Shadow banks and macroeconomic instability

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Abstract

We develop a macroeconomic model in which commercial banks can offload risky loans to a highly levered 'shadow' banking sector, and financial intermediaries trade in securitized assets. We show how an endogenous tightening of shadow bank credit constraints can exacerbate the effect of shocks by limiting the ability of banks to securitize. The model is able to reproduce the cyclical behavior of bank and non-bank credit and leverage. Macroeconomic shocks that directly impact the worth of financial sector are particularly harmful to economic activity, but purely redistributive intra-financial shocks can also generate recessions. We discuss the relative ineffectiveness of stabilization policy aimed solely at the securitization markets.

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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 in particular underwent a shift, away from its traditional activities of loan origination and deposit issuing, towards a business model variously referred to as 'shadow' or 'securitized' banking (Gorton and Metrick, forthcoming)[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 led to financial instability, recession, and a substantial contraction in securitization activity. Yet shadow banking remains an important piece of the financial system even in the wake of the crisis. The share of all credit accounted for by the broadly defined shadow banking system remains substantial, ranging from around a fifth in Australia, France and the United Kingdom to more than a third in Canada and the United States, and policymakers maintain an active interest in shadow banking reform (Adrian and Shin, 2009; Tucker, 2010; Financial Stability Board, 2011).

Many accounts of the run-up to the subprime crisis have emphasized how flaws in the securitized banking model contributed to the eventual collapse in shadow banking activity. But there is also a need to understand the increasingly central role played by securitization in credit provision over the decades prior to the crisis. 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 also periods when shadow bank credit underwent cyclical expansion. 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 monetary tightening. Similar evidence has been found in bank level data (Altunbas, Gambacorta, and

[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). The financial system we describe later in this paper resembles the securitized banking model in Gorton and Metrick.

Marquez-Ibanez, 2009; Loutskina and Strahan, 2009)[2]. These observations suggest that a macroeconomic model which seeks to account for the behavior of intermediary credit should be able to account for the different behaviors of credit supply across institutions, as well as the collapse in securitization during the crisis.

In this paper, our main purpose is to construct a simple model that reproduces some of the key features of an economy in which traditional and shadow banking interact. We claim three contributions. First, we develop a quantitative 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 model can reproduce the cyclical properties of commercial and shadow bank credit when banks use securitization to gain pass-through exposure to a broad collateral pool[3]. Further, we show how high leverage in the shadow banking system combined with demand for risk free securities can amplify macroeconomic disturbances. Second, we demonstrate that even purely transitory disturbances within the financial sector ('cross sectional' shocks) can have long-lasting real effects, but that the ability of commercial banks to securitize protects the supply of credit in the face of some disturbances. Last, we show how in a securitization crisis government policies targeted at one part of the financial system, such as purchases of asset backed securities, can have spillover effects on the rest of the system which weaken the effectiveness of interventions. 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 Gertler, 2010, or Woodford, 2010).

The main elements of the model we develop can be summarized as follows. Financial intermediaries face endogenous balance sheet constraints which depend on their net worth, as in standard models of the financial accelerator. The commercial banking sector purchases primary claims from the economy's ultimate borrowers, which we will call loans. They optimally choose the amount of such loans to retain on balance sheet, and the amount to sell to the shadow banking system. Commercial banks then acquire claims

[2]Without a general equilibrium model, it is hard to assess the welfare consequences of these developments. The shift towards securitization helped to shield loan supply from shocks, but at the same time lengthened intermediation chains and so created conditions under which incentive problems were more acute.

[3]Securitization is the issuance of tradeable securities against the collateral of an underlying pool of assets, including mortgages, consumer credit or business loans. 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 (see section 3.2).

on shadow banks in the form of asset-backed securities (ABS)[4]. These claims, backed ultimately by pools of assets, are more pledgeable than the opaque and idiosyncratic on balance sheet loans they retain. By improving the quality of collateral on their balance sheets, the constraint on commercial banks is loosened, and they are able to increase their leverage and their profitability. Shadow banks can therefore be thought of as manufacturers of collateral, who take the raw material of loans produced by commercial banks, and transform it into ABS. 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[5].

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 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. A final limitation related to the foregoing points is that our analysis of securitization crises relies on exogenous shocks to liquidity and capital, as in some other recent work, rather than being microfounded (see Del Negro, Eggertsson, Ferrero, and Kiyotaki, 2011).

[4]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. In our model, ABS is backed by claims on physical capital.

[5]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.

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 banks and brokers, 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.

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)[6]. 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,

[6] 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.

commercial banks.

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. We do not analyze the consequences of changes in risk or in risk premiums explicitly, although we recognize the potential importance of both. However the approximation methods we employ when we solve the model are geared towards quantitative results, rather than the purely qualitative ones of Shin, and Adrian and Shin[7].

Our model shares with Gennaioli, Shleifer, and Vishny (2011) 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 is arguably 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. As in the present paper, Verona, Martins, and Drumond (2011) introduce a distinct class of financial intermediaries labeled shadow banks into a DSGE model. 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. Faia (2010) presents a model in which banks are able to sell loans on a secondary market to households, but buyers cannot observe whether the loan is being sold because of liquidity need, or because it is a lemon. She gives conditions under which bank leverage is higher, and output is more volatile, than in a baseline model without loan sales. Goodhart, Kashyap, Tsomocos, and Vardoulakis (2012) study a variety of regulatory policies in a two period general equilibrium model with heterogeneous

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

households, banks and shadow banks. The basic set of financial balance sheets resemble those in our model, with commercial banks funding shadow bank holdings of securitized assets through repurchase agreements. 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 endowment 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 how very similar effects arise in our model. Finally, 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, intermediary balance sheets play 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, who 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[8].

[8] 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.

We argue that evidence from changes in the bankruptcy code suggest that banks' demand for securitized assets was strongly affected by their collateral value. 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)[9].

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

3.1 The financial system

The financial system is comprised of two types of financial intermediary, commercial banks and brokers. 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[10].

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 sheet. The loan pools S^b that result from loan sales

[9]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.

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

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[11].

3.1.1 Commercial bankers

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, and as a result the amount of external finance 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'[12]. In our case, secondary creditors are shadow banks; their loan purchase decisions are discussed below.

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 debt ('deposits') and inside equity[13]. The balance sheet identity

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

[12]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.

[13]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.

of an individual commercial bank (mnemonic c) at the end of period t is given by:

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

where Q_t is the price of a primary claim on a firm, q_t is the price of a claim on a broker, and other lower-case symbols represent the individual-level counterparts to the aggregate amounts described above[14].

Since banks face credit constraints, it is optimal for them to defer transfers of internal funds to the household for as long as possible. An individual bank's net worth is therefore determined by the accumulation of its retained earnings. 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)

$$n_t^c = R_{st} Q_{t-1} s_{t-1}^c + R_{mt} q_{t-1} m_{t-1}^c - R_t d_{t-1}.$$

where the returns on loans and asset backed securities are R_{st} and R_{mt} respectively, and R_t is the deposit rate. After using the balance sheet identity (1) to substitute out ABS holdings, the law of motion for the net worth of a commercial bank becomes:

$$n_t^c = (R_{st} - R_{mt}) Q_{t-1} s_{t-1}^c + (R_{mt} - R_t)\, d_{t-1} + R_{mt} n_{t-1}^c. \tag{2}$$

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. If bankers receive the exit signal, it is at the start of the period, after any aggregate shocks are realized. Upon exit, they transfer the entire net worth of the bank back to their ultimate owners, households. 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}. The going concern value of the commercial bank at the end of period $t-1$ is then given by:

$$V_{t-1}^c = \mathrm{E}_{t-1} \Lambda_{t-1,t} \left[(1 - \sigma) n_t^c + \sigma V_t^c \right] \tag{3}$$

The banker's objective is to maximize the value of the enterprise through appropriate choice of asset portfolio $\{Q_t s_t^c, m_t^c\}$ and, by choice of deposits, its scale of operation.

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

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

that between adjacent time periods the banker has an opportunity to transfer a fraction of the assets under his or her control to the home household[15]. Our key assumption is that creditors regard on balance sheet loans as less good collateral than asset backed securities. The motivation 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 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[16].

To formally capture the collateral value of securitized assets, we give bankers the ability to divert a weighted fraction of the end of period balance sheet value of the firm, with ABS receiving a lower weight than loans. Incentive compatibility requires that the going concern value of the enterprise should exceed the value of assets that the banker can divert:

$$V_t^c \geq \theta_c(Q_t s_t^c + [1-\omega_c]q_t m_t^c) \tag{4}$$

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 loosen the incentive constraint by $\theta_c\omega_c$. To see this, notice that by reducing loan holdings by a marginal unit, the bank reduces divertible assets by θ_c; and by increasing ABS holdings by a marginal unit, the bank raises divertible assets by $\theta_c(1-\omega_c)$, with the total effect being the sum of the two. Intuitively, banks will value ABS so long as $\omega_c > 0$ because such a switch relaxes the incentive constraint (4). Set against this, banks have reason to prefer loans because they carry a yield advantage over ABS, as we demonstrate below.

The commercial bank's value function is linear in $\{v_{st}^c, v_{mt}^c, v_t^c\}$, which are time-varying coefficients solved for in Appendix A. There, we show that these coefficients are discounted expected returns on (respectively) loans, ABS and deposits, where the discount factor applied depends on the tightness of the bank's incentive constraint. Defining the

[15]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).

[16]According to the Flow of Funds of the United States, commercial bank holdings of all types of MBS 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.

excess value of loans over ABS $\mu^c_{st} := (v^c_{st}/Q_t - v^c_{mt}/q_t)$, write the value function as:

$$V^c_t = \mu^c_{st} Q_t s^c_t + \left(v^c_{mt}/q_t - v^c_t\right) d_t + v^c_{mt} n^c_t \tag{5}$$

The first order necessary conditions for optimal $\{s^c_t, d_t, \lambda^c_t\}$ are:

$$\mu^c_{st} \leq \theta_c \omega_c \frac{\lambda^c_t}{1+\lambda^c_t}, \quad \text{with equality if} \quad s^c_t > 0 \tag{6a}$$

$$\frac{v^c_{mt}}{q_t} - v^c_t \leq \theta_c(1-\omega_c)\frac{\lambda^c_t}{1+\lambda^c_t}, \quad \text{with equality if} \quad d_t > 0 \tag{6b}$$

$$(\mu^c_t - \theta_c\omega_c)Q_t s^c_t + (v^c_{mt}/q_t - v^c_t - \theta_c[1-\omega_c])d_t + (v^c_{mt}/q_t - \theta_c[1-\omega_c])n^c_t \geq 0$$
$$\text{with equality if } \lambda^c_t > 0 \tag{6c}$$

When the commercial bank's incentive constraint binds, we may combine (1), (4) and (5) to find its portfolio optimization problem yields an ABS demand function

$$q_t m^c_t = \frac{1}{\omega_c} d_t - \left\{\frac{v^c_{st}/Q_t - \theta_c}{\theta_c\omega_c - \mu^c_{st}}\right\} n^c_t \tag{7}$$

Away from corners, the demand for ABS is decreasing in net worth and increasing in deposits. Dividing (7) through by total funding $d_t + n^c_t$, 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 in the sequel, let us provide some intuition for it. The Lagrange multiplier on the incentive constraint in the static maximization of (5) subject to (4) is

$$\lambda^c_t = \frac{\mu^c_{st}}{\theta_c\omega_c - \mu^c_{st}} \tag{8}$$

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 $1/(\theta_c\omega_c - \mu^c_{st}) > 1$ dollars, which raises firm value by μ^c_{st} 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 $v^c_{mt}/q_t - \theta_c(1-\omega_c)$. (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^c_{mt}/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^c_t. As shown in (A.9), the sum of these effects equals the expected value of bank net worth at the end of period t

$$\begin{aligned}\Omega^c_t &:= (1 - \sigma) + \sigma\{v^c_{mt}/q_t + \lambda^c_t(v^c_{mt}/q_t - \theta_c[1 - \omega_c])\} \\ &:= (1 - \sigma) + \sigma\{v^c_{st}/Q_t + \lambda^c_t(v^c_{st}/Q_t - \theta_c)\} \end{aligned} \tag{9}$$

where the first order condition for s^c_t is used in the second line to give an equivalent expression in terms of v^c_{st}, which tells us how bank value is affected if net worth is invested in loans rather than ABS.

3.1.2 Brokers

There are many competitive brokerage firms or shadow banks, each owned and managed by a broker. 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. (2011), and the mechanisms by which financial institutions effected such concentration are discussed in Acharya and Schnabl (2009). However, we will also be interested in how risk is distributed between commercial and shadow banks, and that depends on the architecture of the securitization market. Section 3.2 discusses the cases of risk sharing and risk taking shadow banking in detail.

As with banks, brokers face credit constraints which make them want to defer consumption until exit, and so a broker's (mnemonic b) internal equity is the accumulation of earnings retained from their securitization activities are:

$$n^b_t = (R_{st} - R_{mt})Q_{t-1}s^b_{t-1} + R_{mt}n^b_{t-1}. \tag{10}$$

In our baseline model, securitization is '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[17].

Brokers face an endogenous financial constraint which is similar to that faced by banks. 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[18]. Both considerations lead to the presumption that the fraction of divertible assets be no higher for brokers than it is for banks. Indeed, if it were higher, moving loans off commercial banks' balance sheets and onto that of brokers could result in no gains from trade.

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

$$Q_t s_t^b = q_t m_t^b + n_t^b \tag{11}$$

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 abscond with:

$$V_t^b \geq \theta_b Q_t s_t^b \tag{12}$$

and we will take it that $\theta_b < \theta_c$. Brokers face the same random probability $1 - \sigma$ of being replaced by new management as do banks[19]. Define the excess return of loans over ABS to the broker as $\mu_{st}^b := v_{st}^b / Q_t - v_{mt}^b / q_t$. Then the broker's value function is linear in balance sheet size and net worth:

$$V_t^b = \mu_{st}^b Q_t s_t^b + (v_{mt}^b / q_t) n_t^b \tag{13}$$

where values for the time varying coefficients $\{v_{st}^b, v_{mt}^b\}$ are derived in Appendix A. We show that they are equal to discounted expected returns on loan pools and ABS, where the discount factor applied depends on the tightness of the broker's incentive constraint.

[17] 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.

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

[19] As banks and brokers have identical exit rates and ownership structure, there are no differences between institutions because of impatience or risk aversion.

The first order necessary conditions for $\{s_t^b, \lambda_t^b\}$ are:

$$\mu_{st}^b \leq \theta_b \frac{\lambda_t^b}{1+\lambda_t^b}, \quad \text{with equality if} \quad s_t^b > 0 \tag{14a}$$

$$\left(\mu_{st}^b - \theta_b\right) Q_t s_t^b + \left(\frac{v_{mt}^b}{q_t}\right) n_t^b \geq 0 \quad \text{with equality if } \lambda_t^b > 0 \tag{14b}$$

When the broker's incentive constraint binds, we may combine (11), (12) and (13) to find their asset to equity ratio $\phi_t^b := (v_{mt}^b/q_t)/(\theta_b - \mu_t^b)$, and their ABS supply:

$$q_t m_t^b = \frac{v_{st}^b/Q_t - \theta_b}{\theta_b - \mu_t^b} n_t^b = (\phi_t^b - 1) n_t^b \tag{15}$$

The expression shows that the supply of high quality collateral depends on the financial condition brokers. As their leverage ϕ_t^b is typically much larger than unity, ABS supply will be highly sensitive to changes in broker net worth. It also depends on the returns on loans pools, and the ABS spread. Higher returns or wider spreads shift the supply of ABS outward because the broker's going concern value is raised, so relaxing their incentive constraint.

The shadow value of broker net worth can be understood as follows. Whenever the broker is operational, $s_t^b > 0$, equation (14a) holds with equality, and the Lagrange multiplier on the incentive constraint (12) is

$$\lambda_t^b = \frac{\mu_{st}^b}{\theta_b - \mu_{st}^b} \tag{16}$$

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 figure 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), and as shown in (A.18), the total increase in value is the sum of these effects:

$$\begin{aligned}\Omega_t^b &:= (1-\sigma) + \sigma \left\{ v_{st}^b/Q_t + \lambda_t^b (v_{st}^b/Q_t - \theta_b) \right\} \\ &:= (1-\sigma) + \sigma(1+\lambda_t^b)(v_{mt}^b/q_t). \end{aligned} \tag{17}$$

where the second line follows from (A.15a), and intuitively tells us the effect on broker value of using additional net worth to acquire loan pools rather than save ABS costs.

3.2 Risk sharing and risk taking securitization

In our model, shadow banks always retain the equity or first loss tranche of the securitization. But the distribution of the remaining aggregate risk amongst shadow banks and investors in ABS, in our case commercial banks, depends on the type of liabilities issued by shadow banks. We consider two cases. In the first, aggregate risk is shared between originators and holders of loans. In the second, aggregate risk attaching to loans originated and sold is transferred wholly to the holders of loans pools, shadow banks. The general case in which both types of liability are issued is a straightforward extension.

In our baseline model we assume that asset backed securities offer pass-through exposure to a broad collateral pool. Historically this has been the predominant mode of financing for large classes of securitized assets such as mortgages in the United States. In this case, the returns on ABS depend on the cash flows on the underlying assets held by shadow banks[20]. In general, the price of a claim on shadow banks q_t is different from the price of a primary claim on firms Q_t. Also, as shadow banks are partly hedged against aggregate risk, under these arrangements shadow banks do not take on 'bank like' risks. We refer to this as the risk sharing model of shadow banking.

By contrast, one argument advanced to explain the financial sector's drive to produce highly rated securities in the run-up to the subprime crisis centers on strong portfolio preferences for safe, liquid assets by large institutional cash pools (Pozsar, 2011; Gorton and Metrick, 2012) and by foreign creditors (Bernanke, 2011). 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 non-contingent return between period t and $t+1$ of $R_{m,t+1}$. Under these arrangements, originating banks effect a complete transfer of aggregate risk from their balance sheets, onto those of shadow banks. We refer to this as the risk taking model of shadow banking.

3.3 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 4.2, the current section analyzes the behavior of

[20] The return on pass-through securitizations is defined in (24) below.

the ABS market in isolation.

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 $\mu^c - \theta_c \omega_c$. 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 $[QS^c]^*$ of loans is held on balance sheet. The balance sheet identity implies banks' demand for ABS is equal to the length of the interval $N^c + D - [QS^c]^*$.

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 $\mu^b - \theta_b$. 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 $[M^b]^*$, which by the balance sheet identity determines their demand for loan bundles. Total intermediation in the economy, equal 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 the return on capital 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).

3.4 Households and production

The non-financial sectors of the economy closely resemble those of a standard real business cycle 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):

$$U_0 = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \tag{18}$$

$$u(c_t, l_t) = \ln(c_t - hC_{t-1}) - \frac{\chi}{1+\varphi} l_t^{1+\varphi} \tag{19}$$

Here c_t is the consumption of the household, C_{t-1} is lagged aggregate consumption, and l_t are household labor hours. To effect transfers of resources across time, households acquire fixed (non-contingent) claims on commercial banks, called 'deposits' for short[21]. 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

$$Y_t = \mathrm{e}^{a_t} K_{t-1}^{\alpha} L_t^{1-\alpha} \tag{20}$$

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

$$K_t = I_t + (1-\delta) K_{t-1} \tag{21}$$

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

[21] 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).

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[22]. The adjustment cost function satisfies $f(1) = f'(1) = 0$ and the inverse elasticity of investment is defined by $\varepsilon := f''(1) > 0$. 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:

$$Q_t = 1 + f\left(\frac{I_t}{I_{t-1}}\right) + \left(\frac{I_t}{I_{t-1}}\right) f'\left(\frac{I_t}{I_{t-1}}\right) - \mathrm{E}_t \Lambda_{t,t+1} \left(\frac{I_{t+1}}{I_t}\right)^2 f'\left(\frac{I_{t+1}}{I_t}\right) \tag{22}$$

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.

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

$$R_{st} = \frac{Z_t + (1-\delta)Q_t}{Q_{t-1}} \tag{23}$$

and the return on asset backed securities as

$$R_{mt} = \frac{Z_t + (1-\delta)\, q_t}{q_{t-1}} \tag{24}$$

in the baseline case of pass-through securitization.

3.5 Aggregation, market clearing and competitive equilibrium

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

$$N_t^c = (\sigma + \xi_c)\left\{R_{st} Q_{t-1} S_{t-1}^c + R_{mt} q_{t-1} M_{t-1}^c\right\} - \sigma R_t D_{t-1} \tag{25}$$

$$N_t^b = (\sigma + \xi_b) R_{st} Q_{t-1} S_{t-1}^b - \sigma R_{mt} q_{t-1} M_{t-1}^b \tag{26}$$

[22] 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.

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

$$S_t^c + S_t^b = K_{t+1} \tag{27}$$

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

$$M_t^c = M_t^b \tag{28}$$

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

$$D_t = Q_t(S_t^c + S_t^b) - (N_t^c + N_t^b) \tag{29}$$

Equality between labor demand and supply gives

$$W_t(C_t - hC_{t-1})^{-1} = \chi L_t^{\varphi} \tag{30}$$

Finally, the aggregate resource constraint is

$$Y_t = C_t + \left[1 - f\left(\frac{I_t}{I_{t-1}}\right)\right] I_t \tag{31}$$

The model has 29 endogenous variables, of which 7 are prices (Q_t, q_t, R_{st}, R_{mt}, 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 12 are quantities (Y_t, C_t, I_t, K_t, L_t, D_t, M_t^c, N_t^c, S_t^c, M_t^b, N_t^b, S_t^b), jointly determined by the 29 equations (B.1)–(B.29) given in Appendix B.

3.5.1 Steady state return on ABS

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

Proposition 1 (Equilibrium ABS spread)**.** *In deterministic steady state, the return on ABS is a weighted average of the return on primary securities and the risk free rate:*

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

The equilibrium ABS spread is therefore related to the wedge between ultimate borrowers and ultimate lenders (the 'gross financial wedge') by:

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

□

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. This section first discusses how parameter values were chosen for numerical simulations of the model. It goes on to analyze the quantitative effects of two types of shock in the model: aggregate shocks, and 'cross-sectional' or purely redistributive shocks affecting the financial system. We end by discussing when introducing heterogeneity amongst financial institutions is most relevant.

4.1 Calibration

Values for the parameters of the model used in our simulations are given in table 1. The parameters fall into two groups. The first group consists of 7 familiar parameters which match key macroeconomic quantities. The second consists of 6 parameters specific to the financial system (with subscript b for shadow banks, and c for commercial banks). We consider two main model calibrations. In the baseline, the model reproduces the main features of a financial system roughly comparable to that of the U.S. in the decade preceding the subprime crisis. In the alternative, we suppose that there is no securitization, and calibrate the model according to the features of the U.S. financial system of the early 1990s (when there was some securitization activity, but lending was still overwhelmingly done by banks).

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.

Amongst the parameters specific to the financial system, we set the per-period survival probability for bankers and brokers σ to generate a mean survival time of 8 years (one could also think of this as a payout ratio of 12.5%). We calibrate the remaining five parameters $(\theta_c, \xi_c, \omega_c, \theta_b, \xi_b)$ to match five financial variables. These are the gross financial wedge $R_s - R$, the ABS spread $R_m - R$, the share of securitized assets in total credit $M/(S^c + S^b)$, the loan to equity ratio of commercial banks QS^c/N^c, and the asset to equity ratio of shadow banks QS^b/N^b.

We set the steady state loan-deposit spread (gross financial wedge) is 100 basis points, as in Gertler and Karadi (2011). 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 in the model. The aggregate ratio of commercial bank loans to equity is 4.5 times, which is close to the median ratio of total loans and leases to tier 2 capital at commercial banks in the call report data. We set the share of securitized assets at 30%, based on call report data on bank assets sold and securitized. The aggregate shadow bank loan pool to equity ratio was set at 10 times, based on data on the leverage in RMBS securitizations[23].

Finally, we consider a calibration of the model without securitization. In this case we suppose that the gross financial wedge in the economy is 20 basis points higher than under the baseline. There is a range of evidence from various markets that borrowing rates fell amongst assets that could be securitized. For example, in the market for corporate loans, Nadauld and Weisbach (forthcoming) cite a reduction in the yield of 15 basis points. The aggregate ratio of commercial bank loans to equity is maintained at 4.5 times in this scenario[24].

[23]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 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.

[24]Brokers can be eliminated from the model 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. The resulting representative bank economy is then a real version of that presented in Gertler and Karadi (2011).

4.2 Experiments

We are interested in understanding the effects of two types of disturbance on the model economy. The first is a conventional aggregate disturbance, in this case affecting productivity[25]. The second are 'cross sectional' disturbances which affect the financial sector. This type of shock has been emphasized in the recent literature by Iacoviello (2011) and Jermann and Quadrini (2012) amongst others. We look at the effects of two purely transitory redistributive shocks, one affecting the net worth of commercial banks, and the other affecting the distribution of net worth within the financial system. We offer various ways to understand their effects.

4.2.1 Aggregate shocks

The responses of selected variables to a unanticipated 1% reduction in total factor productivity are given in figure 4. As in a standard business cycle model, 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, also declines. But the quantitatively most important effects are from credit supply, as we now discuss.

The response of credit supply can be understood by considering the two principal effects of the 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 (7), 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, (15) tells us ABS supply is reduced by $(v_s^b/Q - \theta_b)\lambda^b/\mu_s^b \cdot \mathrm{d}N^b$. 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 (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 leads them to rebalance their portfolios away from loans and towards ABS (which as they anticipate

[25]We condition on productivity shocks as, in the absence of nominal rigidities, they allow the model to reproduce the comovement of output, hours, investment and consumption seen in the aggregate data.

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 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.

Under the risk taking securitization model (dash line), commercial banks hold fixed claims on shadow banks. The adverse productivity shock produces substantial contractions in shadow bank net worth, assets and ABS outstanding. The yield on ABS increases by 280 basis points relative to the risk free rate. 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, aggregate credit undergoes a substantially larger contraction in this case, resulting in larger declines in investment, and so a deeper recession.

4.2.2 Quantitative assessment of the model

We now make a first pass quantitative assessment of the model. We compare theoretical correlations and volatilities of output and sources of credit, conditional on productivity shocks, with aggregate data on financial flows from 1984:1 to 2007:2 from the United States flow of funds. Following Adrian and Shin (2010), we group U.S.-Chartered Commercial Banks, Savings Institutions and Credit Unions in the traditional banking sector, and group Security Brokers and Dealers, Issuers of Asset-Backed Securities, Agency- and GSE-Backed Mortgage Pools, and Government-Sponsored Enterprises in the shadow banking sector[26]. The reason for assessing the model on data prior to the subprime crisis is that we take the view that the contraction of 2008-2009 was not principally the result of a large aggregate business cycle shock, as we discuss in section 5. Although the exercise presented here stops well short of a statistical assessment of model fit, it is nevertheless a useful way of establishing if the model is broadly plausible.

Table 2 presents correlations between credit and output. As shown in columns 1 and 3, the model with risk sharing broadly replicates the patterns of comovement seen in the data. (Appendix D.3 discusses the robustness of the correlations in detail.) Commercial banks' direct lending is procyclical with a correlation of 0.71 in the model, compared to 0.51 in the data (although amongst the components of the traditional banking aggregate, credit unions' lending is counter-cyclical). The model predicts that shadow bank credit

[26]Details of the data sources used in the construction of tables 2 and 3 can be found in Appendix D. See also den Haan and Sterk (2010) for an in-depth analysis of the cyclical behavior of credit sub-aggregates, and their responses to shocks.

is counter-cyclical with a correlation of -0.46, a little below the actual figure of -0.35 but well within the 95% confidence interval. Lastly, leverage is counter-cyclical for both types of intermediary in the data and the model. For the traditional banking aggregate, the correlation is -0.44 in the data, and -0.19 in the model (depending on the exact measure of leverage used, it is also the case that the components of the aggregate are either negatively correlated with output, or insignificantly different from zero). A limitation for the shadow banks is that aggregate leverage is particularly difficult to gauge from the available data. Focusing on broker-dealers alone, the correlation is -0.23, compared to -0.38 in the model.

Statistics for the risk taking shadow bank case, given in column 2 of table 2, predicts correlations that are at odds with the average behavior of credit aggregates up to the onset of the subprime crisis in 2007:2. Although overall credit remains procyclical, the correlations between components of credit and output have their signs reversed.

Table 3 shows that total credit is about as volatile relative to output in the model as in the data. The model predicts that the relative volatility of both bank and shadow bank credit is high compared to the data, but it is worth noting that bank credit is always less volatile than shadow bank credit, as in the data. In the risk taking case volatility of shadow bank credit is very high indeed. In addition, the volatility of output is also quarter higher under risk taking (not shown in the table), for the same share of securitized assets in total lending.

An important implication of the model is that the risk sharing model of securitization has a moderating influence on the volatility of credit and the macroeconomy in the face of aggregate disturbances. By contrast, when commercial banks can use securitization to transfer risk completely off balance sheet, the result is macroeconomic instability. 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, although allowing for such effects tends to reinforce the result.

4.2.3 Shocks to commercial banks

We now examine the effects of a 10% reduction in commercial bank net worth. This can be thought of as an unexpected and purely temporary increase in bank funding costs, or alternatively, as an increase in loan write-offs similar to Iacoviello (2011). Any unanticipated shock to commercial bank profitability could be captured in this way. As a point of comparison, we consider the case where banks are unable to securitize (the representative bank model). With a representative bank calibrated to pre-securitization era data (described in section 4.1), the reduction in net worth results in a squeeze in bank credit. As shown in figure 5, this leads to a 4% downturn in investment, and an output recession of 0.6%. The effects are persistent in spite of the one-off nature of the shock, as net worth is slow to recover.

When banks have access to securitization, the effect of the shock is damped. Total credit is more stable in the presence of securitization, and investment and output fall less – by 2.8% and 0.4% respectively – and recover more quickly. This is true in spite of the higher overall leverage of the financial sector in the securitization case[27]. The shock to commercial banks' net worth causes them to rapidly expand their securitization activity. Because their balance sheets remain relatively healthy, shadow banks are able to absorb some inflow of loans. Notice, however, that commercial bank deleveraging imposes a pecuniary externality on shadow banks, whose net worth suffers as a result of lower capital prices.

The pattern of comovement predicted by the model resembles the responses of bank and non-bank consumer credit to a monetary policy shock remarked upon in den Haan and Sterk (2010). They find that, in the post-1984 period, non-bank financial institutions tended to increase their holdings of mortgages following a monetary policy shock. Taking the experiment here to be a rough proxy for the funding effects of such a shock, our model offers an explanation for this surprising result. The model's responses are also consistent with the micro evidence in Altunbas et al. (2009). Using their definition of commercial bank lending including loans securitized, the model predicts an initial lending decline of 2.9%, which turns to a modest expansion after three quarters. This compares to an impact lending decline of 5.8% absent securitization, followed by persistently below average lending.

4.2.4 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 1/4 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 both the aggregate and cross-section shocks discussed above, will trigger the dynamics we discuss[28]. Naturally, all intra-financial redistributions are

[27] Net leverage, which is total real economy lending divided by total equity of the financial sector, is 15% higher in the model with securitization than in the representative bank model under our calibration. The results discussed are for the risk sharing model of securitization, but the shock is always damped when net leverage is equalized.

[28] Although we see this shock as a way 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

neutral in a representative bank economy. Results are given in figure 6. The first point to note is that a purely temporary, purely redistributive shock has real effects in this economy, with investment declining on impact by 1.5% and output by 0.2%. 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 on output are surprisingly modest. The implication of this finding is that the dynamics of macroeconomic aggregates in response to moderate macroeconomic shocks may be well approximated by a representative bank model. There are two caveats, however. The first is that to keep matters simple, we have refrained from a full treatment of bank-level idiosyncratic risk, and the risk-sharing benefits that securitization brings in that case. The second 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[29]. Although in normal times, the effect of heterogeneity is limited, any disruption to the securitization markets is likely to be exacerbated by such factors. The following section considers the effects of just such a disruption.

5 Crises and interventions

In our discussion to this point, we have concentrated on explaining the average cyclical behavior of credit supplied by the commercial and shadow bank sectors. In this section, we instead focus 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. The 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. It does not require that there be a large macro shock, such as the aggregate shock to capital in Gertler and Karadi (2011),

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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.

[29] 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'). When the elasticity of θ_b to the share is high (and negative), the economy becomes 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.

but instead resembles the liquidity shock in Del Negro et al. (2011) (although their model does not explicitly include financial intermediaries).

The problems experienced in credit and interbank markets at the onset of the subprime crisis in August 2007 were swiftly followed 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 have been a prominent component of the policy response (Pozsar et al., 2010). These have included a policy of providing long-term liquidity through the TALF[30], and outright purchases of Agency MBS and debt funded by central bank reserves[31]. In section 5.2 we describe the operation of government backstops for the securitization market.

5.1 A securitization crisis

We begin by considering the effects of an exogenous tightening of leverage constraints. 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. An immediate consequence of such a shock is to reduce the supply of securitized assets by tightening the broker incentive constraint (12). 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 (4). There are a twin effects. Because ABS is less pledgeable, to obtain a given amount of funding the commercial bank now has to

[30]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.

[31]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 for the purpose of open market operations.

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.

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, government does not face financing 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[32].

The government may purchase primary securities directly (lending to firms) or in securitized form as ABS (lending to brokers)[33]. The government budget constraint takes the form

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

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

$$G_t - T_t = (R_{st} - R_t) Q_{t-1} S_{t-1}^g + (R_{mt} - R_t) q_{t-1} M_{t-1}^g \tag{32}$$

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

[32] 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).

[33] 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.

gives rise to non-zero public expenditure, parameterized by τ.

$$G_t = \tau(S_t^g + M_t^g) \tag{33}$$

Finally, the market clearing conditions (27) and (28) are altered to read

$$S_t^c + S_t^b + S_t^g = K_{t+1} \tag{34}$$

and

$$M_t^c + M_t^g = M_t^b \tag{35}$$

Government is taken to purchase a fraction φ_t^i of the steady state stock of each asset type i. The policy response to the crisis takes the form of a feedback rule on the spreads (a star denotes steady state values), with the parameter γ_{1i} determining the strength of the response:

$$\varphi_t^s = \gamma_{0s} + \gamma_{1s}\{\mathrm{E}_t(R_{s,t+1} - R_{t+1}) - (R_{s*} - R_*)\} \tag{36}$$

$$\varphi_t^m = \gamma_{0m} + \gamma_{1m}\{\mathrm{E}_t(R_{m,t+1} - R_{t+1}) - (R_{m*} - R_*)\} \tag{37}$$

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 (that could be thought of as related to household defaults). 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 7, 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

[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.

bank equity. Parallel to the quantity movements are large movements in spreads. In particular, the spread of ABS over safe rates 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, forthcoming).

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 ameliorated responses of investment, output and credit shown as the dash line in figure 7. The increase in government loan holdings takes its share of all directly held credit outstanding to approximately 14%, or 110% of steady state GDP. The principal effect of the policy is to stabilize asset values Q_t, 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 $\gamma_{1m} = 20$, which raises the government's share of (steady state) ABS outstanding to 50%, or approximately 95% of steady state GDP. This brings the size of the government asset portfolio as a share of GDP to approximately the same level as in the loan purchase case. Figure 8 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 initial 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 (7), which tells us that lower

[35]Setting γ_{1m} to a much higher value does not overturn this result.

deposits translate into lower demand for ABS from commercial banks. As a consequence, total demand for ABS summing across banks and the government is lower than in the absence of intervention. To clear the market as in (35), the loan-ABS spread must fall. A lower spread hurts profits, and triggers reductions net worth and second round tightening of financial constraints for both intermediary types, see (2) and (10). 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 suggests in this section imply that a policy that raises asset values through direct loan purchases are more effective than a policy that supports the price of ABS, reducing funding costs for shadow banks. 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.

6 Concluding remarks

The shift to a 'shadow' or 'securitized' banking model in the United States and elsewhere over the course of the 1990s and 2000s has had a profound effect on the behavior of credit aggregates, and so on the macroeconomy. The subprime crisis of 2007-2009 drew attention to the failings of this business model and to the incentive problems that badly affected loan origination standards, in particular those for residential mortgages. But shadow banking has not disappeared in the wake of the crisis, and the securitization market is likely to remain an important source of credit supply. Reform of shadow banking thus remains high on the agenda of the regulatory authorities. The aim of the present paper is accordingly to examine the effects of securitization taking into account the interaction and feedbacks between the traditional and shadow banking systems, and between the financial system as a whole and the macroeconomy.

We develop a dynamic general equilibrium model with heterogeneous financial intermediaries in which securitization plays a key role in credit market dynamics. We show that the model can replicate the different behavior of traditional bank and shadow bank credit seen in the data over the course of the business cycle. The model allows us to study the macroeconomic consequences of shadow banking arrangements that entail risk sharing or risk taking on the part of the shadow banking system. Under risk taking, shadow banks replicate the credit and maturity transformation functions of the traditional banking system, making aggregate credit supply is excessively vulnerable to macroeconomic shocks. However, in line with bank-level studies, we find that the ability of banks to securitize loans when their net worth is impaired is an important safety valve which can stabilize aggregate credit supply.

Turning to the financial crisis of 2007-9, we show that the model responses to liquidity shocks to the shadow banking sector, which affect the collateral value of both its assets and liabilities, produces a synchronized downturn in credit supply across the entire financial system. We find 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 ineffective.

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	0.9	Persistence of productivity 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	Fraction of assets transferred to new brokers:	
	0.0083	securitization case
	0	no securitization
θ_c	Divertibility of bank loans:	
	0.2216	securitization case
	0.2564	no securitization
ξ_c	Fraction of assets transferred to new banks:	
	0.0134	securitization case
	0.0172	no securitization

Note: For the calibration without securitization, commercial bank parameters are set to broadly replicate the value of financial ratios in the early 1990s.

Table 2: Correlation between credit and output in the model and the data

	Risk sharing shadow banks	Risk taking shadow banks	Data
Output	1	1	1
			(n.a.)
Investment	0.90	0.95	0.8
			(0.71, 0.86)
Total credit	0.75	0.82	0.12
			(-0.09, 0.31)
Commercial bank credit	0.71	-0.80	0.51
			(0.34, 0.65)
Shadow bank credit	-0.46	0.83	-0.35
			(-0.52, -0.16)
Commercial bank leverage	-0.19	-0.81	-0.34
			(-0.50, -0.14)
Broker-dealer leverage	-0.38	0.82	-0.23
			(-0.41, -0.03)

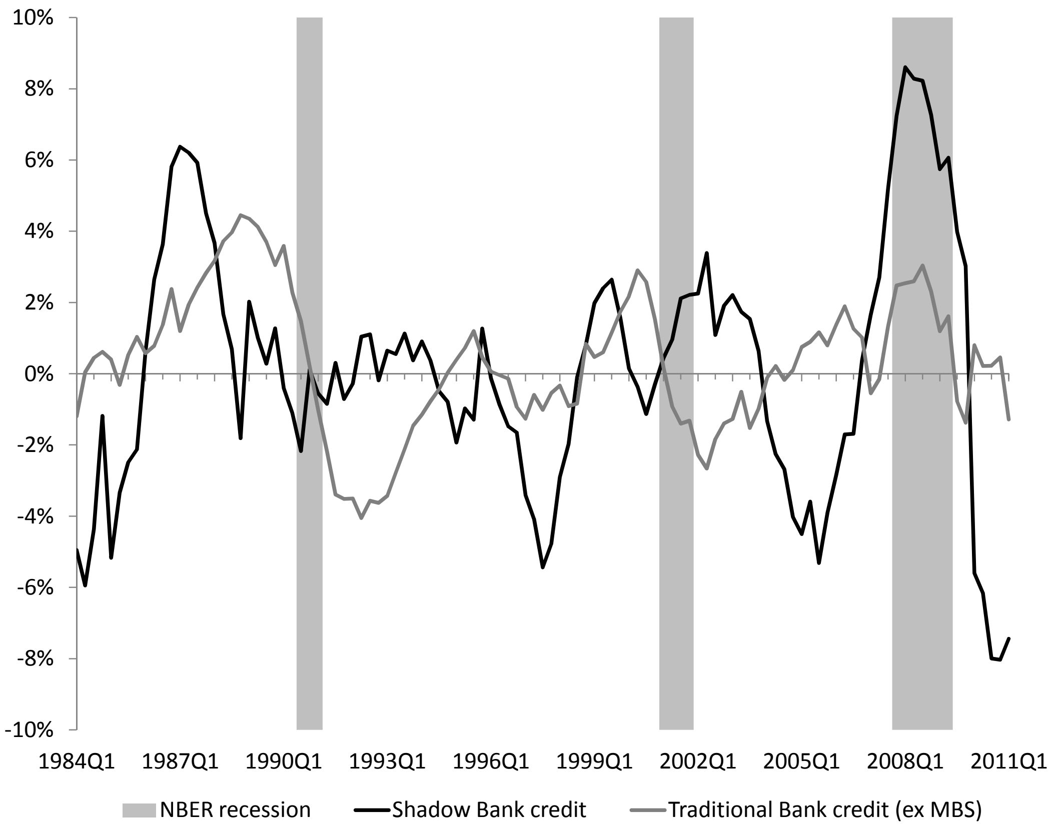
Note: Theoretical correlations are conditional on productivity shocks only. Data correlations are on Hodrick-Prescott filtered series taken from the United States Flow of Funds, 1984:1–2007:2. A 95% confidence interval is given in parentheses. Full details of data construction can be found in Appendix D.

Table 3: Relative volatility of credit in the model and the data

	Risk sharing shadow banks	Risk taking shadow banks	Data
Output	1	1	1
Investment	2.7	3.6	3.9
Total credit	1.6	1.8	1.5
Bank credit	3.9	6.6	1.8
Shadow bank credit	7.6	25.3	2.5

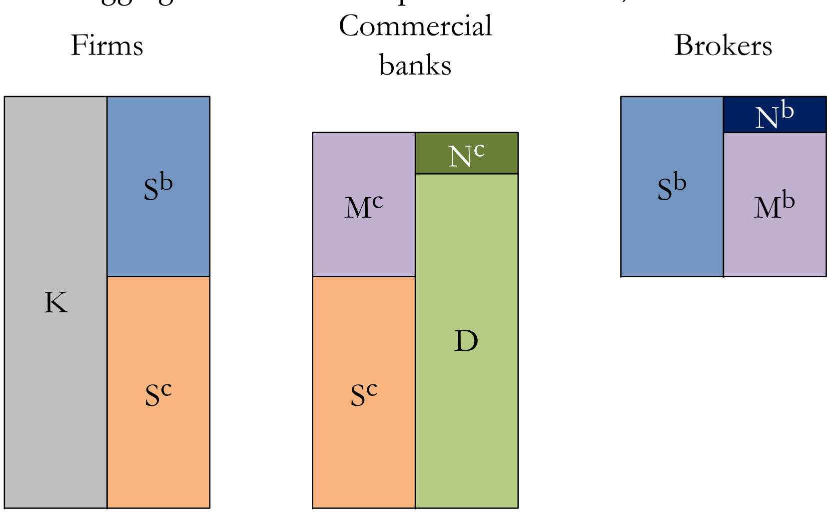
Note: Theoretical standard deviations relative to output are conditional on productivity shocks only. Data volatilities are calculated on HP filtered series taken from the United States Flow of Funds, 1984:1–2007:2. Full details of data construction can be found in Appendix D.

Figure 1: Credit cycles in traditional and shadow banking



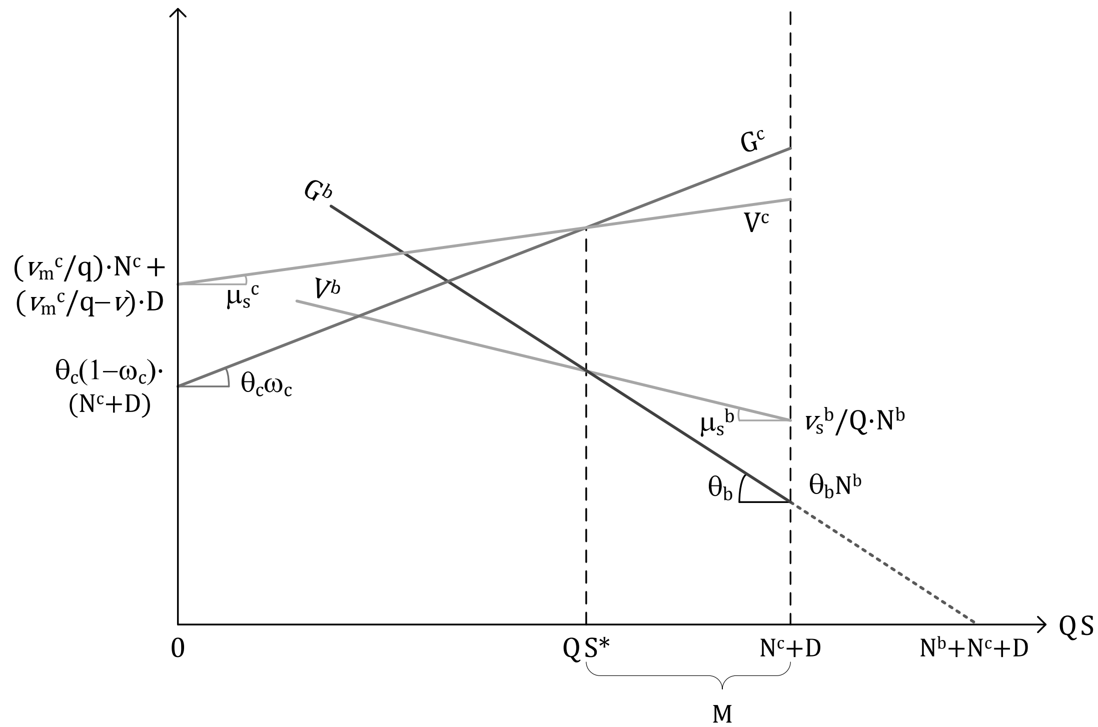
Note: Figure shows the percentage deviation from the HP trend for commercial and shadow bank credit aggregates taken from the United States Flow of Funds. The bank credit series is for on balance sheet credit. Between 1990Q1 and 2007Q2, the correlation between the series is -0.25. Full details of data construction and sources can be found in Appendix D.

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



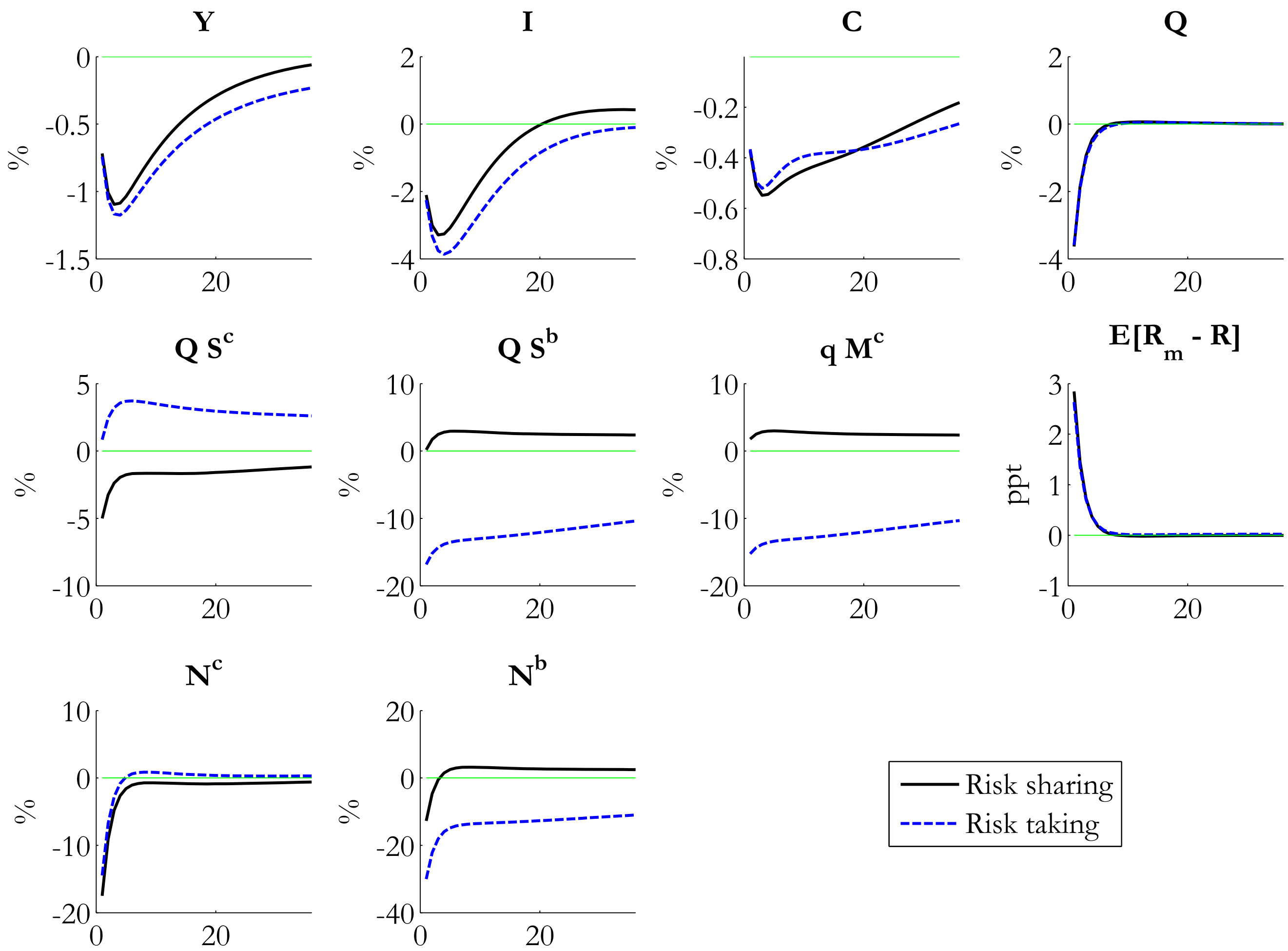
Note: A stylized representation of sectoral balance sheets in the steady state equilibrium. For each sector: height of LH column represents assets; height of RH column represents liabilities. Shaded areas are of equal height. Key: *K* - aggregate physical capital; *S* - primary securities (bank loans); *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.

Figure 3: ABS market partial equilibrium



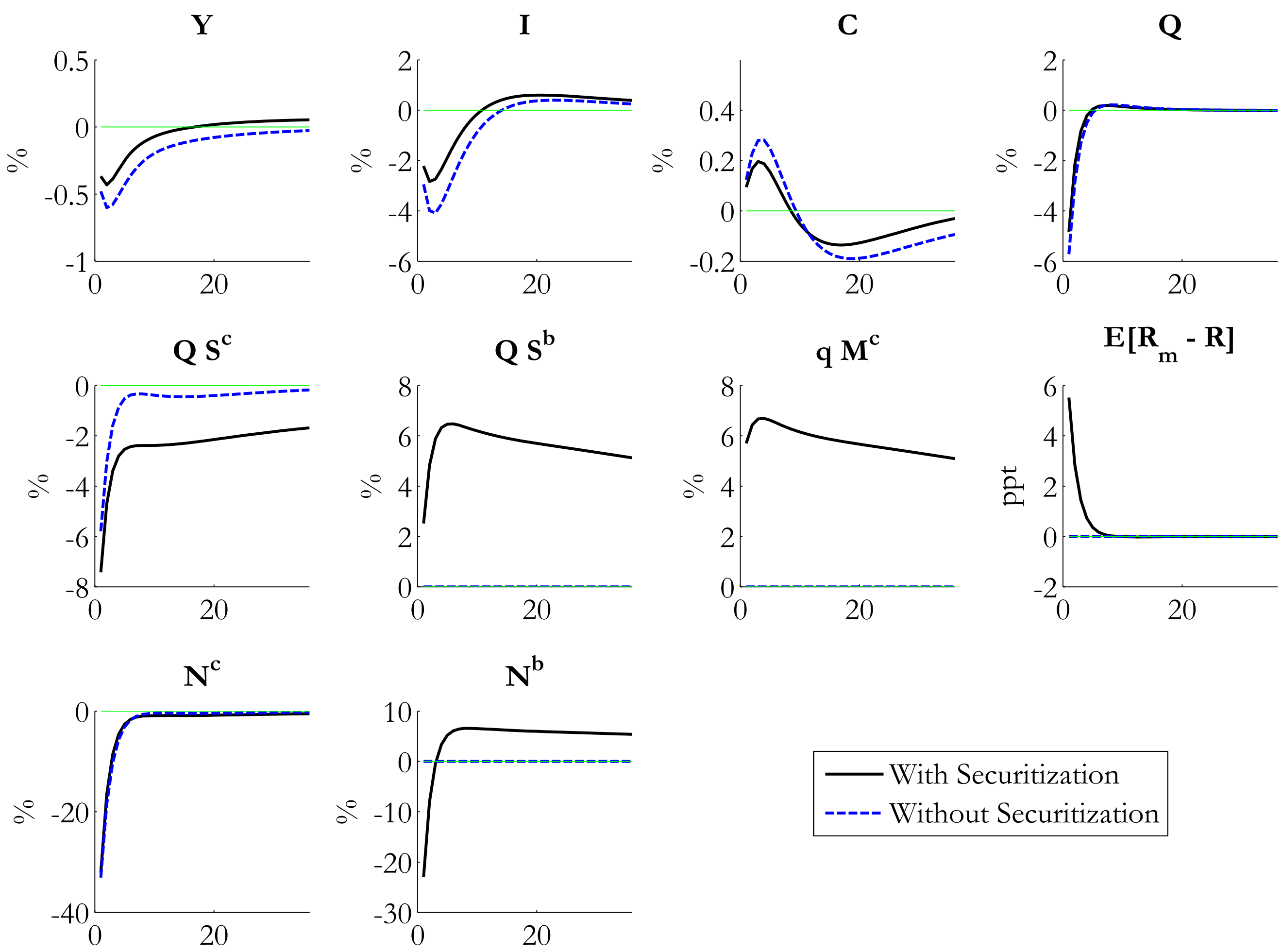
Note: A stylized representation of partial equilibrium in the ABS market, assuming N^c, N^b and D are given. The vertical axis gives the going concern value V^τ and amount of divertible assets G^τ for each intermediary type. The horizontal axis gives loan holdings. Commercial bank loan holdings are read 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.

Figure 4: Technology shocks



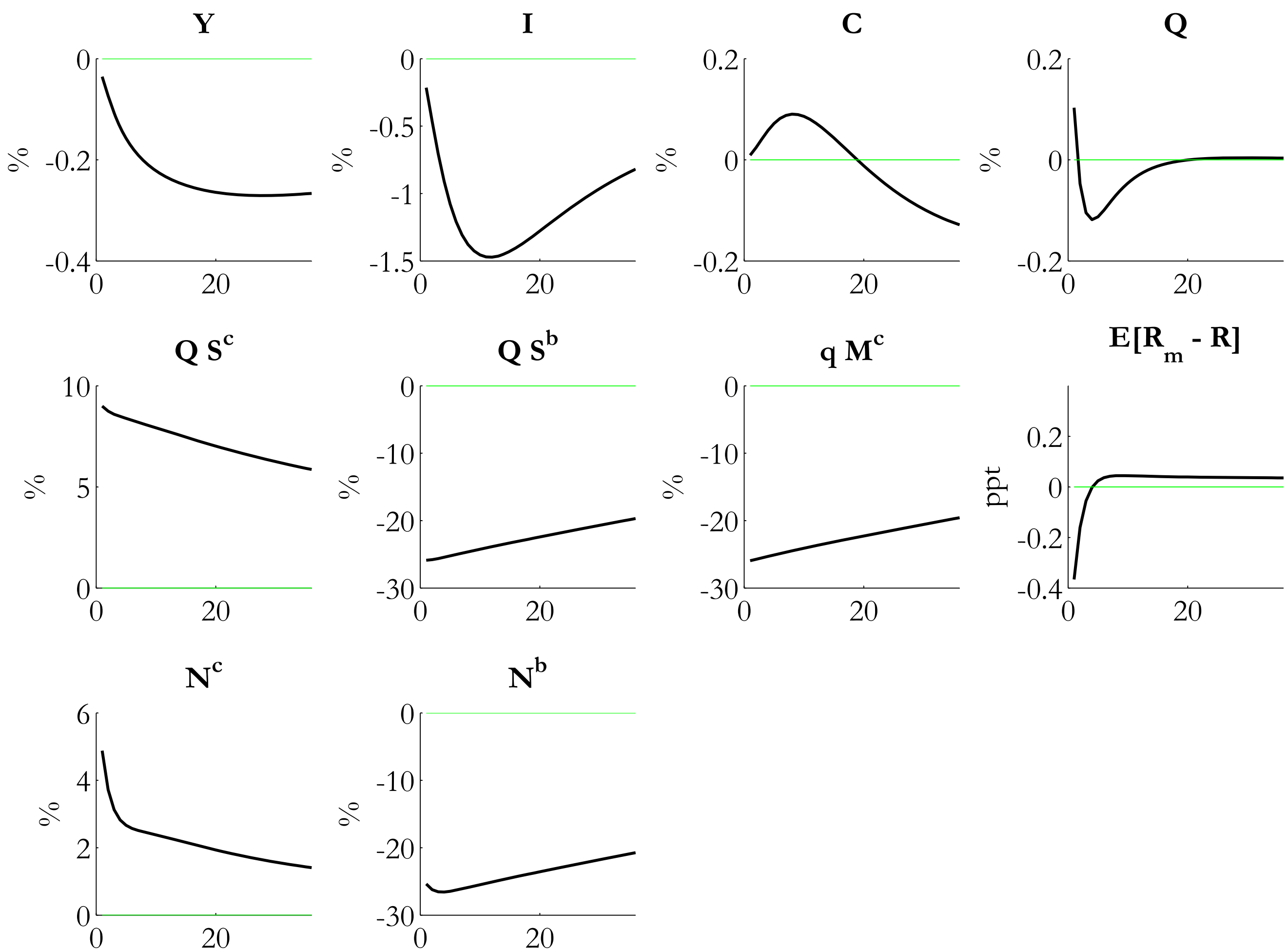
Note: Figure compares responses to a persistent 1% decline in total factor productivity (ρ_a = 0.9). The solid line is the baseline risk sharing securitization model (pass-through securitization). Returns on ABS are given by (24). The dash line is the risk taking securitization model, where ABS pays a fixed return.

Figure 5: Bank equity shocks



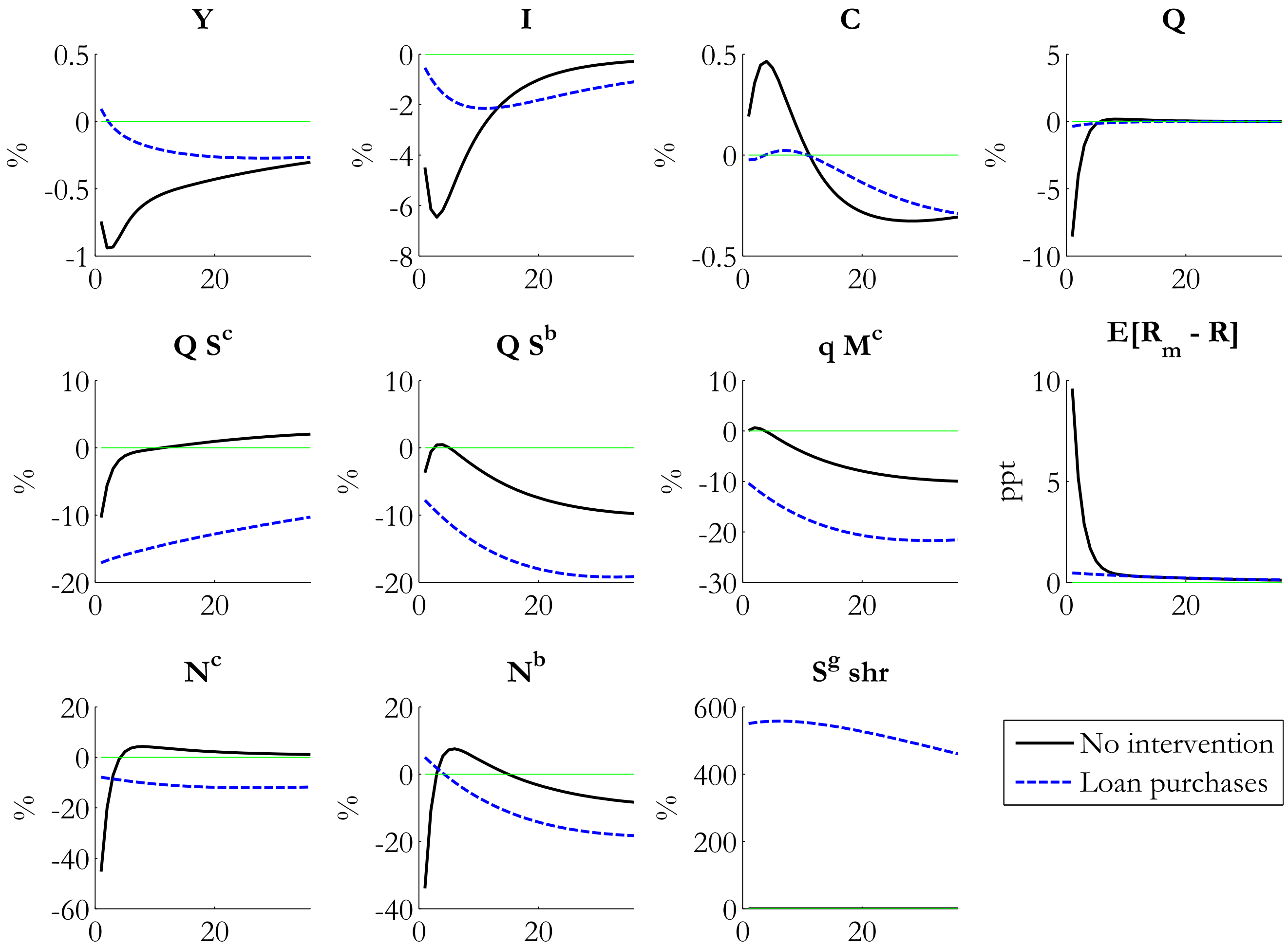
Note: Figure compares responses to a one-off reduction in bank equity. The 'no securitization' case is a model where banks hold all loans on balance sheet, calibrated to early 1990s data. The 'securitization' case is our benchmark 'risk sharing' shadow banking model.

Figure 6: Redistribution shocks



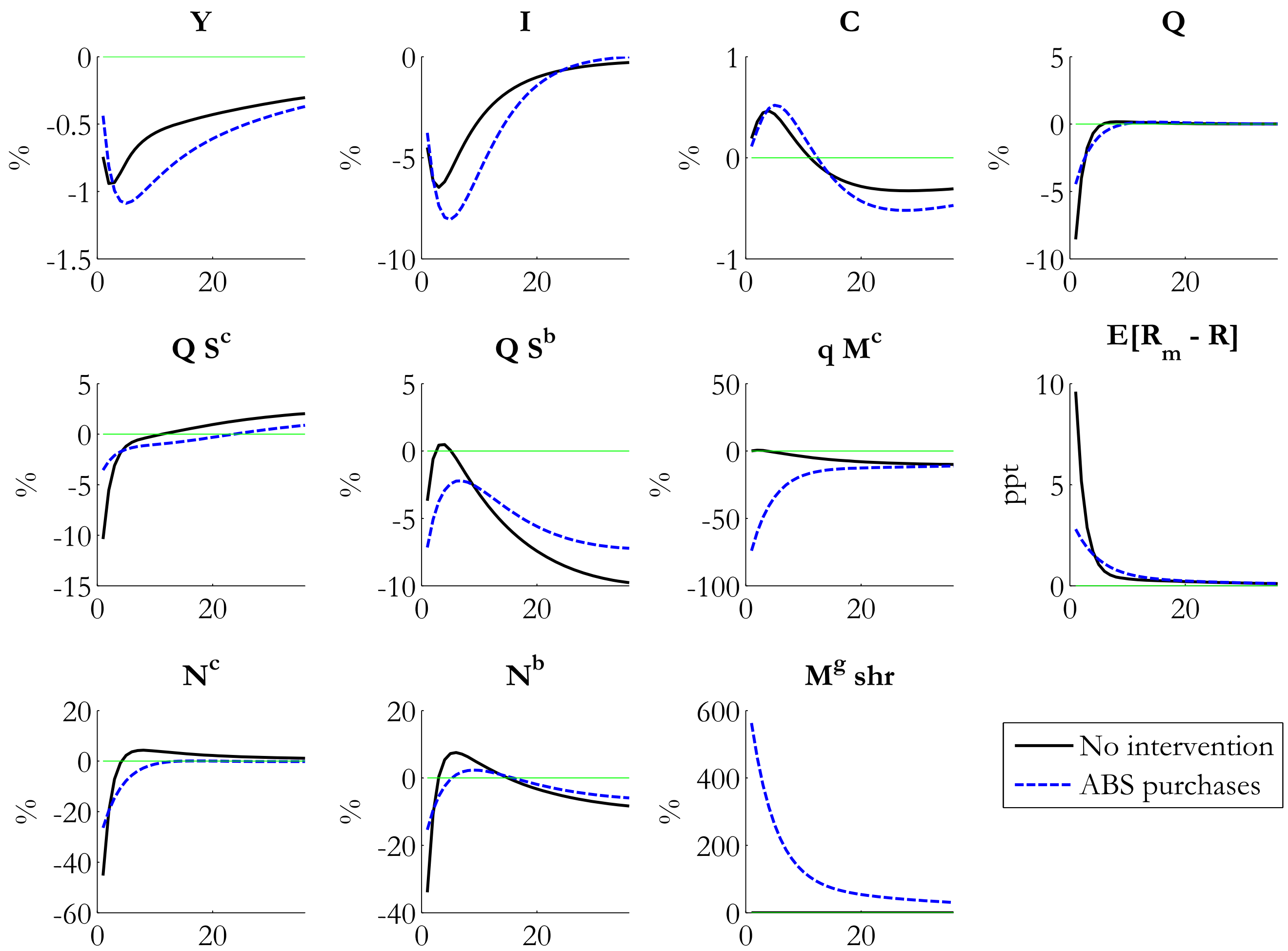
Note: Figure shows responses to a one-off redistribution of net worth from shadow banks to commercial banks equivalent to 25% of shadow bank net worth under the risk sharing securitization model (results for the risk taking securitization model are very similar).

Figure 7: Securitization crisis - Loan purchases



Note: Figure compares the effects of a securitization crisis with and without government purchases of primary securities under the risk sharing securitization model. Details of the shock are given in the main text.

Figure 8: Securitization crisis - ABS purchases



Note: Figure compares the effects of a securitization crisis with and without government purchases of asset backed securities under the risk sharing securitization model. Details of the shock are given in the main text.

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Additional Material

A Solution for the bank and broker problems

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 (4), 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 (4). 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

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

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

$$V^c_t = \mu^c_{st}\{\gamma_{dt} + (1-\omega_c)/\omega_c\}\, d_t + \left\{v^c_{mt}/q_t + \mu^c_{st}\gamma_{nt}\right\} n^c_t \tag{A.7}$$

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:

$$\begin{aligned} v^c_{mt}/q_t + \mu^c_{st}\gamma_{nt} &= \frac{v^c_{mt}}{q_t} + \mu^c_{st}\frac{\theta_c(1-\omega_c) - v^c_{mt}/q_t}{\mu^c_{st} - \theta_c\omega_c} \\ &= (1+\lambda^c_t)(v^c_{mt}/q_t) - \lambda^c_t\theta_c(1-\omega_c) \end{aligned} \tag{A.8}$$

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

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

$$\begin{aligned} &\mu^c_{t-1}Q_{t-1}s^b_{t-1} + (v^c_{m,t-1}/q_{t-1} - v^c_{t-1})d_{t-1} + (v^c_{m,t-1}/q_{t-1})n^b_{t-1} = \\ &\qquad \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n^c_t + \sigma\{(1+\lambda^c_t)(v^c_{mt}/q_t) - \lambda^c_t\theta_c(1-\omega_c)\}n^c_t\right] \end{aligned} \tag{A.9}$$

Define $\Omega^c_t := (1-\sigma) + \sigma\{(1+\lambda^c_t)v^c_{mt}/q_t - \theta_c(1-\omega_c)\lambda^c_t\}$, then:

$$\begin{aligned} &\mu^c_{t-1}Q_{t-1}s^b_{t-1} + (v^c_{m,t-1}/q_{t-1} - v^c_{t-1})d_{t-1} + (v^c_{m,t-1}/q_{t-1})n^b_{t-1} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^c_t n^c_t \\ &\quad = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^c_t\left\{(R_{st} - R_{mt})Q_{t-1}s^c_{t-1} + (R_{mt} - R_t)d_{t-1} + R_{mt}n^c_{t-1}\right\} \end{aligned} \tag{A.10}$$

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

$$\mu^c_{s,t-1} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^c_t(R_{st} - R_{mt}) \tag{A.11a}$$

$$v^c_{t-1} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^c_t R_t \tag{A.11b}$$

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

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

$$V^b_{t-1} = \max_{\{s^b_{t-1}, m^b_{t-1}\}} \mathrm{E}_{t-1}\Lambda_{t-1,t}\left[(1-\sigma)n^b_t + \sigma V^b_t\right] \tag{A.12}$$

subject to the balance sheet (11), incentive compatibility (12), and non-negativity constraints. Guess, and later verify, that the value function is linear in the time-varying coefficients $\{v^b_{st}, v^b_{mt}\}$:

$$V^b_t = \left(\frac{v^b_{st}}{Q_t}\right)Q_t s^b_t - \left(\frac{v^b_{mt}}{q_t}\right)q_t m^b_t \tag{A.13}$$

After using (11) to substitute out for ABS, we get the Lagrangian:

$$\mathcal{L} = (1+\lambda^b_t)\left[\left(\frac{v^b_{st}}{Q_t} - \frac{v^b_{mt}}{q_t}\right)Q_t s^b_t + \left(\frac{v^b_{mt}}{q_t}\right)n^b_t\right] - \lambda^b_t \theta_b Q_t s^b_t \tag{A.14}$$

where λ^b_t is the Lagrange multiplier on (12). The first order necessary conditions for $\{s^b_t, \lambda^b_t\}$ are:

$$\mu^b_{st} \leq \theta_b \frac{\lambda^b_t}{1+\lambda^b_t}, \quad \text{with equality if} \quad s^b_t > 0 \tag{A.15a}$$

$$\left(\mu^b_{st} - \theta_b\right)Q_t s^b_t + \left(\frac{v^b_{mt}}{q_t}\right)n^b_t \geq 0 \quad \text{with equality if } \lambda^b_t > 0 \tag{A.15b}$$

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

$$Q_t s^b_t = \frac{v^b_{mt}/q_t}{\theta_b - \mu^b_t} n^b_t \tag{A.16}$$

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

$$V^b_t = v^b_{mt}/q_t(1+\lambda^b_t)n^b_t \tag{A.17}$$

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

$$\mu^b_t Q_{t-1}s^b_{t-1} + \frac{v^b_{mt}}{q_t}n^b_{t-1} = \mathrm{E}_{t-1}\Lambda_{t-1,t}\left\{(1-\sigma)n^b_t + \sigma\frac{v^b_{mt}}{q_t}(1+\lambda^b_t)n^b_t\right\} \tag{A.18}$$

Define $\Omega^b_t := (1-\sigma) + \sigma(1+\lambda^b_t)v^b_{mt}/q_t$, then:

$$\begin{aligned}\mu^b_t Q_{t-1}s^b_{t-1} + \frac{v^b_{mt}}{q_t}n^b_{t-1} &= \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^b_t n^b_t \\ &= \mathrm{E}_{t-1}\Lambda_{t-1,t}\Omega^b_t\left\{(R_{st}-R_{mt})Q_{t-1}s^b_{t-1} + R_{mt}n^b_{t-1}\right\}\end{aligned} \tag{A.19}$$

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.

Banks

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

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

$$v^c_{mt}/q_t - v^c_t = \mathrm{E}_t\Lambda_{t,t+1}\theta_c(1-\omega_c)\lambda^c_t/(1+\lambda^c_t) \tag{B.3}$$

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

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

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

where

$$\Omega^c_t = (1-\sigma) + \sigma\left\{(1+\lambda^c_t)v^c_{mt}/q_t - \theta_c(1-\omega_c)\lambda^c_t\right\} \tag{B.7}$$

Aggregate commercial bank net worth and balance sheet identity:

$$N^c_t = (\sigma + \xi_c)\left\{R_{st}Q_{t-1}S^c_{t-1} + R_{mt}q_{t-1}M^c_{t-1}\right\} - \sigma R_t D_{t-1} + N^b_* \epsilon^n_t \tag{B.8}$$

$$D_t = Q_t S^c_t + q_t M^c_t - N^c_t \tag{B.9}$$

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

$$\lambda^b_t = \mu^b_{st}/(\theta_b - \mu^b_{st}) \tag{B.10}$$

$$Q_t S^b_t = (v^b_{mt}/q_t)/(\theta_b - \mu^b_{st}) \cdot N^b_t \tag{B.11}$$

$$\mu^b_{st} = \mathrm{E}_t\Lambda_{t,t+1}\Omega^b_{t+1}(R_{s,t+1} - R_{m,t+1}) \tag{B.12}$$

$$v^b_{mt}/q_t = \mathrm{E}_t\Lambda_{t,t+1}\Omega^b_{t+1}R_{m,t+1} \tag{B.13}$$

where

$$\Omega^b_t = (1-\sigma) + \sigma(1+\lambda^b_t)v^b_{mt}/q_t \tag{B.14}$$

Aggregate broker net worth and balance sheet identity:

$$N_t^b = (\sigma + \xi_b)R_{st}Q_{t-1}S_{t-1}^b - \sigma R_{mt}q_{t-1}M_{t-1}^b - N_*^b\epsilon_t^n \tag{B.15}$$

$$Q_tS_t^b = N_t^b + q_tM_t^b \tag{B.16}$$

Households and firms

$$u'(C_t) = (C_t - hC_{t-1})^{-1} \tag{B.17}$$

$$\Lambda_{t,t+1} = \beta u'(C_{t+1})/u'(C_t) \tag{B.18}$$

$$W_tu'(C_t) = \chi L_t^{\varphi} \tag{B.19}$$

$$Y_t = \mathrm{e}^{a_t}K_t^{\alpha}L_t^{1-\alpha} \tag{B.20}$$

$$Z_t = \alpha\mathrm{e}^{a_t}(L_t/K_t)^{1-\alpha} \tag{B.21}$$

$$W_t = (1-\alpha)\mathrm{e}^{a_t}(L_t/K_t)^{-\alpha} \tag{B.22}$$

$$R_{st} = \{Z_t + (1-\delta)Q_t\}/Q_{t-1} \tag{B.23}$$

$$R_{mt} = \{Z_t + (1-\delta)q_t\}/q_{t-1} \tag{B.24}$$

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

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

where $f(1) = f'(1) = 0$ and $\varepsilon := f''(1) > 0$.

Market clearing

Goods market, loan market and ABS market clearing conditions:

$$Y_t = C_t + [1 + f(I_t/I_{t-1})]I_t \tag{B.27}$$

$$S_t^c + S_t^b = K_{t+1} \tag{B.28}$$

$$M_t^c = M_t^b \tag{B.29}$$

Exogenous processes

The logarithm of the productivity forcing process is:

$$a_t = \rho_a a_{t-1} + \epsilon_t^a \tag{B.30}$$

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

C Proofs

Proof of Proposition 1 (Equilibrium ABS spread). We start by noting 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

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

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

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

Equating (B.23) with (B.24) and rearranging yields

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

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 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

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

[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.

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 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-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

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

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)

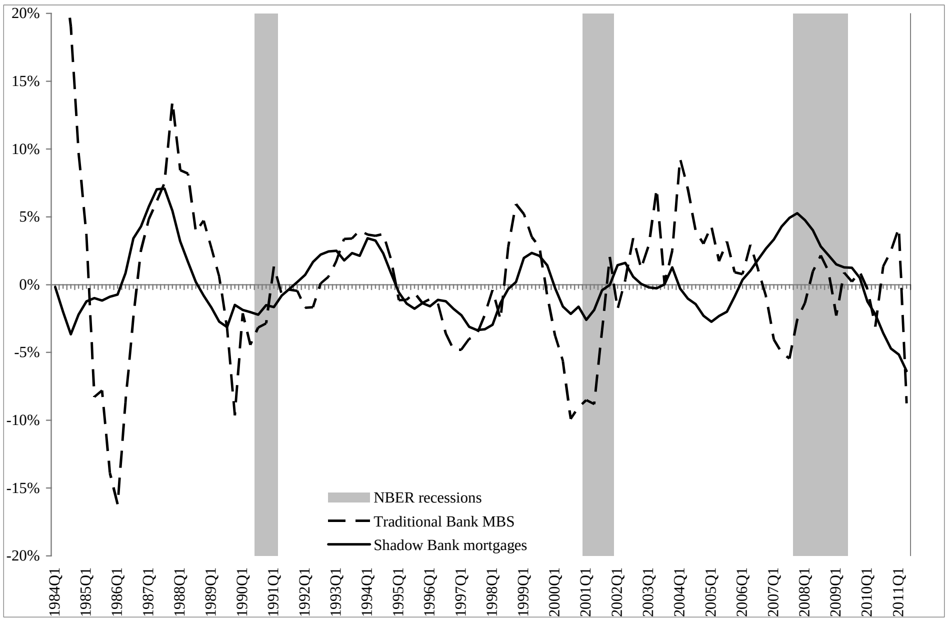
Note: CB - commercial banks; CU - credit unions; SI - savings institutions; ABS - Issuers of ABS; MP - mortgage pools; BD - broker-dealers; GSE - Government Sponsored Enterprises. Correlations among HP-filtered cycles in real output and Credit Market Instruments. Standard errors in parentheses. Data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

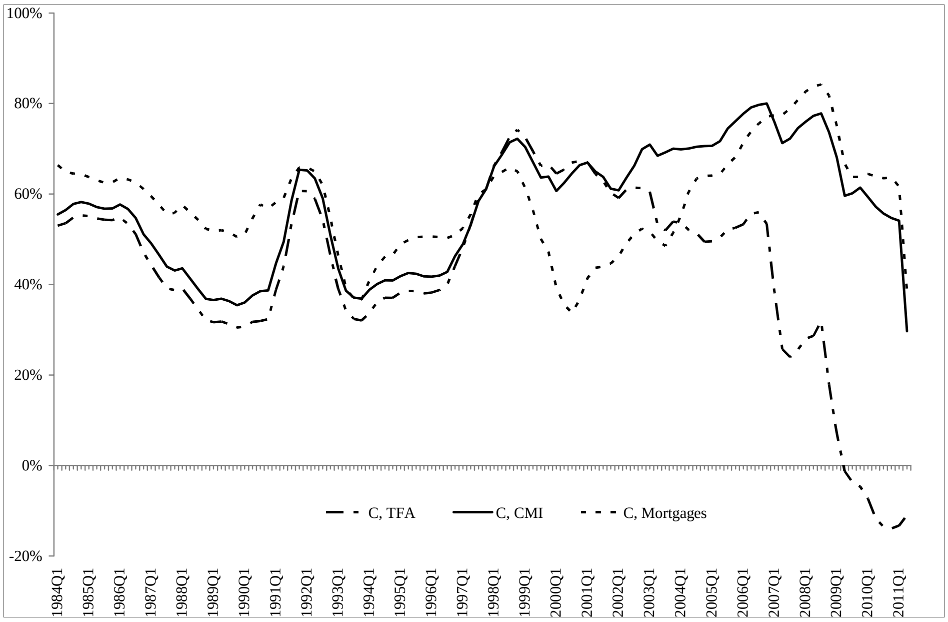
Note: CB - commercial banks; CU - credit unions; SI - savings institutions; ABS - Issuers of ABS; MP - mortgage pools; BD - broker-dealers; GSE - Government Sponsored Enterprises. Correlations among HP-filtered cycles in real output and (a) Total Financial Asset Leverage = TFA/(TFA-TL); (b) Credit Leverage = 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.

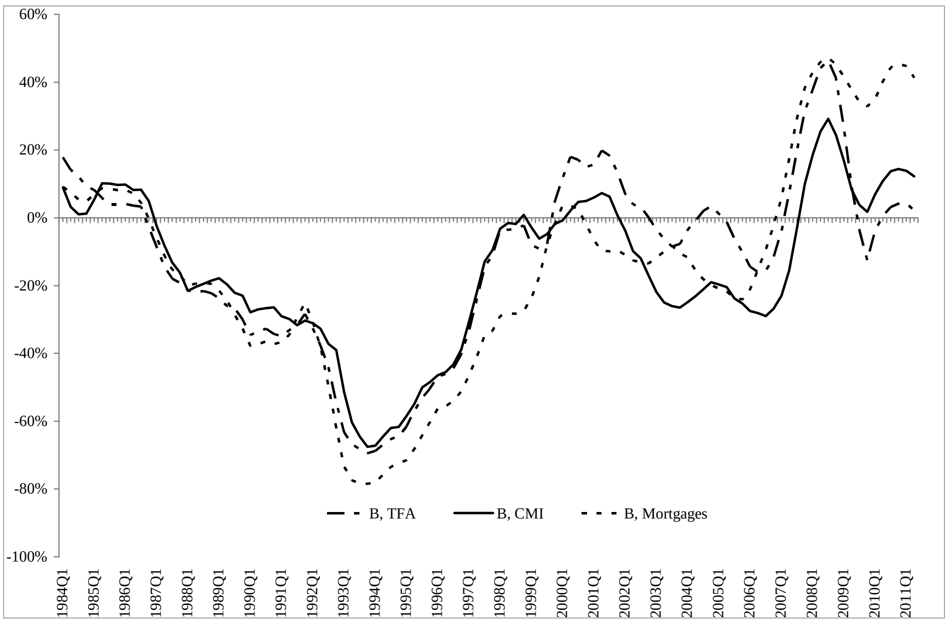
Figure D.1: Shadow bank mortgages and commercial bank stock of MBS



Note: Data source: United States Flow of Funds.

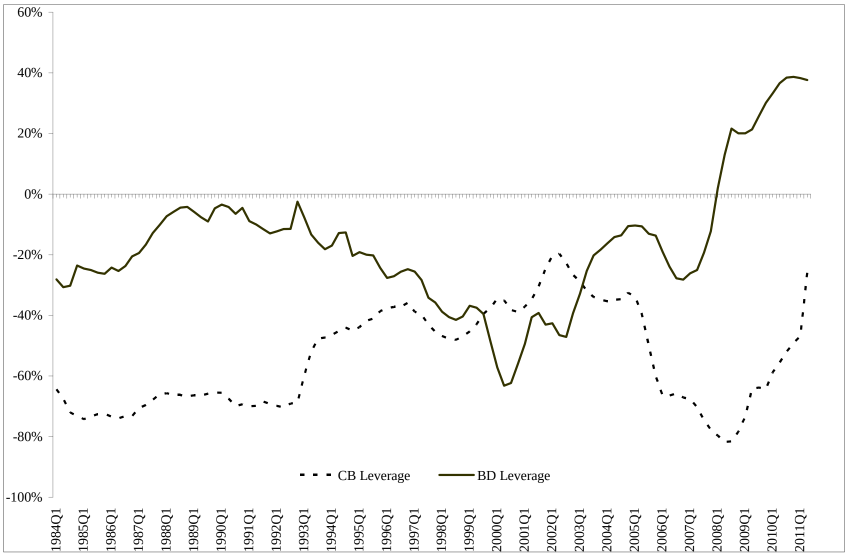
Figure D.2: Rolling correlations between output and commercial and shadow bank credit





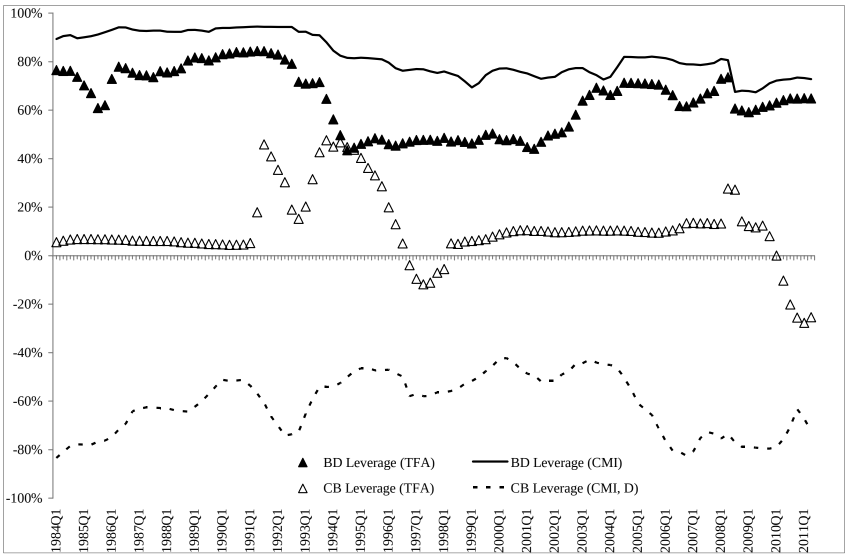
Note: A 10-year window is used to compute the rolling correlation. C - Commercial banks; B - shadow banks; TFA - Total Financial Assets; CMI - Credit Market Instruments. Data source: United States Flow of Funds.

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.

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