount of divertible assets G^τ for each intermediary type. The horizontal axis gives loan holdings. Commercial bank loan holdings are read left-to-right, starting at the origin. Shadow bank loan holdings are read right-to-left, starting at $N^b + N^c + D$. The amount of securitized assets in issue is labeled M, and is the difference between shadow bank loan holdings and equity N^b.

A graphical illustration of partial equilibrium in the ABS market is given in figure 3. It takes as given intermediary net worth and the supply of funds by households. On the horizontal axis, we measure asset amounts. We read from left to right to determine the on balance sheet loans of commercial banks, starting from 0; and from right to left to determine the holdings of loan pools by brokers, starting from $N^b + N^c + D$. The vertical axis registers the going concern value (V^τ) and the value of divertible assets (G^τ) for each institution type $\tau \in \{c, b\}$.

We start by asking what asset mix commercial banks would choose. As loans yield more than ABS, the commercial bank can always increase its value by switching from ABS into loans. However, ABS are less divertible than on balance sheet loans. The effect of switching a marginal unit of funds from ABS to loans is to tighten the incentive constraint by $\mu_s^c - \theta_c \omega_c$. The intersection of the V^c and G^c schedules gives the portfolio equilibrium condition, where the bank's incentive constraint is just binding. An amount QS^* of loans is held on balance sheet. The balance sheet identity implies banks' demand for ABS is equal to the length of the interval $N^c + D - QS^*$.

Brokers mirror commercial banks in the figure. At the point $N^c + D$, brokers hold an amount N^b of loan pools. As we move leftward along the horizontal axis, they acquire additional loans by issuing ABS. As their balance sheet expands, each additional unit of loans purchased tightens their incentive constraint by $\mu_s^b - \theta_b$. The point at which the V^b and G^b schedules intersect determines the maximum size of the shadow bank sector. Total ABS issuance is given by M^*, which by the balance sheet identity determines their demand for loan bundles. (We need only consider total ABS issuance, since the two types are equally divertible.) Total intermediation in the economy, equal to the aggregate amount of loans held by commercial and shadow banks, is given by the length of the interval $[0, N^b + N^c + D]$.

In equilibrium, commercial bank demand for ABS must be met by supply from shadow banks. From any initial position of disequilibrium, the loan-ABS spread adjusts to clear the market. For example, taking loan returns and net worth as given, an excess demand for ABS is met with a decline in ABS yields which raises the spread, reducing bank demand (by making on balance sheet loans relatively attractive) and increasing broker supply (by relaxing their funding constraint).

3.3 Households and production

The non-financial sectors of the economy closely resemble those of a standard DSGE model. There is a continuum of identical households, each comprised of a contingent of workers, bankers and brokers. Each household member consumes a final good (c_t), and enjoys perfect consumption insurance with the other household members. In every period, a fixed proportion of householders are assigned to act as bankers or brokers, whereupon they manage their respective financial institutions until exiting the industry at random. Upon exit, bankers and brokers remit the retained earnings ($n_t^\tau, \tau \in \{c, b\}$) from their activities back to the household unit. (The management decisions of bankers and brokers are described below). Meanwhile workers sell a single type of labor (L_t) to goods producers, and likewise remit their wages (W_t) back to the household unit.

Household preferences are described using an external habit formulation common in the recent DSGE literature (Smets and Wouters, 2003; Christiano, Eichenbaum and Evans, 2005):

$$U_0 = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \tag{21}$$

$$u(c_t, l_t) = \mathrm{e}^{\zeta_t} \ln(c_t - hC_{t-1}) - \frac{\chi}{1+\varphi} l_t^{1+\varphi} \tag{22}$$

Here c_t is the consumption of the household, C_{t-1} is lagged aggregate consumption, l_t are household labor hours and ζ_t is a consumption preference (demand) shock. To effect transfers of resources across time, households acquire fixed (non-contingent) claims on commercial banks, called 'deposits' for short.[20] Deposits promise to pay a gross interest rate R_t, which is known in advance, and have aggregate value D_t. All household claims on firms, and so on the capital stock, are held indirectly through the financial system either as deposits, or as equity stakes in financial institutions which they manage. Finally, households may earn profits through their ownership of competitive capital goods producers (described below).

Competitive firms employ labor and capital K_{t-1} to produce final goods Y_t, using identical constant returns technologies

$$Y_t = \mathrm{e}^{a_t} K_{t-1}^{\alpha} L_t^{1-\alpha} \tag{23}$$

where a_t is the (logarithm) of total factor productivity, which follows an exogenous autoregressive process. Capital depreciates at a constant rate per period, such that

$$K_t = I_t + (1-\delta) K_{t-1} \tag{24}$$

is the amount remaining at the end of period t. Firms must purchase capital from specialized producers prior to use. They finance their purchases by issuing primary market securities, which are claims on the cash flows generated by the asset. We assume that commercial banks are costlessly able to enforce payment on primary securities, and as a result there are no financing frictions between firms and banks.

Competitive capital producers transform final goods into new capital goods, which they sell to final goods firms. As in Christiano et al. (2005), there are increasing convex costs $f(I_t/I_{t-1})$ to adjusting the rate of investment.[21] The adjustment cost function satisfies $f(1) = f'(1) = 0$ and the inverse elasticity of investment is defined by $\varepsilon := f''(1) > 0$.

[20] All debt in our model can be thought of as collateralized. Fixed claims on commercial banks can be thought of as deposits, or as short term secured funding such as repurchase agreements (repos).

[21] These authors argue that second-order costs to adjusting investment enable the model to better account for observed investment and output dynamics than does a first order adjustment cost specification.

Capital producers maximize profits by equating the price of new capital goods Q_t with their marginal cost, which gives rise to an upward-sloping supply function:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \left(\frac{I_t}{I_{t-1}}\right) f'\left(\frac{I_t}{I_{t-1}}\right) - \mathrm{E}_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right) \tag{25}$$

As is standard, this specification guarantees that the deterministic steady state of the economy is independent of ε, while first-order dynamics depend on this parameter alone.

Letting Z_t denote the marginal product of capital, we may define the return on primary securities as:

$$R_{st} = \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}} \tag{26}$$

Finally, returns on pass-through ABS depend on the cash flows from the underlying assets held by shadow banks according to:

$$R_{mt}^{\mathrm{PT}} = \frac{Z_t + (1-\delta)\, q_t}{q_{t-1}}. \tag{27}$$

3.4 Aggregation, market clearing and competitive equilibrium

To find aggregate intermediary net worth, we sum across the mass σ of continuing and $1-\sigma$ of entering financiers. The net worth of continuing intermediaries at time t consists of the net earnings on their accumulated stocks of assets. Assume that households supply a fraction ξ_τ of the total assets of each intermediary type $\tau \in \{c, b\}$ to new financiers of each type, each period. Then the laws of motion for bank and broker net worth, including total net transfers from households, are (respectively)

$$N_t^c = (\sigma + \xi_c)\left\{R_{st} Q_{t-1} S_{t-1}^c + R_{mt} M_{t-1}^c\right\} - \sigma R_t D_{t-1} \tag{28}$$

$$N_t^b = (\sigma + \xi_b)\, R_{st} Q_{t-1} S_{t-1}^b - \sigma R_{mt} M_{t-1}^b \tag{29}$$

The model is closed with market clearing conditions for primary securities, asset backed securities, deposits and labor. The primary securities markets clear when total demand from banks and brokers is equal to total issuance by firms

$$S_t^c + S_t^b = K_{t+1} \tag{30}$$

Clearing in the ABS market similarly occurs when total demand by banks and total supply by brokers are equated

$$M_t^c = M_t^b \tag{31}$$

with identical shares of pass-through ABS

$$\eta_t^c = \eta_t^b$$

Total deposits are given by the balance sheet identity of commercial and shadow banks as the residual funding requirement, given intermediary equity

$$D_t = Q_t(S_t^c + S_t^b) - (N_t^c + N_t^b) \tag{32}$$

Equality between labor demand and supply gives

$$W_t e^{\zeta_t}(C_t - hC_{t-1})^{-1} = \chi L_t^{\varphi} \tag{33}$$

Finally, the aggregate resource constraint is

$$Y_t = C_t + \left[1 - f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{34}$$

The model has 33 endogenous variables, of which 9 are prices (Q_t, q_t, R_{st}, R_{mt}, R_{mt}^{PT}, R_{mt}^{D}, R_t, W_t, Z_t), 10 are shadow prices (Λ_t, λ_t^c, Ω_t^c, λ_t^b, Ω_t^b, μ_t^c, v_{mt}^c, v_t^c, μ_t^b, v_{mt}^b), and 14 are quantities (Y_t, C_t, I_t, K_t, L_t, D_t, M_t^c, η_t^c, N_t^c, S_t^c, M_t^b, η_t^b, N_t^b, S_t^b), jointly determined by the 33 equations (B.1)–(B.29) given in Appendix B.

3.4.1 Steady state return on ABS

For the case of a deterministic steady state, the return on asset backed securities is given by the following intuitive result.

Proposition 1 (Equilibrium ABS spread)**.** *In deterministic steady state, the return on pass through (R_m^{PT}) and debt-like (R_m^D) varieties of ABS are equalized. Their common return R_m depends on the return on primary securities and the risk free rate:*

$$R_m = (1 - \omega_c)R_s + \omega_c R$$

where ω_c parameterizes the relative pledgeability of ABS. It follows immediately that the equilibrium ABS spread is related to the 'gross financial wedge', $R_s - R$, by:

$$R_m - R = (1 - \omega_c)(R_s - R)$$

Proof. *See Appendix C.*

□

Proposition 1 gives some useful insights into the effect of changing ABS pledgeability. When ABS is no more pledgeable than on balance sheet loans, $\omega_c = 0$, then their returns are equalized, $R_s = R_m$. The intuition for this result is that if ABS has no collateral value, then commercial banks would sell it whenever $R_s > R_m$. That would have the effect of pushing down its price, and pushing up its return (commercial banks would not hold loans if $R_s < R_m$, and selling loans would push up their yield). If ABS can never be diverted, $\omega_c = 1$, and the return on ABS is the same as on a safe claim, $R_m = R$. Intuitively, if $R_m > R$ then commercial banks would earn a spread on every unit of ABS they acquired, and because ABS is not divertible their creditors would permit them to purchase ABS without limit. The price of ABS is therefore driven up, and its yield is driven down, until $R_m = R$ (commercial banks would not hold ABS if $R_m < R$).

4 Model analysis

We analyze the log-linear dynamics of our model economy around the deterministic steady state, that is, the steady state that pertains when the variance of all shocks is zero. A particular feature of the equilibrium portfolio share of pass-through ABS η warrants further comment in this context. As can be seen from the first order portfolio optimality conditions for banks and brokers given in sections 3.1.2 and 3.1.3, the value of η in not uniquely pinned down in the model's deterministic steady state. One way to proceed would be to solve for the model's stochastic steady state, in which the share is pinned down by the distribution of shocks (see Gertler et al., 2012, for an application of this approach). Several considerations weigh against pursuing this route, however: first, the specification of the model's stochastic processes is itself subject to considerable uncertainty; furthermore, it is not straightforward to accurately compute the model's stochastic steady state, and several definitions of it co-exist in the literature.

Consistent with the arguments advanced in section 3.1.1, we therefore choose to take the share of pass-through securities in total issuance as being determined by forces outside the model. This choice has the virtue of keeping the solution of the model simple, while also having the drawback of limiting somewhat the scope of questions that we can address. In practical terms, the approach we take in the simulation exercise reported in section 4.2 is to examine the sensitivity of the model to different portfolio shares.[22]

The remainder of this section discusses how parameter values were chosen for numerical simulations of the model. It goes on to analyze the quantitative effects of two conventional aggregate business cycle disturbances, and to explain the relevance of heterogeneity amongst financial institutions in light of a purely redistributive shock affecting the financial system. In section 5, we turn to an analysis of a securitization crisis.

[22]Sensitivity analysis is also necessary given that precise portfolio shares are not readily observable. An alternative device to produce a unique value for the portfolio share, but in the deterministic steady state, would be to arbitrarily introduce (for example) a small difference in divertibility between pass-through and debt-like ABS; or a small difference in bundling costs.

4.1 Calibration

Values for the parameters that we use when we simulate the model are given in table 1. The parameters fall into two groups. The first group consists of nine parameters that govern key macroeconomic quantities familiar from other studies. The second consists of six parameters specific to the financial system (with subscript b for shadow banks, and c for commercial banks). We choose parameters that allow the model to reproduce the main features of a financial system roughly comparable to that of the United States in the decade preceding the subprime crisis.

Amongst the macroeconomic parameters, we use conventional values for the discount factor β, the capital share α, and the depreciation rate δ. For the elasticity of investment ε, and households' degree of habit persistence h and labor supply elasticity φ, we adopt values taken from estimates readily available in the literature. Households' disutility of labor χ is set so that one third of their time endowment is spent in work in steady state. The parameters ρ_a and ρ_ζ are set to impart moderate persistence to the aggregate shocks, their precise values being unimportant in the sequel.

Amongst the parameters specific to the financial system, we fix the per-period survival probability for bankers and brokers, σ, to generate a mean survival time of ten quarters (one could also think of this as a payout rate of 10%). We then calibrate the remaining five parameters $(\theta_c, \xi_c, \omega_c, \theta_b, \xi_b)$ to match the average values of five financial variables in steady state. These are the gross financial wedge $R_s - R$, the ABS spread $R_m - R$, the share of assets held in securitized form M/S^c, the loan to equity ratio of commercial banks S^c/N^c, and the asset to equity ratio of shadow banks S^b/N^b.

The steady state risk free rate is β^{-1} implying $R \approx 4.1\%$ per annum. We set the steady state gross financial wedge $(R_s - R)$ to 100 basis points, which is roughly equal to the spread between the yields on good quality long-term corporate and government bonds. The 2000–2007 average ABS spread over comparable swap rates for high-quality securitizations varied from around 7 basis points for credit card and auto receivables, to 25 basis points for large equipment and 70 basis points for non-conforming mortgages. We adopt a rough mid-point of 50 basis points for the steady state ABS spread $(R_m - R)$ in the model. Using proposition 1, it can be seen that the value of ω_c required to match this spread may be found by computing:

$$\omega_c = \frac{R_s - R_m}{R_s - R}$$

The aggregate ratio of commercial bank loans to equity S^c/N^c is 4.5 times, which is close to the median ratio of total loans and leases to the sum of tier 1 and 2 capital at commercial

Table 1: Parameter values used in simulations

Parameter	Value	Description
α	0.3	Share of capital in production
β	0.99	Household discount factor (quarterly)
δ	0.025	Capital depreciation rate (quarterly)
h	0.70	Habit persistence in consumption
χ	12.37	Disutility of labor
φ	0.30	Inverse labor supply elasticity
ε	3.0	Elasticity of investment
ρ_a	0.6	Persistence of productivity shocks
ρ_ζ	0.6	Persistence of prreference shocks
σ	0.90	Survival probability for financiers
θ_b	0.1224	Divertibility of broker loans
ω_c	0.5	Relative divertibility of ABS
ξ_b	0.0083	Fraction of assets transferred to new brokers
θ_c	0.2216	Divertibility of bank loans
ξ_c	0.0134	Fraction of assets transferred to new banks
		No securitization economy
ξ_b^*	0.0†	Fraction of assets transferred to new brokers
θ_c^*	0.2564	Divertibility of bank loans
ξ_c^*	0.0172	Fraction of assets transferred to new banks

† Shadow banks are eliminated from the 'No securitization' economy by setting ξ_b^* close to zero. In this case, the share of total lending accounted for by the shadow banking system is small enough that they do not affect aggregate dynamics.

banks in the call report data.[23] We set the share of securitized assets M^c/S^c at 30%, based on call report data on bank assets sold and securitized. Together, these two ratios imply that the deposit-equity ratio $D/N^c = 4.85$. Using this information, the value of ξ_c may be set according to:

$$\xi_c = \frac{1 - \sigma R_m - \sigma(R_m - R)(D/N^c) - \sigma(R_s - R_m)(S^c/N^c)}{(R_s - R_m)(S^c/N^c) + R_m(1 + D/N^c)}$$

We take a value of shadow banks' asset to equity ratio S^b/N^b of 10 times, based on data on the leverage in MBS securitizations.[24] The value for ξ_b may then be found from:

$$\xi_b = \frac{1 - \sigma R_m}{R_s} \frac{N^b}{S^b} - \sigma \frac{R_s - R_m}{R_s}$$

Last, the asset divertibility parameters θ_c and θ_b may be found by computing:

$$\theta_c = \frac{\beta(1-\sigma)(R_s - R_m)}{\omega_c - \beta\sigma[R_m - (1-\omega_c)R_s](1+\lambda^c)} \frac{1+\lambda^c}{\lambda^c} \tag{35}$$

$$\theta_b = \frac{\beta(1-\sigma)(R_s - R_m)}{(1-\beta\sigma R_m) - \beta\sigma R_m \lambda^b} \frac{1+\lambda^b}{\lambda^b} \tag{36}$$

where

$$\lambda^c = \beta(R_s - R_m)\left[\frac{S^c}{N^c} + \frac{1-\omega_c}{\omega_c}\left(1 + \frac{D}{N^c}\right)\right] \quad \text{and} \quad \lambda^b = \beta(R_s - R_m)\frac{S^b}{N^b}$$

which, given the values assigned to the financial ratios and yield spreads described above, implies $\theta_b < \theta_c$ as anticipated by the discussion in section 3.1.3.

In an alternative to the baseline calibration, we consider the limiting case of an economy with a representative commercial bank. Our model then collapses to a real version of that presented in Gertler and Karadi (2011). We set parameters to broadly replicate the value of financial ratios in the early 1990s when there was little securitization activity. For this economy, we suppose that the gross financial wedge in the economy is 20 basis points higher than under the baseline case, in line with a range of evidence from various markets

[23]Reports of Condition and Income ('Call Reports') are filed by U.S. regulated financial institutions on a quarterly basis, and are made available online by the Federal Deposit Insurance Corporation.

[24]It is not straightforward to measure leverage for the shadow banking system as a whole for a number of reasons. Foremost is the diversity of institutional arrangements that come under the shadow banking umbrella. Some entities, such as ABCP (Asset Backed Commercial Paper) conduits, held effectively zero equity, as they had backup contingent credit lines from commercial banks (in the event that investors failed to roll over their holdings, see Acharya et al., forthcoming). Others, such as securities brokers and dealers, had leverage ratios based on regulatory capital of 30 or 40 times, but as their name suggests much of their activity was not shadow banking. Further details of the data used in calibration can be found in Appendix D.

that borrowing rates fell amongst assets that could be securitized.[25] The aggregate ratio of commercial bank loans to equity is maintained at 4.5 times for this scenario.

4.2 Results

4.2.1 Business cycle shocks

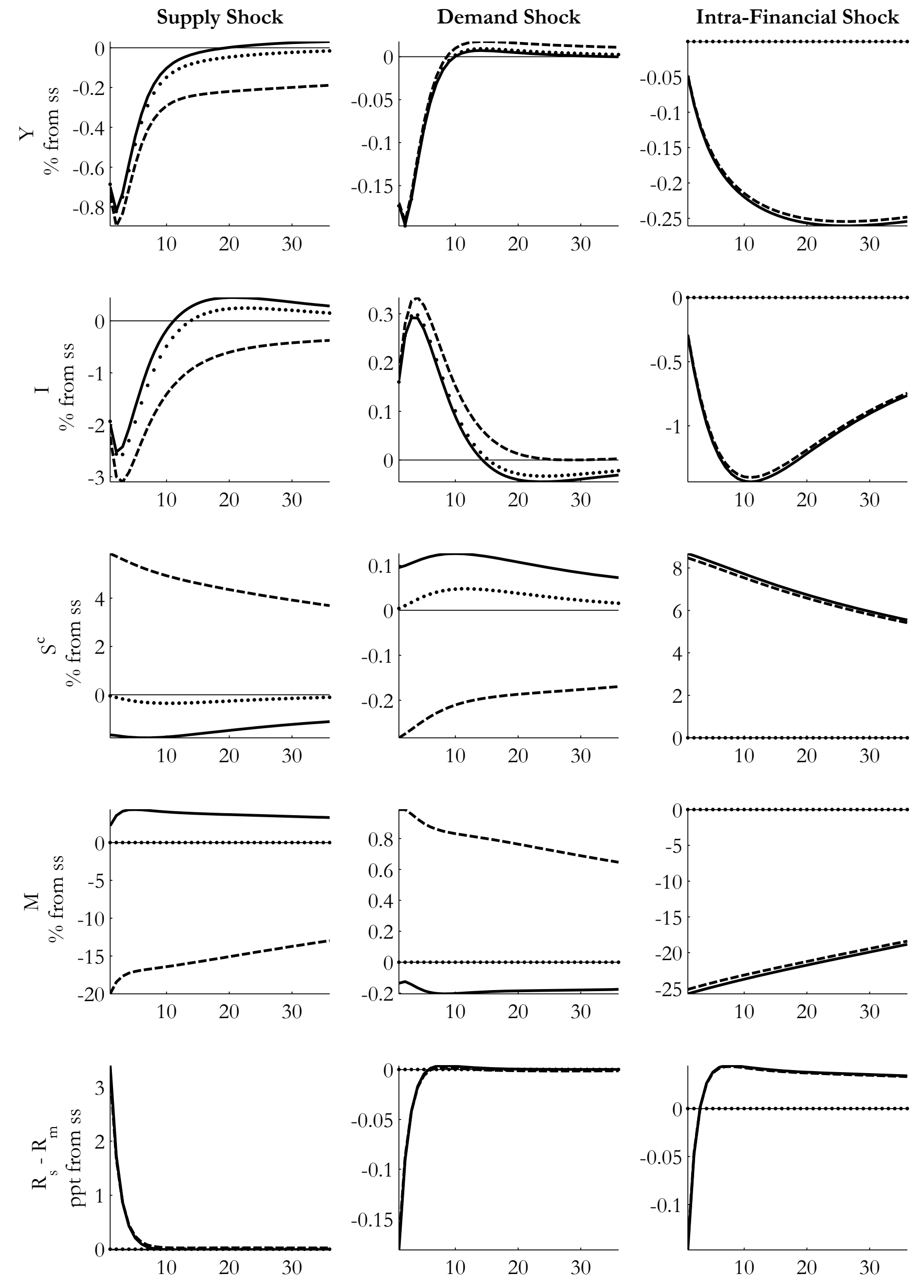
We begin by considering the responses of selected variables to two familiar business cycle shocks. Column one of figure 4 shows model responses following an unanticipated 1% reduction in aggregate supply (total factor productivity). As is the case in the absence of financial frictions, capital demand shifts inward, capital prices fall, and the expected return on capital increases. Demand for credit, which derives from the demand for capital goods, declines. But the quantitatively most important effects derive from shifts in credit supply, as we now discuss.

The response of credit supply can be understood by considering the two principal effects of the productivity shock on the financial system. First, the fall in capital prices triggers a revaluation of the balance sheets of both banks and brokers, causing their net worth to decline. This 'net worth effect' causes a multiple contraction in loan holdings by banks of $1/(\theta_c\omega_c - \mu_s^c) \cdot \mathrm{d}N^c$, and in holdings by brokers of $1/(\theta_b - \mu_s^b) \cdot \mathrm{d}N^b$. By (8), the fall in bank equity values increases the demand for ABS by $(v_s^c/Q - \theta_c)\lambda^c/\mu_s^c \cdot \mathrm{d}N^c$. At the same time, (17) tells us ABS supply is reduced by $(v_s^b/Q - \theta_b)\lambda^b/\mu_s^b \cdot \mathrm{d}N^b$. For given R_s, the opposing shifts in demand and supply put downward pressure on the ABS yield, which tends to widen the loan-ABS spread. Second, the expected return on capital is raised. For given R_m, the consequence of higher R_s is to raise the going concern value V^τ of intermediaries of both types, which partly relaxes their incentive constraints. This 'expected return effect' works against the net worth effect by partly reversing the shifts in demand and supply, but is insufficient to equilibriate the market without an increase in the loan-ABS spread.

Under the risk sharing securitization model ($\eta = 1$; figure 4, solid line), commercial banks are exposed to aggregate risk through both loan and ABS prices. The losses they make on ABS reinforce the losses they make on loans, reducing their balance sheet capacity, and lead them to rebalance their portfolios away from loans and towards ABS (which as they anticipate appreciates in value following the shock). Meantime, shadow banks also find that their balance sheet capacity has been reduced. But the decline in the mark-to-market value of their liabilities as the price of ABS falls offers partial protection

[25] For example, in the market for corporate loans, Nadauld and Weisbach (forthcoming) cite a reduction in yields of 15 basis points.

Figure 4: Impulse response functions



Note: Figure compares responses to a persistent 1% decline in total factor productivity, a persistent 1% adverse demand shock, and a one-off 20% redistribution from shadow banks to commercial banks. The three cases are: $\eta = 1$ (—); $\eta = 0$ (- -); representative commercial bank/no securitization ($\cdots$). Symbols: Y output, I investment, S^c bank credit, M securitized credit, $R_s - R_m$ loan-ABS spread.

to their net worth. As a result of the widening loan-ABS spread, brokers are able to expand their holdings of loans somewhat by taking on increased leverage. The ability of commercial banks to securitize insulates the overall supply of credit in much the same way that Altunbas et al. (2009) report occurs in their micro data.

Under the risk taking securitization model ($\eta = 0$; figure 4, dash line), commercial banks hold fixed claims on shadow banks. The decline in asset prices triggered by the adverse productivity shock is now fully absorbed by shadow bank net worth, which undergoes a substantial contraction. Assets held and ABS issued by the shadow banking system are forced to decline. As commercial bank net worth is partly protected, they are able to expand their loan holdings, even as they scale back their securitization activity. However, the total effect on aggregate credit is a substantially larger contraction than under risk sharing securitization, resulting in larger declines in investment, and so a deeper recession.

The representative commercial bank economy has no role for changes in securitization activity or ABS spreads (figure 4, dotted line). But it presents something of an intermediate case as far as the declines in output and investment are concerned. Compared to the baseline model with $\eta = 1$, commercial banks are less exposed to aggregate risk, and consequently their on balance sheet credit undergoes a comparatively smaller decline in response to the shock. But without the ability to securitize, total credit falls by more. (The preceding logic is reversed when comparing with the case $\eta = 0$ in the baseline model.)

The effects of an unanticipated 1% reduction in aggregate demand (consumption preferences) are shown in column two of figure 4. There, the financial system can be seen to behave somewhat differently compared to the supply shock case. As is standard, lower consumption translates into lower overall output, but at the same time generates an increase in investment, and pushes up on asset prices. The latter effect this time produces a positive 'net worth effect' on both types of intermediary, raising their going concern values and slackening their incentive constraints. The 'expected return effect' once again works in the opposite direction to the net worth effect, so putting downward pressure on going concern values by reducing future profitability. With $\eta = 1$, commercial bank net worth receives an additional boost from the revaluation of their ABS portfolios as q rises. They therefore reduce their overall demand for ABS, inducing the loan-ABS spread to fall to eliminate the resulting excess supply. In the $\eta = 0$ case, the higher leverage of the shadow banking sector tends to create a large ABS supply response which again leads the loan-ABS spread to fall.

A notable feature of the responses to aggregate supply and demand shocks shown

Table 2: Signs of correlations between selected variables

	Supply shocks		Demand shocks		Data
	$\eta = 1$	$\eta = 0$	$\eta = 1$	$\eta = 0$	(unconditional)
$\text{corr}(Y, S^c)$	+	−	−	+	+
$\text{corr}(Y, R_s - R)$	−	−	+	+	−
$\text{corr}(Y, S^b)$	−	+	+	−	−
$\text{corr}(Y, R_m - R)$	−	−	+	+	−
$\text{corr}(S^c, S^b)$	−	−	−	−	−

Note: Key to symbols: Y output, S^c commercial bank credit, S^b shadow bank credit, $R_s - R$ external finance premium, $R_m - R$ ABS spread. The proportion of pass-though ABS is η. Output and credit data run 1984:1–2007:2, HP filtered; spread data run 1994:2–2007:2. Full details of data construction and sources can be found in Appendix D.

in figure 4 is the greater macroeconomic volatility observed under the $\eta = 0$ case, compared to the cases of $\eta = 1$ or of no securitization. This increased volatility is a result of the higher effective leverage of the financial system when shadow banks issue debt-like claims. Accordingly, an implication of the model presented here is that if the expansion in shadow banking prior to the subprime crisis was funded by investors with strong preferences for safe claims, or by regulatory arbitrage, the result would have been increased macroeconomic vulnerability to business cycle shocks. This result does not require there to be incentive effects arising from a lack of 'skin in the game' following loan sales, as commonly argued, but allowing for such effects would most likely reinforce the result.

Finally in this section, table 2 summarizes the model-implied correlations between several key variables in response to aggregate supply and aggregate demand shocks, under the polar cases of risk sharing and risk taking securitization.[26] The table also shows the direction of comovements observed under pre-crisis business cycle conditions. It is intended to convey a rough idea of the implications of the model for observables. A clear message from line $\text{corr}(S^c, S^b)$ in the table is that the model implies that commercial and shadow bank credit tend to move in different directions in response to business cycle shocks, as is observed in the data (recall figure 1). However, the cyclical behavior of credit components and spreads depend on the source of the shock, as they depend on the differential responses of aggregate investment. To replicate the unconditional correlations between output and commercial and shadow bank credit seen in the data – lines $\text{corr}(Y, S^c)$

[26]The signs of the conditional correlations are unaffected by the persistence of the shocks, although altering persistence does affect their magnitude.

and corr(Y, S^b) – sufficient conditions are either that supply shocks dominate and $\eta = 1$, or that demand shocks dominate and $\eta = 0$. For spreads, the typical counter-cyclical pattern seen in the data holds conditional on supply shocks, but not under demand shocks.

4.2.2 The importance of heterogeneity

In this section, we give a flavor of the quantitative importance of introducing heterogeneity within the financial system for macroeconomic outcomes. Suppose there is an unanticipated one-off redistribution of 20% of steady state broker net worth to commercial banks. This experiment is useful because any shock causing a relative shift between bank and broker equity, including the aggregate shocks discussed above, will trigger the dynamics described below.[27] We scale the shock to 20% because this is the approximate magnitude of the shift in relative net worth caused by the business cycle shocks discussed in the previous section.

Results are given in the third column of figure 4. The first point to note is that a purely temporary shock that redistributes wealth amongst financial intermediaries has real effects in this economy. It can be seen that investment declines by up to 1.5%, and output declines by 0.25%. In the representative bank economy, naturally enough, such shocks have no effect. Second, the ABS spread falls; this is the result of the excess supply of ABS caused by the combined relaxation in the incentive constraint of the commercial bank, and tightening of the incentive constraint of the broker.

On the face of it, the effects of the redistribution channel on investment and particularly on output might seem surprisingly modest. An implication would be that the dynamics of macroeconomic aggregates in response to standard macroeconomic shocks can be well approximated by a representative bank model. There are several caveats, however. The first issue is that we have not introduced any information frictions between originators and holders of loans that could lead to an endogenous deterioration in the quality of loan pools. Time variation in collateral quality, for example due to adverse selection, could well be an important source of amplification that would not be present in a representative bank setting.[28] Second, we cannot rule out the possibility that re-

[27] Although we see this shock primarily as a means of illustrating the mechanism of our model, one could place a loose economic interpretation on it. Consider a situation in which the shadow banking system holds a claim on commercial banks which is marked down, causing equal and offsetting declines in broker assets, and bank liabilities. As an example of this situation relevant to the subprime crisis, one could think of commercial bankers withdrawing credit enhancement from impaired assets held by brokers.

[28] One way to capture, albeit in a reduced form way, a deterioration in the quality of the collateral underlying loan pools is to have the parameter θ_b be an endogenous function of the share of all loans held in pools, rather than on bank balance sheets. The idea is that when there is relatively little securitization activity, the loans that banks choose to sell are more likely to be 'lemons' than when securitization activity is high (a 'fair mix').

distributive shocks are themselves an important source of fluctuations; for example, a decline in investment of a similar magnitude to that generated by a 1% demand shock can be generated by an intra-financial shock that is roughly four times smaller than the one reported in figure 4. Relatedly, although in normal times one might conclude that the importance of heterogeneity is somewhat limited, any disruption to the securitization markets forces the issue to center stage. The following section considers the effects of just such a disruption.

5 Crises and interventions

In this section, our focus will be on the behavior of the economy in a securitization crisis. The crisis experiment described in section 5.1 is triggered by a shock that affects directly the leverage of financial intermediaries. Its aim is to capture, albeit in a somewhat reduced form way, the idea that the collateral value of assets held or issued by the shadow banking system became impaired at the onset of the subprime crisis. As our simulations show, the securitization shock results in a substantial contraction in real activity. Crucially, these real effects do not require that there be a large macroeconomic shock, such as the aggregate shock to capital in Gertler and Karadi (2011).

The problems experienced in credit and interbank markets at the onset of the subprime crisis in August 2007 were swiftly followed by government actions, including cuts in official interest rates and enhanced provision of liquidity. As the crisis intensified, the scope of these actions was considerably broadened, with the number of announced crisis measures exceeding 150 across the major advanced economies by 2009 (see International Monetary Fund, 2009). In the United States, official backstops for the shadow banking system were a prominent component of the policy response (Pozsar et al., 2010). These have included a policy of providing long-term liquidity through the TALF (Term Asset-Backed Securities Loan Facility), and outright purchases of Agency MBS and debt funded by central bank reserves.[29,30] In section 5.2 we describe the operation of government

Knowing this, creditors regard loan pools as less pledgeable in low activity states. When the elasticity of θ_b to the share is high, the economy can become significantly more volatile (results are available on request from the authors). Kurlat (2010) studies a model in which the degree of adverse selection responds endogenously to aggregate disturbances.

[29] In the United Kingdom, the SLS (Special Liquidity Scheme) was also aimed at long-term liquidity provision. It allowed banks to undertake swaps of securitized assets for Treasury bills, which could then be used as collateral to obtain secured funding in wholesale markets.

[30] Central bank asset purchases in jurisdictions other than the United States have mainly been restricted to commercial paper, corporate bonds, covered bonds and government securities, rather than securitized assets. As Pozsar et al. (2010) remark, the Federal Reserve was able to undertake purchases of Agency liabilities without creating new facilities as such securities were already considered to be eligible collateral

backstops for the securitization market.

5.1 A securitization crisis

We begin by considering the effects of an exogenous tightening of financial constraints, which resembles the liquidity shock in Del Negro, Eggertsson, Ferrero and Kiyotaki (2011) (although their model does not explicitly include financial intermediaries). The first aspect of the crisis is that assets held by the shadow banking system become less effective for raising secured funding. We model this as an unanticipated increase in θ_b, which to recall parameterizes the divertibility of shadow bank assets. An immediate consequence of such a shock is to reduce the supply of securitized assets by tightening the broker incentive constraint (14). Referring back to figure 3, it can be seen that the G^b schedule, describing the value of assets the broker can divert, becomes steeper and shifts upward. Commercial banks take loans back onto their balance sheets, but forced selling by shadow banks pushes down capital prices which impairs the net worth of both sectors. The relatively higher leverage of brokers makes their balance sheet contraction large relative to banks. The effects mentioned work towards reducing securitization activity.

The second aspect of the crisis is that shadow bank liabilities become less valuable as collateral for commercial banks. We model this as an unanticipated decrease in ω_c, which directly impacts the bank incentive constraint (5) by raising the divertibility of ABS. There are twin effects. Because ABS is less pledgeable, to obtain a given amount of funding the commercial bank now has to hold more of it in its asset portfolio. At the same time, a unit of ABS is relatively less attractive compared to loans, and banks would prefer to hold less of it. In terms of figure 3, the former effect shifts the G^c schedule upward, whereas the latter effect flattens it, and so the total effect on ABS demand depends on which dominates. The final aspect of the crisis is a redistribution of net worth away from commercial banks, that could be thought of as related to household defaults.

5.2 Securitization with government backstops

We now suppose that the consolidated government sector utilizes its balance sheet to lend directly to firms and intermediaries. Credit policies take the form of purchases of assets from the private sector financed by issuance of government debt. Government debt is held by households, who regard it as substitutable for bank deposits. The rationale for such policies is that in contrast to private actors, the government does not face financing

for the purpose of open market operations.

constraints. As a result, the composition of its balance sheet will not matter for its cost of funding, which is always at the risk free rate.[31]

The government may purchase primary securities directly (lending to firms) or in securitized form as ABS (lending to brokers).[32] The government budget constraint takes the form

$$G_t + Q_t S_t^g + M_t^g + R_t D_{t-1}^g = T_t + D_t^g + R_{st} Q_{t-1} S_{t-1}^g + R_{mt} M_{t-1}^g$$

where D_t^g denotes 1 period government bonds, and lump sum taxes on households T_t adjust to ensure budget balance. After substituting the financing policy, the constraint becomes

$$G_t - T_t = (R_{st} - R_t) Q_{t-1} S_{t-1}^g + (R_{mt} - R_t) M_{t-1}^g \tag{37}$$

We assume that there is a real resource cost associated with government asset purchases, which represent its relative lack of specialization in managing investments, and which gives rise to non-zero public expenditure, parameterized by τ.

$$G_t = \tau(S_t^g + M_t^g) \tag{38}$$

Finally, the market clearing conditions (30) and (31) are altered to read

$$S_t^c + S_t^b + S_t^g = K_{t+1} \tag{39}$$

and

$$M_t^c + M_t^g = M_t^b \tag{40}$$

Government is taken to purchase a fraction φ_t^i of the steady state stock of each asset type i.[33] The policy response to the crisis takes the form of a feedback rule on the spreads (a

[31] The policy described here differs from the Federal Reserve's large-scale asset purchase (LSAP) program, which has taken the form of purchases of federal government and agency liabilities funded by central bank reserves. In our model, the purchase of one type of consolidated government liability funded by issuing another type of government liability would have no effect. The effect of the policy on bank deposits also differs. Under the LSAP program, purchases of mortgage backed securities from the public result in higher deposits at banks, who hold correspondingly higher reserve balances at the Fed. In the model, debt and deposits are substitutes in the household asset portfolio, so when the government's balance sheet expands, bank deposits decline. The effects of a debt-funded expansion of intermediation in a model with monetary policy are discussed in Gertler and Karadi (2011).

[32] A third option is to lend to banks by purchasing deposits. However, it is straightforward to show that this policy has no effect, $G_t = T_t = 0$, so long as the resource cost parameter τ is zero, and the government lends on the same terms as other creditors, meaning there are no changes to banks' incentive constraints. Christiano and Ikeda (2011) discuss the failure of irrelevance conditions such as this in various types of models with financial frictions.

[33] For the sake of conciseness, we take $\eta = 1$ in the crisis experiments. The message of this section is not affected by choice of η.

star denotes steady state values), with the parameter γ_{1i} determining the strength of the response:

$$\varphi_t^s = \gamma_{0s} + \gamma_{1s}\{\mathrm{E}_t(R_{s,t+1} - R_{t+1}) - (R_{s*} - R_*)\} \tag{41}$$

$$\varphi_t^m = \gamma_{0m} + \gamma_{1m}\{\mathrm{E}_t(R_{m,t+1} - R_{t+1}) - (R_{m*} - R_*)\} \tag{42}$$

These rules, which are anticipated by the public, capture the idea that the principal goal of intervention is to bring down the lending spread in funding markets, for ultimate borrowers or intermediaries.

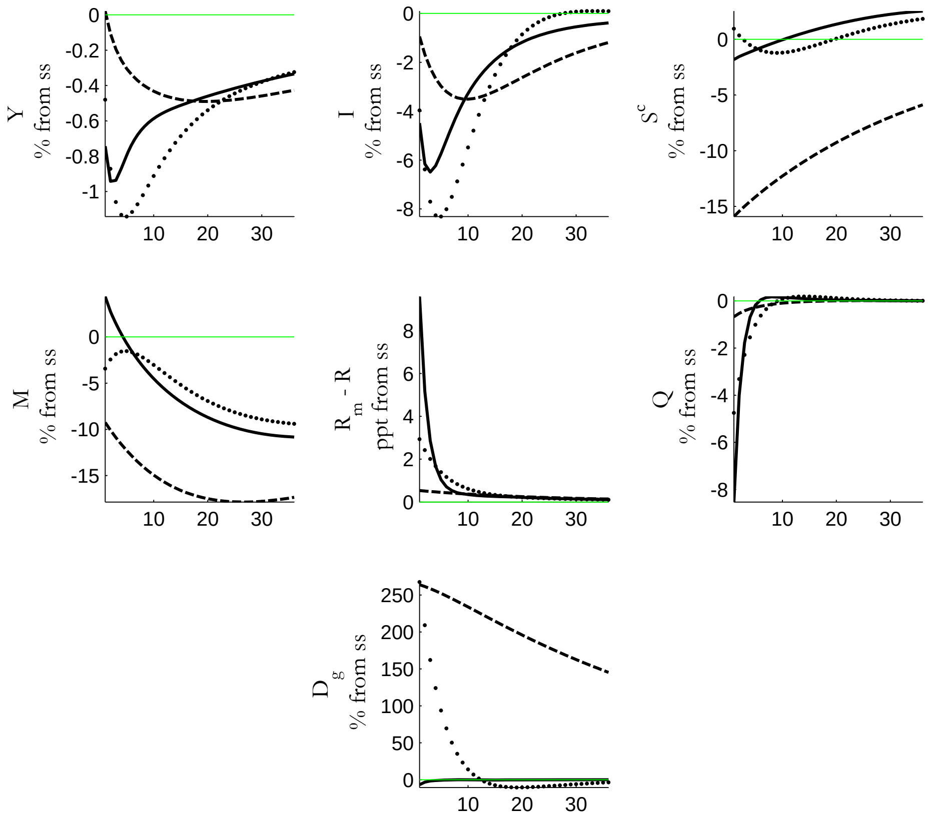
5.3 Results

In the crisis simulation, consider a roughly 5% reduction in the pledgeability of shadow bank assets and a collapse in the collateral value of ABS to approximately 20% of its prior value, combined with a one-off 5% redistribution of net worth away from commercial banks. The shock to collateral values has high persistence, with an autoregressive coefficient of 0.95, to give the flavor of a structural shift away from securitization. The result, shown by the solid line in figure 5, is a decline in investment of a little over 6% after one year.[34] On balance sheet credit extended by both banks and shadow banks undergoes a decline, as does the value of loans securitized. As discussed above, the principal cause of the contraction in shadow banking is the structurally lower capacity to maintain leverage when θ_b is high. The contraction in commercial banking arises from a combination of a lower ω_c, and lower bank equity. Parallel to the quantity movements are large movements in spreads. In particular, the spread of ABS over safe rates, $R_m - R$, rises by close to 10 annual percentage points, mirroring the 'blow out' in spreads on such assets during the subprime crisis (see Gorton and Metrick, 2012a).

In the case of government intervention, we set the resource cost of asset holdings τ to 0.002, or 2 tenths of a cent on the dollar, and the steady state fraction of assets held by the consolidated government sector γ_{0i} at 2.5%. We first consider the effect of direct lending to firms through loan purchases. Setting $\gamma_{1s} = 400$ produces the responses of investment, output and credit shown as the dash line in figure 5. The increase in government loan holdings takes its share of all directly held credit outstanding to approximately 14%, or 110% of steady state GDP. There is a corresponding decline in loans held on commercial bank balance sheets, S^c. The principal effect of the policy is to stabilize asset values, Q,

[34]The decline in output is moderated by a rise in consumption following the shock. Higher consumption is the result of lower real interest rates. In the model of Del Negro et al. (2011), a combination of nominal rigidities and the zero lower bound on nominal interest rates prevent the real interest rate from falling sufficiently to generate a consumption boom following a financial shock.

Figure 5: A securitization crisis



Note: Figure compares the effects of a securitization crisis: without a policy response (—); with government purchases of primary securities (- -); and with government purchases of asset backed securities ($\cdots$). Symbols: Y output, I investment, S^c bank credit, M securitized credit, $R_m - R$ ABS-government bond spread, Q capital asset prices, D^g government debt. Details of the shock are given in the main text.

which fall by much less than in the absence of intervention. This is helpful because it protects the net worth of intermediaries, and as a result the fall in investment is initially ameliorated. But there is an offsetting effect arising from the compression of spreads. When prices fall, the high returns that intermediaries expect to earn in the transition back to steady state raise their going concern value, and so relax their incentive constraint. Under intervention intermediary profit growth is very slow, and consequently their net worth remains low for a protracted period.

The second type of intervention is where government instead lends directly to shadow banks through outright purchases of ABS. We adopt a value for $\gamma_{1m} = 25$, which raises the government's share of (steady state) ABS outstanding to something over 50%. This brings the expansion of the government asset portfolio to the same level as in the loan purchase case. The dotted line in the figure shows that, although the policy of funding shadow banks is successful in bringing down the yield spread on ABS over safe rates, it is less effective in stabilizing real activity than are direct loan purchases. Although the on-impact decline in output is cushioned, the peak decline in both output and investment is greater than in the absence of intervention.[35]

The reason for this seemingly perverse effect can be explained as follows. Holding returns constant, the incentive constraint of the shadow banking system is unaffected by the government's purchases. As their constraint is binding, they cannot expand their balance sheets to meet the increased demand for ABS. The first round effect of the government's purchases is therefore to reduce commercial bank holdings of ABS, while at the same time commercial bank deposits fall as households substitute into government debt. The key to understanding the response can be seen from (8), which tells us that lower deposits translate into lower demand for ABS from commercial banks; indeed, so long as $\omega_c < 1$, ABS demand falls more than one-for-one with the loss of deposits as commercial banks require less pledgeable collateral to support their reduced leverage. As a consequence, total demand for ABS summing across banks and the government is actually lower than in the absence of intervention. To clear the market as in (40), the loan-ABS spread must fall. A lower spread hurts profits, and triggers reductions in net worth and second round tightening of financial constraints for both intermediary types, see (3) and (13). The policy helps to stabilize asset prices, as in the case of loan purchases, as demand for loans from commercial banks is higher than in the absence of intervention, and is high relative to shadow banks (recall that banks are roughly twice the size of brokers). But in our simulations the boost to intermediary net worth from the asset price channel is too weak to persistently raise credit supply.

In summary, the results in this section imply that a policy that raises asset values through direct loan purchases is more effective than a policy that supports the price of ABS, reducing funding costs for shadow banks. Intuitively, by diverting household saving into government bonds the policies incentivize commercial banks to retain loans, which works with the policy of loan purchases, but against the policy of ABS purchases. The results also point to the importance of combining asset purchases with recapitalizations, which would counteract the effects of the protracted margin squeeze intermediaries face.

[35]Setting γ_{1m} to a much higher value – leading to more aggressive official ABS purchases and a greater compression in spreads – leads to larger, not smaller, peak declines in output and investment.

6 Concluding remarks

In this paper, we developed a dynamic macroeconomic model in which a traditional commercial banking sector and a 'shadow' banking sector interact through the market for securitized assets. We examined the consequences of 'securitized banking' for aggregate activity, credit supply and credit spreads under business cycle disturbances and financial shocks. We found that the ability of banks to securitize loans when their net worth is impaired can have a beneficial effect on the macroeconomy, acting as a stabilizing force for aggregate activity and credit supply. But when securitization is accompanied by high leverage in the shadow banking system, as is the case when ABS have debt-like characteristics, the economy instead becomes excessively vulnerable to aggregate disturbances.

To address the financial crisis of 2007-9, we demonstrated that liquidity shocks, which affect the collateral value of shadow bank assets and liabilities, produce a sharp downturn in credit supply and economic activity. We further showed that although direct government lending to firms through the purchase real economy assets is an effective stabilization tool, lending to shadow banks by purchasing asset-backed securities is, in our environment, a much less attractive policy. These findings underline the importance for successful policy design of anticipating spillovers within the financial system.

In conclusion, shadow banking remains an important piece of the financial system even in the wake of the crisis (Financial Stability Board, 2011). Policymakers maintain an active interest in its reform, which has so far been only partially addressed in post-crisis financial regulation (Tucker, 2010; Hanson, Kashyap and Stein, 2011). The present paper provides a framework, albeit a somewhat stylized one, for thinking about the economy-wide implications that such reforms may entail.

References

Acharya, Viral V. and Matthew Richardson (2009) "Causes of the financial crisis," *Critical Review*, Vol. 21, pp. 195–210.

Acharya, Viral V. and Philipp Schnabl (2009) "How banks played the leverage game," in Viral V. Acharya and Matthew Richardson eds. *Restoring financial stability: How to repair a failed system*: Wiley, pp. 83–100.

Acharya, Viral V., Philipp Schnabl, and Gustavo Suarez (forthcoming) "Securitization without risk transfer," *Journal of Financial Economics*.

Adrian, Tobias and Hyun Song Shin (2008) "Financial intermediaries, financial stability and monetary policy," in *Maintaining stability in a changing financial system*, pp. 287–334: Federal Reserve Bank of Kansas City Economic Policy Symposium.

——— (2010) "Liquidity and leverage," *Journal of Financial Intermediation*, Vol. 19, pp. 418–437.

Altunbas, Yener, Leonardo Gambacorta, and David Marquez-Ibanez (2009) "Securitization and the bank lending channel," *European Economic Review*, Vol. 53, pp. 996–1009.

Bernanke, Ben S. (2011) "International capital flows and the returns to safe assets in the United States 2003–2007," in *Financial Stability Review No. 15*: Banque De France, pp. 13–26.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist (1999) "The financial accelerator in a quantitative business cycle framework," in J.B. Taylor and M. Woodford eds. *Handbook of Macroeconomics*, Vol. 1c: Elsevier, pp. 1341–93.

Blinder, Alan S. (2013) *After the music stopped*: Penguin Press.

Brunnermeier, Markus K. (2009) "Deciphering the liquidity and credit crunch 2007-2008," *Journal of Economic Perspectives*, Vol. 23, pp. 77–100.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans (2005) "Nominal rigidities and the dynamic effects of a shock to monetary policy," *Journal of Political Economy*, Vol. 113, pp. 1–45.

Christiano, Lawrence J. and Daisuke Ikeda (2011) "Government policy, credit markets and economic activity," June, Working Paper.

Coval, Joshua, Jakub Jurek, and Erik Stafford (2009) "The economics of structured finance," *Journal of Economic Perspectives*, Vol. 23, pp. 3–25.

Del Negro, Marco, Gauti Eggertsson, Andrea Ferrero, and Nobuhiro Kiyotaki (2011) "The Great Escape? A quantitative evaluation of the Fed's liquidity facilities," Staff Report 520, Federal Reserve Bank of New York.

DeMarzo, Peter M. (2005) "The pooling and tranching of securities: A model of informed intermediation," *Review of Financial Studies*, Vol. 18, pp. 1–35.

den Haan, Wouter J. and Vincent Sterk (2010) "The myth of financial innovation and the great moderation," *Economic Journal*, Vol. 121, pp. 707–739.

Financial Stability Board (2011) "Shadow banking: Strengthening oversight and regulation," October.

Gennaioli, Nicola, Andrei Shleifer, and Robert Vishny (forthcoming) "A model of shadow banking," *Journal of Finance*.

Gerali, Andrea, Sefano Neri, Luca Sessa, and Federico M. Signoretti (2010) "Credit and banking in a DSGE model of the Euro Area," *Journal of Money, Credit and Banking*, Vol. 42, pp. 107–141.

Gertler, Mark (2010) "Macroeconomics in the wake of the financial crisis," *Journal of Money, Credit and Banking*, Vol. 42, pp. 217–219.

Gertler, Mark and Peter Karadi (2011) "A model of unconventional monetary policy," *Journal of Monetary Economics*, Vol. 58, pp. 17–34.

Gertler, Mark and Nobuhiro Kiyotaki (2011) "Financial intermediation and credit policy in business cycle analysis," in *Handbook of Monetary Economics*, Vol. 3A: Elsevier, Chap. 11, pp. 547–599.

Gertler, Mark, Nobuhiro Kiyotaki, and Alberto Queralto (2012) "Financial crises, bank risk exposure and government financial policy," *Journal of Monetary Economics*, Vol. 59, pp. S17–S34.

Goodhart, Charles A. E., Anil K. Kashyap, Dimitrios P. Tsomocos, and Alexandros P. Vardoulakis (2012) "Financial regulation in general equilibrium," March, NBER Working Paper 17909.

Gorton, Gary and Andrew Metrick (2012a) "Securitized banking and the run on repo," *Journal of Financial Economics*, Vol. 104, pp. 425–451.

——— (2012b) "Getting up to speed on the financial crisis: A one-weekend-reader's guide," *Journal of Economic Literature*, Vol. 50, pp. 128–150.

Hanson, Samuel G., Anil K. Kashyap, and Jeremy C. Stein (2011) "A macroprudential approach to financial regulation," *Journal of Economic Perspectives*, Vol. 25, pp. 3–28.

Hobijn, Bart and Federico Ravenna (2010) "Loan securitization and the monetary transmission mechanism," September, Working Paper.

Holmström, Bengt and Jean Tirole (1997) "Financial intermediation, loanable funds and the real sector," *Quarterly Journal of Economics*, Vol. 112(3), pp. 663–691.

——— (2011) *Inside and outside liquidity*: MIT.

International Monetary Fund (2009) *Global Financial Stability Report: Navigating the Financial Challenges Ahead*: International Monetary Fund, Washington D.C.

Kiyotaki, Nobuhiro and John Moore (2005) "Financial deepening," *Journal of the European Economic Association*, Vol. 3, pp. 701–713.

Kurlat, Pablo (2010) "Lemons, market shutdowns and learning," October, Working Paper.

Loutskina, Elena and Philip E. Strahan (2009) "Securitization and the declining impact of bank finance on loan supply: Evidence from mortgage originations," *Journal of Finance*, Vol. 60, pp. 861–889.

Meh, Césaire A. and Kevin Moran (2010) "The role of bank capital in the propagation of shocks," *Journal of Economic Dynamics and Control*, Vol. 34, pp. 555–576.

Nadauld, Taylor D. and Michael S. Weisbach (forthcoming) "Did securitization affect the cost of corporate debt?" *Journal of Financial Economics*.

Perotti, Enrico (2010) "Systemic liquidity risk and bankruptcy exceptions," October, CEPR Policy Insight No. 52.

Pozsar, Zoltan (2011) "Institutional cash pools and the Triffin dilemma of the U.S. banking system," August, IMF Working Paper 11/190.

Pozsar, Zoltan, Tobias Adrian, Adam Ashcraft, and Hayley Boesky (2010) "Shadow banking," July, FRB New York Staff Report no. 458.

Shin, Hyun Song (2009) "Securitisation and financial stability," *Economic Journal*, Vol. 119, pp. 309–332.

Smets, Frank and Raf Wouters (2003) "An estimated dynamic stochastic general equilibrium model of the Euro area," *Journal of the European Economic Association*, Vol. 1, pp. 1123–1175.

Tirole, Jean (2006) *The Theory of Corporate Finance*: Princeton.

——— (2011) "Illiquidity and all its friends," *Journal of Economic Literature*, Vol. 49, pp. 287–325.

Tucker, Paul (2010) "Shadow banking, financing markets and financial stability," January, Remarks at a BCG partners seminar, London.

Verona, Fabio, Manuel Martins, and Inês Drumond (2011) "Monetary policy shocks in a DSGE model with a shadow banking system," CEF.UP Working Paper.

Woodford, Michael (2010) "Financial intermediation and macroeconomic analysis," *Journal of Economic Perspectives*, Vol. 24, pp. 21–44.

Additional Material

A Solution for the bank and broker problems

In this Appendix, we lay out the approach taken to solving the financial sector block of the model where banks and brokers share the risks attaching to securitized assets.

Commercial banks

We seek a solution to the Bellman equation:

$$V_{t-1}^c = \max_{\{s_{t-1}^c, m_{t-1}^c, d_{t-1}\}} \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n_t^c + \sigma V_t^c\right] \tag{A.1}$$

subject to the balance sheet (1), incentive compatibility (5), and non-negativity constraints. Guess, and later verify, that the value function is linear in the time-varying coefficients $\{v_{st}^c, v_{mt}^c, v_t^c\}$:

$$V_t^c = \left(\frac{v_{st}^c}{Q_t}\right)Q_t s_t^c + \left(\frac{v_{mt}^c}{q_t}\right)q_t m_t^c - v_t^c d_t \tag{A.2}$$

After using (1) to substitute out for ABS, we get the Lagrangian:

$$\mathcal{L} = (1+\lambda_t^c)\left[\left(\frac{v_{st}^c}{Q_t} - \frac{v_{mt}^c}{q_t}\right)Q_t s_t^c + \left(\frac{v_{mt}^c}{q_t} - v_t^c\right)d_t + \left(\frac{v_{mt}^c}{q_t}\right)n_t^c\right] \\ - \lambda_t^c\theta_c[\omega_c Q_t s_t^c + (1-\omega_c)d_t + (1-\omega_c)n_t^c] \tag{A.3}$$

where λ_t^c is the Lagrange multiplier on (5). The first order necessary conditions for $\{s_t^c, d_t, \lambda_t^c\}$ are:

$$\mu_{st}^c \leq \theta_c\omega_c\frac{\lambda_t^c}{1+\lambda_t^c}, \quad \text{with equality if} \quad s_t^c > 0 \tag{A.4a}$$

$$\frac{v_{mt}^c}{q_t} - v_t^c \leq \theta_c(1-\omega_c)\frac{\lambda_t^c}{1+\lambda_t^c}, \quad \text{with equality if} \quad d_t > 0 \tag{A.4b}$$

$$(\mu_t^c - \theta_c\omega_c)Q_t s_t^c + (v_{mt}^c/q_t - v_t^c - \theta_c[1-\omega_c])d_t + (v_{mt}^c/q_t - \theta_c[1-\omega_c])n_t^c \geq 0 \\ \text{with equality if } \lambda_t^c > 0 \tag{A.4c}$$

where $\mu_{st}^c := v_{st}^c/Q_t - v_{mt}^c/q_t$, and we note for future reference that if (A.4a) and (A.4b) hold with equality then the excess marginal values of ABS over deposits, and loans over ABS, are related by

$$\frac{v_{mt}^c}{q_t} - v_t^c = \left(\frac{1-\omega_c}{\omega_c}\right)\mu_{st}^c \tag{A.5}$$

When the banker's constraint binds, $\lambda_t^c > 0$, then using (A.4c) and (A.5) we find demand for on balance sheet loans is given by:

$$Q_t s_t^c = \gamma_{dt} d_t + \gamma_{nt} n_t^c \tag{A.6}$$

where

$$\gamma_{dt} := \frac{\theta_c(1-\omega_c) - \mu_{st}^c(1-\omega_c)/\omega_c}{\mu_{st}^c - \theta_c\omega_c} \quad \text{and} \quad \gamma_{nt} := \frac{\theta_c(1-\omega_c) - v_{mt}^c/q_t}{\mu_{st}^c - \theta_c\omega_c}$$

Using the demand function to eliminate $Q_t s_t^c$ from the candidate value function (A.2) and rearranging, we obtain:

$$V_t^c = \mu_{st}^c \left\{\gamma_{dt} + (1-\omega_c)/\omega_c\right\} d_t + \left\{v_{mt}^c/q_t + \mu_{st}^c\gamma_{nt}\right\} n_t^c \tag{A.7}$$

The term inside the first braces vanishes because the numerator becomes zero. Thus any level of deposits, given a particular return on loans, is seen to yield an identical going concern value for the bank. As a consequence the banking system can scale up or down to absorb any amount of household savings; put another way, there is no constraint on households' ability to save. The term inside the second braces, multiplying net worth, is non-zero:

$$\begin{aligned} v_{mt}^c/q_t + \mu_{st}^c\gamma_{nt} &= \frac{v_{mt}^c}{q_t} + \mu_{st}^c \frac{\theta_c(1-\omega_c) - v_{mt}^c/q_t}{\mu_{st}^c - \theta_c\omega_c} \\ &= (1+\lambda_t^c)(v_{mt}^c/q_t) - \lambda_t^c\theta_c(1-\omega_c) \end{aligned} \tag{A.8}$$

where to get the second line, one uses (A.4a) and the assumption that the bank holds some loans on balance sheet, $s_t^c > 0$.

The final step is to plug the candidate value function into the Bellman equation (A.1):

$$\begin{aligned} &\mu_{t-1}^c Q_{t-1} s_{t-1}^b + (v_{m,t-1}^c/q_{t-1} - v_{t-1}^c) d_{t-1} + (v_{m,t-1}^c/q_{t-1}) n_{t-1}^b = \\ &\qquad \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n_t^c + \sigma\{(1+\lambda_t^c)(v_{mt}^c/q_t) - \lambda_t^c\theta_c(1-\omega_c)\}n_t^c\right] \end{aligned} \tag{A.9}$$

Define $\Omega_t^c := (1-\sigma) + \sigma\{(1+\lambda_t^c)v_{mt}^c/q_t - \theta_c(1-\omega_c)\lambda_t^c\}$, then:

$$\begin{aligned} \mu_{t-1}^c Q_{t-1} s_{t-1}^b + (v_{m,t-1}^c/q_{t-1} - v_{t-1}^c) d_{t-1} + (v_{m,t-1}^c/q_{t-1}) n_{t-1}^b &= \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^c n_t^c \\ = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^c \left\{(R_{st} - R_{mt})Q_{t-1}s_{t-1}^c + (R_{mt} - R_t)d_{t-1} + R_{mt}n_{t-1}^c\right\} \end{aligned} \tag{A.10}$$

where the second line used the law of motion for net worth. Equating terms on $\{s_{t-1}^c, n_{t-1}^c\}$, the solution for the coefficients in (A.2) can be seen to be:

$$\mu_{s,t-1}^c = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^c(R_{st} - R_{mt}) \tag{A.11a}$$

$$v_{t-1}^c = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^c R_t \tag{A.11b}$$

$$\frac{v_{m,t-1}^c}{q_{t-1}} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^c R_{mt} \tag{A.11c}$$

Brokers

The solution to the broker's problem proceeds in parallel fashion to that of the banker's problem. We seek a solution to the Bellman equation

$$V_{t-1}^b = \max_{\{s_{t-1}^b, m_{t-1}^b\}} \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n_t^b + \sigma V_t^b\right] \tag{A.12}$$

subject to the balance sheet (12), incentive compatibility (14), and non-negativity constraints. Guess, and later verify, that the value function is linear in the time-varying coefficients $\{v_{st}^b, v_{mt}^b\}$:

$$V_t^b = \left(\frac{v_{st}^b}{Q_t}\right) Q_t s_t^b - \left(\frac{v_{mt}^b}{q_t}\right) q_t m_t^b \tag{A.13}$$

After using (12) to substitute out for ABS, we get the Lagrangian:

$$\mathcal{L} = (1+\lambda_t^b)\left[\left(\frac{v_{st}^b}{Q_t} - \frac{v_{mt}^b}{q_t}\right) Q_t s_t^b + \left(\frac{v_{mt}^b}{q_t}\right) n_t^b\right] - \lambda_t^b \theta_b Q_t s_t^b \tag{A.14}$$

where λ_t^b is the Lagrange multiplier on (14). The first order necessary conditions for $\{s_t^b, \lambda_t^b\}$ are:

$$\mu_{st}^b \leq \theta_b \frac{\lambda_t^b}{1+\lambda_t^b}, \quad \text{with equality if} \quad s_t^b > 0 \tag{A.15a}$$

$$\left(\mu_{st}^b - \theta_b\right) Q_t s_t^b + \left(\frac{v_{mt}^b}{q_t}\right) n_t^b \geq 0 \quad \text{with equality if } \lambda_t^b > 0 \tag{A.15b}$$

where $\mu_{st}^b := v_{st}^b/Q_t - v_{mt}^b/q_t$. When the broker's constraint binds, $\lambda_t^b > 0$, then using (A.15b) we find demand for loan bundles is given by:

$$Q_t s_t^b = \frac{v_{mt}^b/q_t}{\theta_b - \mu_t^b} n_t^b \tag{A.16}$$

Using this function to eliminate $Q_t s_t^b$ from the candidate value function (A.13) and rearranging, we obtain:

$$V_t^b = v_{mt}^b/q_t(1+\lambda_t^b)n_t^b \tag{A.17}$$

which can be plugged into the Bellman equation (A.12) to find:

$$\mu_t^b Q_{t-1}s_{t-1}^b + \frac{v_{mt}^b}{q_t} n_{t-1}^b = \mathrm{E}_{t-1}\Lambda_{t-1,t}\left\{(1-\sigma)n_t^b + \sigma\frac{v_{mt}^b}{q_t}(1+\lambda_t^b)n_t^b\right\} \tag{A.18}$$

Define $\Omega_t^b := (1-\sigma) + \sigma(1+\lambda_t^b)v_{mt}^b/q_t$, then:

$$\begin{aligned}\mu_t^b Q_{t-1}s_{t-1}^b + \frac{v_{mt}^b}{q_t} n_{t-1}^b &= \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^b n_t^b \\ &= \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega_t^b\left\{(R_{st} - R_{mt})Q_{t-1}s_{t-1}^b + R_{mt}n_{t-1}^b\right\}\end{aligned} \tag{A.19}$$

where the second line used the law of motion for net worth. Equating terms on $\{s^b_{t-1}, n^b_{t-1}\}$, the solution for the coefficients in (A.13) can be seen to be:

$$\mu^b_{t-1} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^b_t(R_{st} - R_{mt}) \tag{A.20a}$$

$$\frac{v^b_{m,t-1}}{q_{t-1}} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^b_t R_{mt} \tag{A.20b}$$

B Summary of baseline model equations

This appendix gathers together the model equation for the baseline bank-broker economy described in the main text.

Banks

$$\lambda^c_t = \mu^c_{st}/(\theta_c\omega_c - \mu^c_{st}) \tag{B.1}$$

$$(\theta_c\omega_c - \mu^c_{st})Q_tS^c_t = (v^c_{mt} - \theta_c[1-\omega_c])N^c_t + (v^c_{mt} - v^c_t - \theta_c[1-\omega_c])D_t \tag{B.2}$$

$$v^c_{mt} - v^c_t = \theta_c(1-\omega_c)\lambda^c_t/(1+\lambda^c_t) \tag{B.3}$$

$$\mu^c_{st} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^c_{t+1}(R_{s,t+1} - R_{m,t+1}) \tag{B.4}$$

$$v^c_t = \mathrm{E}_t\Lambda_{t,t+1}\Omega^c_{t+1}R_{t+1} \tag{B.5}$$

$$v^c_{mt} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^c_{t+1}R_{m,t+1} \tag{B.6}$$

$$\mathrm{E}_t\Lambda_{t,t+1}\Omega^c_tR^{\mathrm{PT}}_{m,t+1} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^c_tR^{\mathrm{D}}_{m,t+1} \tag{B.7}$$

where

$$\Omega^c_t = (1-\sigma) + \sigma\left\{(1+\lambda^c_t)v^c_{mt} - \theta_c(1-\omega_c)\lambda^c_t\right\} \tag{B.8}$$

Aggregate commercial bank net worth and balance sheet identity:

$$N^c_t = (\sigma + \xi_c)\left\{R_{st}Q_{t-1}S^c_{t-1} + R_{mt}M^c_{t-1}\right\} - \sigma R_tD_{t-1} + N^b_*\epsilon^n_t \tag{B.9}$$

$$D_t = Q_tS^c_t + M^c_t - N^c_t \tag{B.10}$$

where N^b_* is the steady state aggregate net worth of the broker sector, and ϵ^n_t is an i.i.d. random variable.

Brokers

$$\lambda^b_t = \mu^b_{st}/(\theta_b - \mu^b_{st}) \tag{B.11}$$

$$Q_tS^b_t = v^b_{mt}/(\theta_b - \mu^b_{st}) \cdot N^b_t \tag{B.12}$$

$$\mu^b_{st} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^b_{t+1}(R_{s,t+1} - R_{m,t+1}) \tag{B.13}$$

$$v^b_{mt} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^b_{t+1}R_{m,t+1} \tag{B.14}$$

$$\mathrm{E}_t\Lambda_{t,t+1}\Omega^b_tR^{\mathrm{PT}}_{m,t+1} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^b_tR^{\mathrm{D}}_{m,t+1} \tag{B.15}$$

where

$$\Omega_t^b = (1-\sigma) + \sigma(1+\lambda_t^b)v_{mt}^b \tag{B.16}$$

Aggregate broker net worth and balance sheet identity:

$$N_t^b = (\sigma + \xi_b)R_{st}Q_{t-1}S_{t-1}^b - \sigma R_{mt}M_{t-1}^b - N_*^b\epsilon_t^n \tag{B.17}$$

$$Q_t S_t^b = N_t^b + M_t^b \tag{B.18}$$

Households and firms

$$u'(C_t) = \mathrm{e}^{\zeta_t}(C_t - hC_{t-1})^{-1} \tag{B.19}$$

$$\Lambda_{t,t+1} = \beta u'(C_{t+1})/u'(C_t) \tag{B.20}$$

$$W_t u'(C_t) = \chi L_t^{\varphi} \tag{B.21}$$

$$Y_t = \mathrm{e}^{a_t}K_t^{\alpha}L_t^{1-\alpha} \tag{B.22}$$

$$Z_t = \alpha \mathrm{e}^{a_t}(L_t/K_t)^{1-\alpha} \tag{B.23}$$

$$W_t = (1-\alpha)\mathrm{e}^{a_t}(L_t/K_t)^{-\alpha} \tag{B.24}$$

$$K_{t+1} = [I_t + (1-\delta)K_t] \tag{B.25}$$

$$Q_t = 1 + f(I_t/I_{t-1}) + (I_t/I_{t-1})f'(I_t/I_{t-1}) - \mathrm{E}_t\Lambda_{t,t+1}(I_{t+1}/I_t)^2 f'(I_{t+1}/I_t) \tag{B.26}$$

where $f(1) = f'(1) = 0$ and $\varepsilon := f''(1) > 0$. Returns are given by:

$$R_{st} = \{Z_t + (1-\delta)Q_t\}/Q_{t-1} \tag{B.27}$$

$$R_{mt}^{\mathrm{PT}} = \{Z_t + (1-\delta)q_t\}/q_{t-1} \tag{B.28}$$

$$R_{mt} = \eta R_{mt}^{\mathrm{PT}} + (1-\eta)R_{mt}^{\mathrm{D}} \tag{B.29}$$

Market clearing

Goods market, loan market and ABS market clearing conditions:

$$Y_t = C_t + [1 + f(I_t/I_{t-1})]I_t \tag{B.30}$$

$$S_t^c + S_t^b = K_{t+1} \tag{B.31}$$

$$\eta_t^c = \eta_t^b \tag{B.32}$$

$$M_t^c = M_t^b \tag{B.33}$$

Exogenous processes

The logarithm of the productivity forcing process is:

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{B.34}$$

while the log consumption preference process is:

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \epsilon_t^\zeta \tag{B.35}$$

and ϵ_t^a, ϵ_t^ζ and (above) ϵ_t^n are i.i.d. random variables.

C Proofs

Proof of Proposition 1 (Equilibrium ABS spread). As discussed in the main text, $\mu_{mt}^c = \mu_{mt}^b = 0$. In equilibrium $\eta_t^c = \eta_t^b$, and so returns on pass-through and debt ABS are equalized in steady state, $R_m^{\mathrm{PT}} = R_m^{\mathrm{D}}$ as is then immediate from (11b) and (20c). Intuitively, equally liquid securities must have equal returns in the absence of risk.

For the main part of the proposition, we note that in a deterministic steady state, (B.4) means we can write bank shadow prices as

$$\mu^c = \beta\Omega^c(R_s - R_m)$$

Equate this expression with μ^c in (B.1) to obtain

$$\beta\Omega^c(R_s - R_m) = \theta_c\omega_c\lambda^c/(1+\lambda^c) \tag{C.1}$$

From (B.5) and (B.6), we have that

$$v_m^c/q - v^c = \beta\Omega^c(R_m - R)$$

Combining with (B.3) we obtain

$$\beta\Omega^c(R_m - R) = \theta_c(1-\omega_c)\lambda^c/(1+\lambda^c) \tag{C.2}$$

Because the bank's incentive constraint binds in steady state, $\lambda^c > 0$, we can divide (C.1) by (C.2) to obtain

$$\frac{R_s - R_m}{R_m - R} = \frac{\omega_c}{1-\omega_c} \tag{C.3}$$

which upon rearrangement yields the desired result:

$$R_m = (1-\omega_c)R_s - \omega_c R$$

□

Comment: We may use the preceding result to solve for steady state q. From the definitions of returns

$$R_s - R_m^{\mathrm{PT}} = Z(1-(1/q)) \tag{C.4}$$

Using the equalities $R_m^{\mathrm{PT}} = R_m^{\mathrm{D}} = R_m$, we can use the result of Proposition 1 to obtain:

$$q = \frac{1}{1 - \frac{(1-\omega_c)(R_s - R)}{Z}} \tag{C.5}$$

D Data

In this appendix, we give details of our data construction and sources, and of correlations between financial and real variables.

D.1 Data used for calibration

We calibrate the model to match average pre-crisis values of key financial variables. To form an estimate of leverage in commercial and shadow banking, and of securitization activity, we use detailed bank-level data on US commercial banks from the FDIC Call Reports, and micro data on residential mortgage securitizations.

First, we construct a 'real economy' leverage ratio for commercial banks as the ratio of *net loans and leases* minus *loans to depository institutions* divided by Tier 2 capital ((lnlsnet - (lndepcb + lndepusb + lndepus + lndepfc + lndepfus) / (rbct1j + rbct2)). This relatively narrow definition of the asset base, which strips out interbank credit and other assets, gives the most relevant point of comparison to the model presented in the main text. The ratio moves between 4.5 and 5.5 between 1992 and 2009; our calibration reflects its lower, early-1990s value.

We can gauge the significance of commercial banks' securitization activity by looking at bank assets sold and securitized (szlnres + szlnhel + szlauto + szlncon + szlnci + szlnoth). This includes sales of mortgages, credit card loans, auto loans, other consumer loans and commercial and industrial loans on which the seller retains servicing and/or provides credit enhancement[1]. For the full sample of banks, this accounted for 14% of total financial assets and 24% of the stock of *Loans and Leases*. For the sub-sample of 'active' banks, namely those for which total securitization is positive for at least one quarter, the figures are 19% and 35% respectively.

Lastly, we measure shadow bank leverage by looking at the leverage in mortgage securitizations. Specifically, we take the ratio of total UK RMBS securitizations to the value of tranches rated B1 and below, taken from Moody's.

As mentioned in the main text, ABS spreads were collected from JP Morgan DataQuery, and are the 2000-2007 average over comparable swap rates.

D.2 Cycles and correlations

The Call Report data does not include non-bank intermediaries, and covers a fairly short period as far as securitization is concerned. Hence, in order to analyze the joint cyclical properties of bank and non-bank credit we turn to the Flow of Funds (as in den Haan and Sterk, 2010). Following Adrian and Shin (2010), we include U.S.-Chartered

[1]The series are only available from 2001; banks with total assets below \$200m are not required to report their exposures.

Commercial Banks, Savings Institutions and Credit Unions in the traditional banking sector (C), and define the shadow banking sector (B) as the sum of Security Brokers and Dealers, Issuers of Asset-Backed Securities, Agency- and GSE-Backed Mortgage Pools, and Government-Sponsored Enterprises. When the distinction between types of traditional banks is irrelevant, we refer to the C aggregate as 'commercial banks'.

We measure shadow bank credit by the stock of Credit Market Instruments (CMI)[2]. Following den Haan and Sterk, we construct a measure of the stock of structured credit products (henceforth MBS) held by the traditional banking sector as the sum of the ABS and CMO components of the *Agency and GSE-backed securities and Corporate and Foreign Bonds* items held by commercial banks, credit unions and savings institutions. We use this as a proxy for the size of the intra-financial flows described by our model. Traditional bank credit is then measured as Credit Market Instruments minus MBS.

Output and investment come from the Federal Reserve Economic Data (FRED) at the St. Louis Fed. Output is Gross Domestic Product at 2005 dollars (GDP), investment is the sum of Gross Private Domestic Investment (GPDI) and Personal Consumption Expenditure on Durables (PCDG). Variables are deflated by the GDP deflator (GDPDEF, also from FRED) and seasonally adjusted. All variables are detrended using the Hodrick-Prescott filter unless otherwise specified.

Chart 1 in the main text shows HP-filtered cycles for bank and shadow bank credit. The two cycles display markedly different behavior, particularly over the 1990-2007 period when securitization markets developed. Commercial bank credit is strongly pro-cyclical, whereas shadow bank credit is counter-cyclical (Table D.1). A similar pattern emerges for narrower measures of 'real economy' credit such as total mortgages or consumer credit. These results are consistent with den Haan and Sterk, but suggest that bank and non-bank credit responded in a different way to most of the shocks that hit the economy over these two decades (rather than just monetary policy shocks).

Chart D.1 compares shadow bank holdings of mortgages with the stock of MBS on commercial bank balance sheets. The comovement between the two series is consistent with the fact that a significant fraction of funding consists of ABS held by the commercial banking sector. This corroborates the accounting identities on the basis of which we model intra-financial flows (the two variables coincide in our model). Given the counter-cyclicality of shadow bank credit documented in Table D.1, the chart also shows that securitization is by this metric itself counter-cyclical, consistent with the model presented in the main text.

Table D.1 summarizes the cyclical properties of credit and leverage by type of institution. Our baseline sample is 1984Q1-2007Q2, and so spans the period from the end of the Volker disinflation to the end of the Great Moderation. We also report correlations

[2]CMI include consumer credit, bank loans not elsewhere classified, open market paper, total mortgages, nonfinancial sector customers' (except Federal Government) liabilities on acceptances outstanding, total U.S. government securities, municipal securities and loans, and corporate and foreign bonds.

for the full sample, which ends in 2011Q2 and includes the 2007-9 subprime crisis and Great Recession. We investigate the stability of the correlations more systematically below. Commercial bank (C) credit is pro-cyclical, while S credit is counter-cyclical. As the bottom of the table shows, the signs of the correlations are broadly robust across the individual constituents of the two macro-sectors, and are not an artefact of our (somewhat arbitrary) aggregation. In particular, GSEs contribute to, but are not the exclusive driver of, the counter-cyclicality of shadow bank credit. C's MBS holdings are weakly counter-cyclical.

The lower panel of Table D.1 reports statistics for the leverage ratio of commercial banks and broker-dealers. These are the 'traditional' and 'market-based' intermediaries for which the ratio has a fairly straightforward interpretation, and can be constructed to match the model presented in the main text. A broader set of results is presented in Table D.3 below. In both cases, the numerator of the ratio is broad credit variable CMI. For commercial banks we can measure the denominator as CMI minus Deposits, to bring it in line with the real economy counterpart analyzed in the model. For broker-dealers, which are not deposit funded, it is *Total Financial Assets* minus *Total Liabilities*[3]. Over the 1984-2007 sample, both ratios are significantly counter-cyclical. For Broker-Dealers, the sign of the correlation changes if the sample is extended to include the crisis.

D.3 Robustness

The cyclical properties of credit and leverage are important for the analysis presented in the main text, and they have been the subject of extensive investigations. In this section we examine the robustness of the key messages conveyed by table D.1 along various dimensions, and relate them to other existing studies.

Table D.2 recomputes the correlations in table D.1 with the Baxter-King filter. A BK band pass filter delivers very similar results to HP. The estimated cycles tend to be less volatile, and the correlations higher, but their signs do not change.

Figure D.2 shows 10-year rolling correlations between output and credit for the aggregate commercial and shadow bank sectors. Of interest here is the stability of the numbers reported in table D.1 over time, and their robustness to alternative definitions of 'credit' which are respectively broader (Total Financial Assets) and narrower (Mortgages) than our preferred measure (CMI). The three measures behave in a very similar way for each sector. The claim that commercial bank credit is pro-cyclical is very strongly corroborated by the chart. For shadow banks, the conclusion is somewhat more sample-dependent, but the correlation is negative for much of the 1984-2007 period.

In a similar spirit, figure D.3 shows 10-year rolling correlations between output and the commercial bank and broker-dealer leverage ratios used in table D.1. The counter-

[3]We thus use a standard measure of net worth, but restrict the asset base to include credit instruments only.

cyclicality of the former is consistent over the whole sample period. For broker-dealers the correlation is typically weaker, but again consistently negative until the crisis. In table D.3 we report pre-crisis output correlations for a range of institutions and definitions of leverage, from broad to narrow. Note that the underlying leverage ratios are not equally reliable and informative, but subject to this caveat, the broad conclusion from the table is that counter-cyclical leverage ratios are the norm. It is particularly pronounced for the aggregate traditional banking sector, but is shared by GSEs and, on the CMI-based measure, Broker-Dealers.

The finding of counter-cyclical (credit) or acyclical (total assets) broker-dealer leverage in table D.3 should be compared to the analysis of Adrian and Shin (2010), and Berrospide and Edge (2010). These authors focus on the correlation between leverage and *assets*, pointing to their strongly positive relationship. Figure D.4 shows rolling correlations between leverage and assets (again in deviations from the HP trend) for commercial banks and broker-dealers. Using *Total Financial Assets*, the Adrian and Shin results can be replicated: Assets and leverage are positively correlated for broker-dealers (which tend to lever up when their balance sheets expand), and zero for commercial banks.

Table D.1: Correlation between output and credit, Hodrick-Prescott filtering

	1984Q1 - 2007Q2	1984Q1 - 2011Q2
Output	1 (-)	1 (-)
Investment	0.80 (0.06)	0.84 (0.05)
Aggregate C,B sectors:		
Total credit	0.12 (0.10)	0.19 (0.19)
C credit	0.44 (0.09)	0.34 (0.09)
C credit ex MBS	0.51 (0.09)	0.40 (0.09)
C MBS	-0.16 (0.10)	-0.14 (0.10)
B credit	-0.35 (0.10)	-0.06 (0.10)
Credit, individual institutions		
CB credit	0.37 (0.10)	0.28 (0.09)
CU credit	-0.14 (0.10)	-0.16 (0.10)
SI credit	0.56 (0.09)	0.63 (0.07)
GSE credit	-0.26 (0.10)	0.02 (0.10)
ABS credit	0.10 (0.10)	0.24 (0.09)
MP credit	-0.39 (0.10)	-0.15 (0.10)
BD credit	-0.22 (0.10)	-0.02 (0.10)
Aggregate C,B sectors:		
CB leverage	-0.34 (0.10)	-0.28 (0.09)
BD leverage	-0.23 (0.10)	0.23 (0.09)

Note: CB - commercial banks; CU - credit unions; SI - savings institutions; ABS - Issuers of ABS; MP - mortgage pools; BD - broker-dealers; GSE - Government Sponsored Enterprises. Correlations among HP-filtered cycles in real output and Credit Market Instruments. Standard errors in parentheses. Data source: United States Flow of Funds.

Table D.2: Correlation between output and credit, Baxter-King filtering

	1984Q1 - 2007Q2	1984Q1 - 2011Q2
Output	1 (-)	1 (-)
Investment	0.83 (0.06)	0.83 (0.05)
Aggregate C,B sectors:		
Total credit	0.20 (0.10)	0.49 (0.08)
C credit	0.52 (0.09)	0.57 (0.09)
C credit ex MBS	0.59 (0.08)	0.65 (0.07)
C MBS	-0.14 (0.10)	-0.38 (0.09)
B credit	-0.40 (0.10)	0.15 (0.10)
Credit, individual institutions		
CB credit	0.43 (0.09)	0.51 (0.08)
CU credit	-0.02 (0.10)	-0.12 (0.10)
SI credit	0.64 (0.08)	0.70 (0.07)
GSE credit	-0.09 (0.10)	-0.26 (0.10)
ABS credit	0.12 (0.10)	0.29 (0.09)
MP credit	-0.55 (0.09)	-0.15 (0.10)
BD credit	-0.21 (0.10)	-0.05 (0.10)
Aggregate C,B sectors:		
CB leverage	-0.44 (0.09)	-0.44 (0.09)
BD leverage	-0.24 (0.10)	0.13 (0.10)

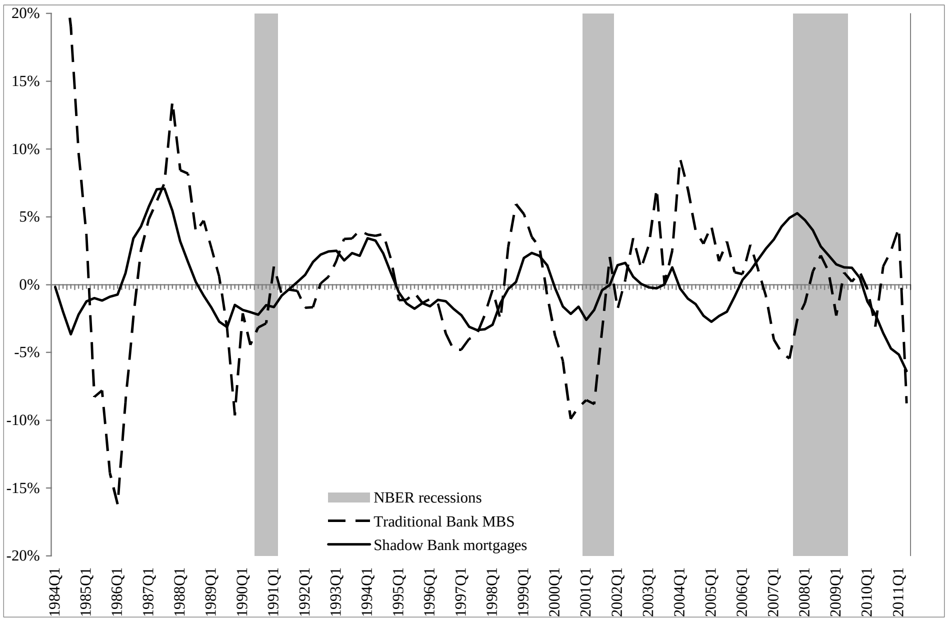
Note: CB - commercial banks; CU - credit unions; SI - savings institutions; ABS - Issuers of ABS; MP - mortgage pools; BD - broker-dealers; GSE - Government Sponsored Enterprises. Correlations among HP-filtered cycles in real output and Credit Market Instruments. Standard errors in parentheses. Data source: United States Flow of Funds.

Table D.3: Correlation between output and leverage, by institution

Institution	Total Financial Asset Leverage	Credit Leverage	Narrow Credit Leverage
CB	0.07 (0.10)	0.07 (0.10)	-0.34 (0.10)
CU	-0.45 (0.09)	-0.01 (0.10)	-0.02 (0.10)
SI	-0.21 (0.10)	-0.21 (0.10)	-0.05 (0.10)
ABS	-0.04 (0.10)	-0.02 (0.10)	-
GSE	-0.51 (0.09)	-0.51 (0.09)	-
BD	0.10 (0.10)	-0.23 (0.10)	-

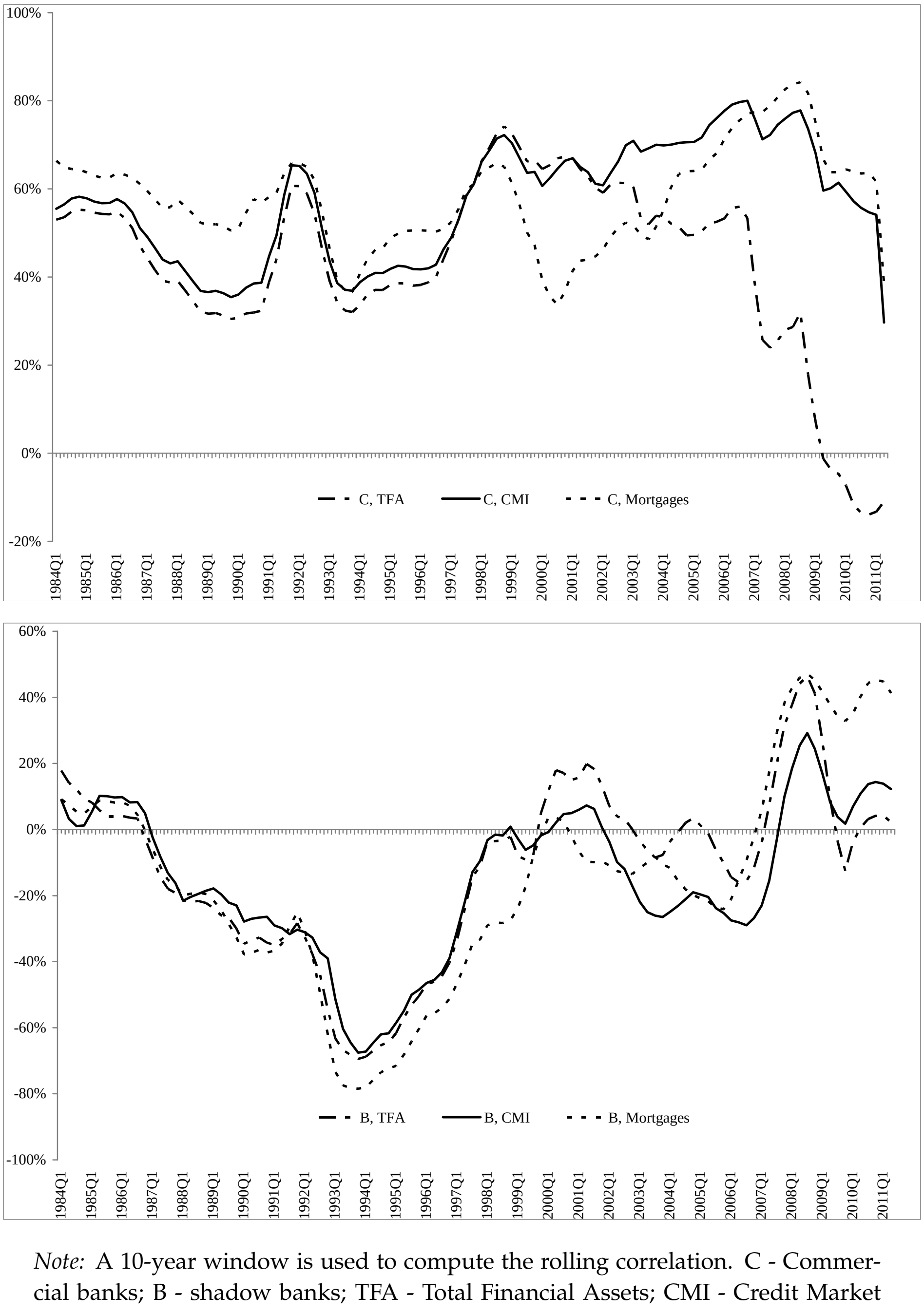
Note: CB - commercial banks; CU - credit unions; SI - savings institutions; ABS - Issuers of ABS; MP - mortgage pools; BD - broker-dealers; GSE - Government Sponsored Enterprises. Correlations among HP-filtered cycles in real output and (a) Total Financial Asset Leverage = TFA/(TFA-TL); (b) Credit Leverage = CMI/(TFA-TL); (c) Narrow Credit Leverage = CMI/(CMI-Deposits). Sample is 1984Q4–2007Q (94 observations). Standard errors in parentheses. Data source: United States Flow of Funds.

Figure D.1: Shadow bank mortgages and commercial bank stock of MBS



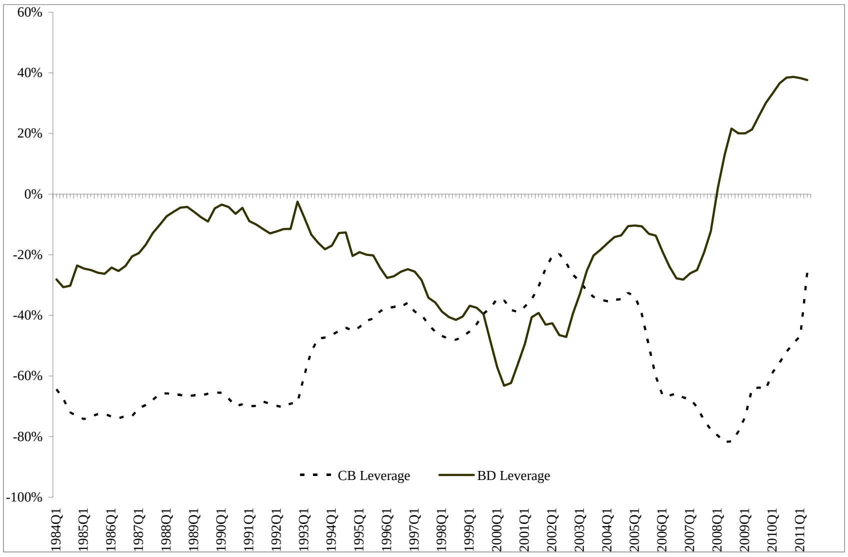
Note: Data source: United States Flow of Funds.

Figure D.2: Rolling correlations between output and commercial and shadow bank credit



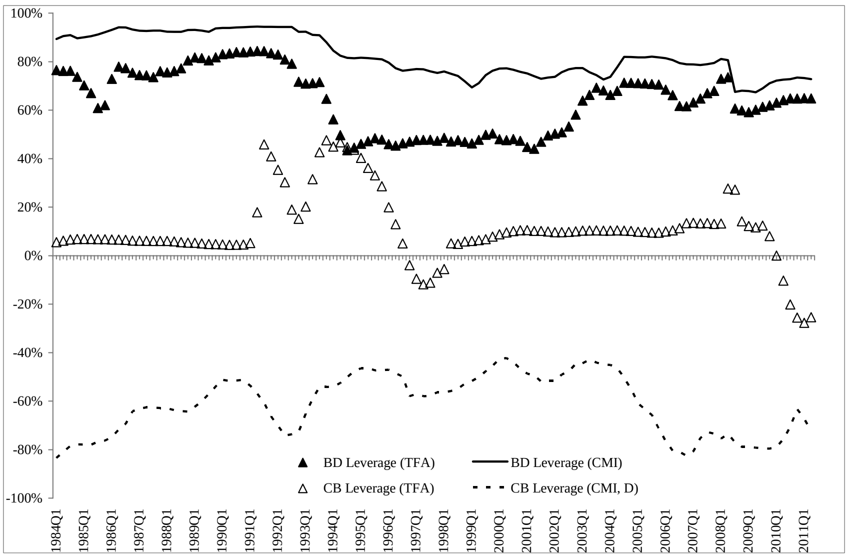
Note: A 10-year window is used to compute the rolling correlation. C - Commercial banks; B - shadow banks; TFA - Total Financial Assets; CMI - Credit Market Instruments. Data source: United States Flow of Funds.

Figure D.3: Rolling correlation between output and leverage



Note: A 10-year window is used to compute the rolling correlation. Commercial bank (CB) leverage = CMI/(CMI-Deposits); Broker-dealer (BD) leverage = CMI/(TFA-TL). Data source: United States Flow of Funds.

Figure D.4: Rolling correlation between leverage and asset growth



Note: A 10-year window is used to compute the rolling correlation. Year-on-year growth rates used for asset measures. CB - Commercial banks; BD - Broker dealers; TFA - Total financial assets; CMI - Credit market instruments. Data source: United States Flow of Funds.

References

Adrian, Tobias and Hyun Song Shin (2010) "Liquidity and leverage," *Journal of Financial Intermediation*, Vol. 19, pp. 418–437.

Berrospide, Jose M. and Rochelle M. Edge (2010) "The effects of bank capital on lending: What do we know and what does it mean?" *International Journal of Central Banking*, Vol. 6, pp. 5–54.

den Haan, Wouter J. and Vincent Sterk (2010) "The myth of financial innovation and the great moderation," *Economic Journal*, Vol. 121, pp. 707–739.