Credit Crises and Private Deleveraging

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Abstract

Private debt shrinks sharply in the aftermath of financial crises. Households' deleveraging and firms' deleveraging have typically been studied in isolation. In this paper I study the aggregate effects of private deleveraging in an economy with two-sided heterogeneity and a housing market. The model shows that the response of the economy to credit crises depends crucially on the financial asset position of the productive sector, a statistic that can be calculated directly from aggregate data. I calibrate the model to match this statistic and study the qualitative and quantitative properties of credit crises triggered in both sides of the economy and its consequences for aggregate output and the price of houses. I use the model to interpret aggregate trends during the most recent crisis and infer how much tightening on each side of the economy the data seems to be calling for. The findings suggest that aggregate data is consistent with a decline in borrowing capacity of 50% in the household side and 21.5% in the productive side. Moreover, counterfactual experiments suggest that the only effect of a larger stock of public debt is crowding out debt issued by the productive sector, with no consequences for the response of aggregate output.

JEL: E20, E21, E40, E44. **Keywords:** Credit Crises, Household debt, Two-sided heterogeneity.

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1 Introduction

In the United States, postwar data indicates that recessions often coincide with large contractions in the stock of private debt. Although these contractions are not specific to a single sector, the literature has typically studied households' deleveraging and firms' deleveraging in isolation. In fact, households' deleveraging has received a great deal of attention in the public and academic debate as an important factor behind the last recession, whereas the interest on firms' deleveraging waned compared to previous recessions[1]. The idea is that by forcing households into a rapid deleveraging, crises push the economy into a recession by depressing aggregate demand (Eggertsson and Krugman (2012)). Although the quantitative assessments of this idea offer mixed conclusions[2], they all share the approach of focusing on the evolution of household debt to understand the response of aggregate variables. In other words, they do not consider the role that others sectors of the economy played through their savings decisions. A thesis of this paper is that the evolution of financial flows across sectors matters for understanding how the economy responds to credit crises.

I start by documenting three facts regarding the evolution of financial flows of the private sector during recessions. First, I show that the net financial asset position (hereafter, NFA) of both households and firms are not only different from zero, but also display meaningful secular trends. In particular, in the last thirty years household debt grew to the point of making the household sector a net borrower at the outset of the most recent downturn. Second, I document a counter-cyclical saving behavior for households, and a pro-cyclical one for firms. In the case of households, this behavior stems from both debt deleveraging and asset accumulation during bad times. In the case of firms, it results from asset depletion dominating debt deleveraging during bad times. This finding highlights the importance of precautionary savings in the household side at business cycle frequencies. Third, I show that financial assets lead the cycle for both households and firms, whereas liabilities lags it. Moreover, liabilities are more persistent than financial assets for both households and firms.

Models with representative agents, and models with heterogeneous agents that postulate asset markets clearing within a single sector are not well-suited to capture these features of the data. Those models predict not only that the NFA is irresponsive to aggregate conditions, but also that, within a sector, debt deleveraging must correlate perfectly with asset depletion. The evolution of financial flows is crucial to determine which prices will bear the burden to

[1] Arguably, this is partly due to the fact that, since the turn of the XXI century the household sector became the largest debtor of the U.S. economy. According to Flow of Funds data, right before the last recession, household debt represented 43% of total credit market debt by domestic actors, firms debt represented 31% and government debt 26%. Currently these shares are 32%, 29% and 39% respectively.

[2] Although the list is not exhaustive, see Justiniano et al. (2015), Philippon and Midrigan (2016), Huo and Rios-Rull (2015), Guerrieri and Lorenzoni (2011), among others.

adjust to a deleveraging process and how aggregate quantities will respond as a consequence. In particular, the equilibrium price of assets that serve as collateral will depend on the saving behavior of all sectors in the economy. To illustrate this idea, suppose there is a negative shock in the borrowing capacity of households. In principle, household deleveraging should crowd in the debt issued firms because of the response of the interest rate. This implies that the pressure for asset depletion in the household sector subsides and the interest rate will not decrease by as much as in an economy with hand-to-mouth firms. Moreover, to the extent that the response of the interest rate is moderate, this would put most of the burden of adjustment on the price of the collateral asset, namely houses.

This paper proposes a parsimonious heterogeneous agents model and considers the aggregate effect of deleveraging processes triggered simultaneously in the household and the productive sectors. The model has three main ingredients. First, I explicitly model housing markets. Houses are assumed to be indivisible and used by households as collateral to access credit markets. This ingredient allows me to have a prediction for the price of houses and study its response to deleveraging forces. Second, it has a meaningful two-sided heterogeneity, in the household side and the firm side of the economy. More precisely, both households and firms face idiosyncratic uncertainty that pushes them to save for precautionary reasons. Third, the asset market must clear for all participants. This implies that intermediation must occur among all agents and consequently, the equilibrium interest rate must balance all saving motives. As simple as they are, these ingredients represent an important departure from previous models because they imply that deleveraging needs to be compensated either with asset depletion or with more debt issuance by other economic agents in order to restore equilibrium. Importantly, which agent does one or the other will have different implications for the evolution of the price of the assets that act as collateral, namely houses.

To explore the effect on aggregate variables, I adopt a stark definition of credit crises as exogenous contractions in the borrowing capacity of economic agents. In a large class of economic models featuring market incompleteness, these contractions trigger a deleveraging process due to the strengthening of the precautionary motive to save. I use the model to infer how much tightening to each side of the market aggregate data seems to be calling for. In doing so, I take into account that, as a response to the crisis, the amount of debt supplied by agents other than households and firms almost doubled in size as a percentage of GDP. Accounting for this change is important for the same reasons mentioned above regarding which prices will bear the burden to adjust, especially considering the trend in foreign demand for domestic public debt and the magnitude of the government response to the crisis.

The findings indicate that the evolution of the aggregate data can be replicated only if one assumes a decline in the access to credit in both sides of the market. To be more precise, had all the deleveraging occurred in the household sector, one should have observed a substantial drop in the price of houses and in the interest rate, although barely any effect in aggregate output and a counterfactual change in the financial asset position of the productive sector. In turn, had all the deleveraging occurred in the productive sector, the model suggests that we should have observed only a modest decline in the price of houses and the interest rate. I interpret these results as suggesting that models that posit all intermediation occurring form one side of the market cannot capture successfully some salient features of aggregate data during the last recession. In contrast, when I consider a contraction in both sides of the economy, the model is capable of reproducing salient features of the recent crisis, namely the decline in output and house prices and negative real interest rates. The results suggest that reduced access to credit is a necessary condition within the model to explain aggregate trends.

To further explore the role of other factors in driving the response of aggregate variables, I consider coupling the reduction in the borrowing capacity with either downward rigid interest rates and an increase in idiosyncratic volatility. Although downward rigidity falls short in reproducing some of the facts mentioned above, an increase in idiosyncratic uncertainty arises as an important factor behind the behavior of aggregates. Moreover, when these three ingredients are combined, the results indicate that aggregate data is consistent with a contraction of the borrowing capacity of 50% and 21.5% in the borrowing capacity of households and firms, respectively. If one takes into account that households faced an increase in the downpayment requirement to access mortgage loans of about 20%, this estimate accounts successfully not only for the tightening of terms of lending but also for the hardening of lending standards.

Motivated by these findings, I use these estimates of credit tightening to study the response of the economy, had the debt of agents other than households and firms remained constant throughout the crisis. Since the increase in debt was mostly due to the government, these counterfactual exercises are informative of the real impact of this debt issuance. I find that by preventing the interest rate of falling any further, the increase in public debt only crowded out the debt issued by firms. In other words, had the amount of government debt remained constant, lower interest rates would have allowed the productive sector to issue more debt in spite of the contraction in their borrowing capacity. More importantly, the response of aggregate output would have been the same, with or without the increase in government debt.

In the remainder of this section I connect the paper to the rest of the literature. In the next section I setup the model economy. The properties of stationary equilibria are analyzed in Section 3. I describe the baseline parameterization in Section 4 and present the comparative statics results in Section 5. Transitional dynamics with and without government intervention are studied in Section 6. Finally, in Section 7 I conclude.

Related literature.

This paper contributes to the literature on financial frictions that stems from the work by Bernanke and Gertler (1989) and Kiyotaki and Moore (1997). These seminal contributions were more concerned about the role of frictions as an amplification mechanism of TFP shocks. In contrast, recent contributions to this literature explore the idea of financial shocks as independent drivers of output fluctuations. In general, these shocks are conceived as perturbations to the borrowing capacity of economic agents. Regarding the recent crisis, a line of research presumes that the initial impulse in the household sector was transmitted to the productive sector by pushing firms' potential lenders into financial distress. A recession, the argument goes, is the result of the difficulties in accessing external funds to finance production (see for instance Jermann and Quadrini (2012)). Other authors dispense with that presumption and focus on the effects of a household credit tightening over economic activity (see Guerrieri and Lorenzoni (2011) or Philippon and Midrigan (2016)). The view in these papers is that recessions are driven by households pulling back private consumption.

Several recent papers have studied the consequences of tightening credit constraints in the household side (see Huo and Rios-Rull (2015), Guerrieri and Lorenzoni (2011) or Justiniano et al. (2015) or in the productive side (see Buera and Nicolini (2016)). These papers offer a wide variety of conclusions. For instance, Huo and Rios-Rull (2015) show that a recession following a credit tightening can be engineered once one considers goods market frictions. On the other side of the spectrum, Justiniano et al. (2015) show that when one fully incorporates housing markets into the picture, the quantitative performance of a mechanism like the one exposed in Eggertsson and Krugman (2012) fails to explain the recent crisis. Philippon and Midrigan (2016) reach a similar conclusion in a model with liquidity constraints. Credit crises in these papers are modeled as an exogenous contraction in borrowing limits. These limits are often interpreted as loan to value ratios. In Justiniano et al. (2015), this interpretation is too literal in the sense they model a leverage cycle as corresponding to changes in the borrowing limits that match, on average, the evolution of loan to value ratios in the data. However, it is worth to point out that in addition to capture the creditworthiness of the borrower, these limits might also stand for a measure of how loose credit standards are. Hence, a contraction intended to capture a worsening of households? borrowing capacity must account for changes in all factors that affect households? access to credit, regardless of whether they are supply or demand driven. In other words, it is preferable to think of it as a reduced form parameter. This paper takes takes that route, just as Huo and Rios-Rull (2015), and Guerrieri and Lorenzoni (2011). Unlike them, in doing so, I allow for tightening to occur in both sides of the market.

This indirect approach to quantify the magnitude of the credit tightening is silent about whether it was supply or demand driven. In a recent paper, Adrian et al. (2012) argue that the recent financial turmoil was indeed supply driven, since firms were able to substitute sources of funds. They show that the substitution of indirect financing (loans) for indirect financing (bonds) provoked an increase in the cost of credit for firms. Since deleveraging must in principle put a downward pressure in the equilibrium interest rate, these findings suggest that it could be appropriate to consider a positive a counter-cyclical spread between borrowing and lending interest rates. I consider that possibility in the quantitative section of this paper.

The economic literature offers two perspectives on the connection between debt and the macroeconomy. The first states that by putting a downward pressure on interest rates, deleveraging could push the economy to the zero lower bound and set in motion a debt-deflation mechanism that explains the Great Recession (see Eggertsson and Krugman (2012)). A second perspective emphasizes the role of debt in providing liquidity services, helping agents to concentrate their expenditures in those periods in which they are more valuable (see Woodford (1990)). This paper follows the second approach. Deleveraging in this case implies that resources are used in a less efficient manner, decreasing aggregate productivity and potentially reducing output. Under this perspective, aggregate output depends on the amount of intermediated funds.

2 Data Motivation

The goal of this section is to provide empirical support to a collection of claims concerning the Net Financial Asset position (NFA position hereafter) and the saving behavior of households and firms. The preliminary step consists in constructing a meaningful statistic for the NFA position. To do so, I use balance sheet data from the Flow of Funds and consider the following sectors: Households, Firms, Government, Financial Sector and Rest of the World[3]. Next, I select debt-like instruments only, in order to construct series for Financial Assets and Liabilities for each sector[4]. The NFA position is then calculated as the difference between Financial Assets and Liabilities. If the construction of these series is valid, it must be that the excess demand, defined simply as the sum of NFA positions across sectors, equals zero. Figure 1 shows that the construction is remarkably accurate, as measured by the implied excess demand, which is small relative to total assets traded and it can be safely attributed to measurement error. The figure also provides support for the first claim which is stated as follows.

Claim 1 *Net Financial Asset positions of households and firms are different from zero and*

[3]A more detailed explanation of how each series is constructed can be found in the the appendix.

[4]Excluding equity-like instruments is consistent with most of the literature studying financial frictions and credit crises episodes, which typically focuses on the market for loanable funds. The implicit assumption is that households own the firms either directly through corporate equities, or indirectly through mutual fund shares or IRAs in pension funds.

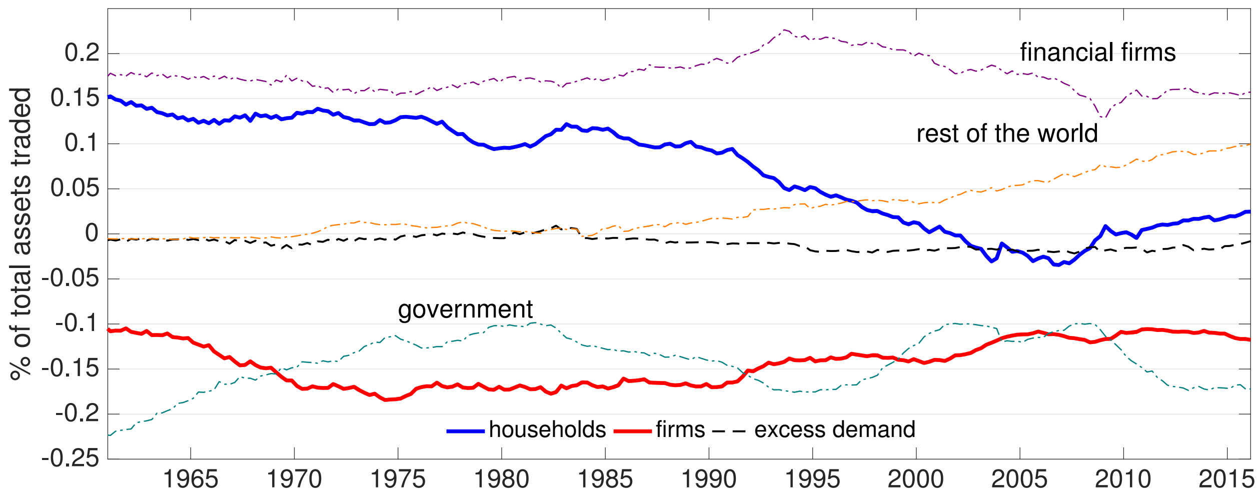

Figure 1
Net Financial Asset Position by Economic Sector
The NFA position is calculated as the difference between financial assets and financial liabilities as a percentage of total assets traded in the market of loanable funds. The construction of each series is detailed in the appendix

display meaningful secular trends.

Since the 90s, households' and firms' NFA positions moved in opposite directions. The downward trend in households NFA position has been very drastic, to the point of making the household sector a net borrower in the midst of the recent crisis. Over the same period, the productive sector experienced the opposite phenomenon, although its NFA position did not change sign.

How to understand the fact that households became net borrowers? The answer to this question is related to the evolution of house prices. Households access to credit is largely determined by the collateral value of its non-financial assets, most notably, houses[5]. Consequently, the evolution of household debt is largely influenced by the state of the housing market. The years preceding the last recession were characterized by increasing house prices and easy credit in the form of loose standards and high loan to value ratios. Both features increased the value of households' collateral and relaxed households' borrowing constraints. Household debt responded by tracking the appreciation of housing structures as financial collateral. This is clearly illustrated in the top panel of Figure 2, which displays the evolution of house prices together with two aggregate measures of household indebtedness: the debt to income ratio and

[5]At the onset of the recent crisis, around 75% of household debt corresponded to mortgages, which are collateralized by the market value of housing structures.

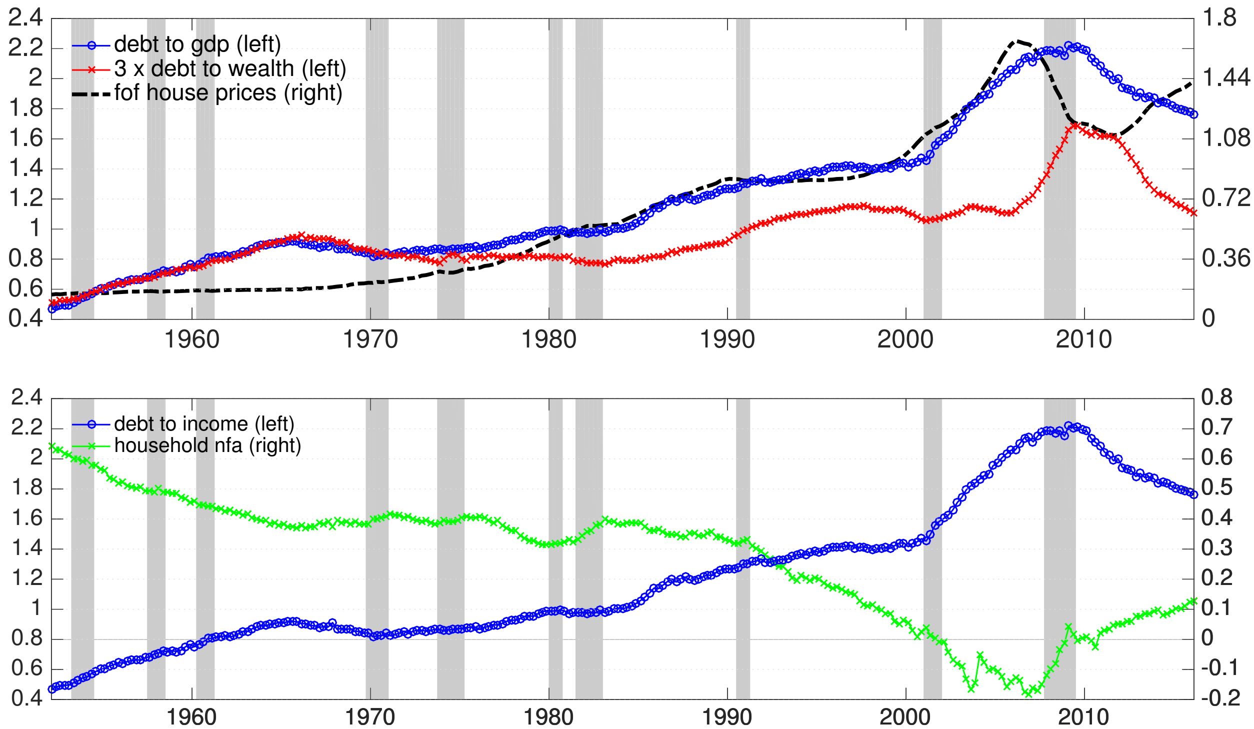

Figure 2
Household Indebtedness and housing prices
Debt to income ratio and debt to wealth ratio are calculated using Tables B100 and F7 from the Flow of Funds. Debt to Income = B100.31/F7.3, Debt to Wealth = B100.33/B100.4. I use the Case-Shiller house price index.

the debt to wealth ratio. One way to interpret these trends is that households reacted to the increase in illiquid wealth by borrowing against it, so as to maintain a relatively constant debt to wealth ratio in the years preceding the last crisis. The figure also suggests that it took some time for households to start deleveraging: in the midst of the crisis the debt to income ratio first remained flat, and only later fell considerably. In turn, the debt to wealth ratio increased drastically first, mostly because house prices plummeted, and it started to decrease after the recession was over.

The bottom panel of Figure 2 shows that the evolution of households' NFA position is basically the mirror image of that of debt to income ratio and therefore, it is largely explained by the increase in household debt. However, in the onset of the recent crisis, the NFA position started increasing before deleveraging took place. This suggests that in spite of the prevalence of liabilities in determining the NFA position of households in the long run, the evolution of financial assets might play a role at higher frequencies. We explore these issues in more detail in the next two claims, and address also the behavior of firms' NFA position .

Table 1
Business Cycle Properties of Financial Flows.
The cyclical component is obtained by fitting a HP trend for the entire sample period. The NFA position is calculated as the ratio of the difference between Financial Assets and Liabilities to Financial Assets. The time series for each balance sheet category adjusts for revaluations to capture only the effect of transactions on the growth of a given asset or liability. Details are in the appendix.

	Corr with rGDP		
	All sample	Before 80Q1	Since 84Q1
Households			
Financial Assets	**−0.00**	**0.23**	**−0.13**
Deposits	0.11	0.42	−0.10
Bonds	−0.14	−0.34	−0.16
Liabilities	**0.63**	**0.72**	**0.47**
Mortgages	0.63	0.72	0.47
Consumer Credit	0.52	0.70	0.33
NFA Position	**−0.41**	**−0.71**	**−0.31**
Firms			
Financial Assets	**0.43**	**0.14**	**0.56**
Deposits	0.47	0.33	0.48
Bonds	0.07	−0.19	0.20
Liabilities	**0.23**	**0.21**	**0.29**
Debt	−0.14	−0.44	−0.03
Loans	0.28	0.32	0.33
NFA Position	**0.14**	**−0.01**	**0.14**

Claim 2 *Saving behavior is counter-cyclical for households and pro-cyclical for firms. In the case of households, there is debt deleveraging and asset accumulation during bad times. In the case of firms, it results from asset depletion dominating debt deleveraging during bad times.*

To support this claim, I consider the cyclical component of the NFA position and of each element of it for both households and firms. Table 1 shows that NFA positions move in opposite directions at cyclical frequencies: it is counter-cyclical for households and pro-cyclical for firms. A counter-cyclical NFA position means that, in the aggregate, households net savings are positive during bad times. In fact, this feature has strengthened over the last 30 years, as the last column of the table shows[6]. However, this finding still hides valuable information since, in principle, there are three different ways in which one could obtain counter-cyclical net

[6]The focus on the period starting in 1984 is common (see for instance Jermann and Quadrini (2012) because it covers a period of substantial financial innovation and deregulation. In addition, it has been documented that many macro series display a break in volatility that can be placed right after the early 80's NBER recessions. For the second column we consider the first part of the sample, excluding the recession years.

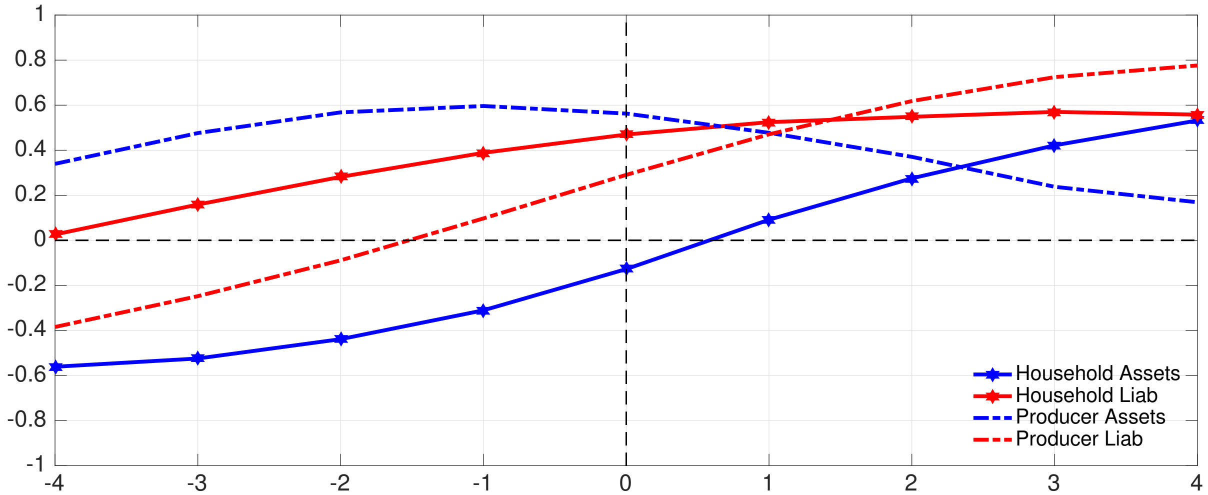

Figure 3
Lag Correlations with GDP by Economic Sector
The cyclical component is obtained using a Hodrick-Prescott filter with a filtering parameter of 1600 as it is customary for quarterly frequency data.

savings: either pro-cyclical liabilities coincide with counter-cyclical assets, or pro-cyclical liabilities dominate pro-cyclical assets, or counter-cyclical assets dominate counter-cyclical liabilities. The table indicates that in the case of households, the first case is the empirically relevant one. Moreover, this finding highlights the importance of precautionary savings in the household side at business cycle frequencies, since it appears to explain saving behavior both at the top and bottom of the wealth distribution. In the case of firms, the behavior of the NFA position is the consequence of pro-cyclical assets dominating pro-cyclical liabilities. Notice however there appears to be some degree of substitution between the sources of funds for firms, since the correlation of bonds and loans with the business display different signs. This feature has also been documented in Adrian et al. (2012), which interprets it as evidence that firm credit being affected by supply shocks that force them to substitute alternative source of funds.

The previous findings bring up the question of whether contemporaneous correlations suffice to characterize the response of financial flows during bad times. For instance, as stated in the discussion of the first claim, the top panel of Figure 2 suggested that deleveraging is a sluggish process that reaches his peak after bad times have passed. The following claim explores these issues in more detail.

Claim 3 *Financial assets lead the cycle for both households and firms, whereas Liabilities lags it. Moreover, Liabilities are more persistent than Financial Assets for both households and firms.*

Table 2
Persistence in Assets and Liabilities.
We estimate $y_t = \rho y_{t-1} + u_t$ for financial assets and liabilities of each sector and report the estimated coefficient $\hat{\rho}$ and the variance of the perturbation $\sigma_u^2 = Var(u)$.

	$\hat{\rho}$	σ_u^2
Household Financial Assets	0.81	0.81
Household Liabilities	0.92	0.69
Firm Financial Assets	0.69	1.94
Firm Liabilities	0.96	0.64

To support this claim, I focus again on the period 1984Q1 to date, which comprises three NBER recessions and covers an era of substantial deregulation in financial markets. Figure 3 displays lead and lag correlations of financial assets and liabilities with real GDP. The figure shows that households' and firms' deleveraging tend to lag the business cycle, but the response of financial assets, in both cases, anticipates the cycle. In other words, household asset accumulation and firms asset depletion behave as leading indicators of economic activity. Deleveraging seems to be a rather long and persistent phenomenon in both sides of the economy. To document this formally, I estimate an AR(1) process using the cyclical component of each category and report the results in Table 2. The evolution of debt, either households' or firms' is more persistent than the evolution of financial assets. Figure 4 shows that the claims would indeed pass an eyeball test if one focus on the NBER recessions during the period starting in 1984.

The findings documented have important implications for modeling strategies since they indicate that models with representative agents, and models with heterogeneous agents that postulate asset markets clearing within a single sector, would be unable to capture the features of the data presented in this section. Those models predict not only that the NFA is irresponsive to aggregate conditions, but also that, within a sector, debt deleveraging must correlate perfectly with asset depletion. These predictions are rejected by the data. More importantly for the purposes of this paper, the behavior of financial flows are key to determine which prices will bear the burden to adjust to a deleveraging process. In particular, the market value of collateral assets will depend on the saving behavior of all sectors in the economy. Therefore, if we consider a collateral asset such as houses, that is in fixed supply and it is traded mostly within a single sector, it matters how other sectors respond to shocks and how the interest rate adjusts as a consequence. For instance, if for some reason the interest rate were irresponsive , this would put all the burden of adjustment on the price of the collateral asset, namely houses.

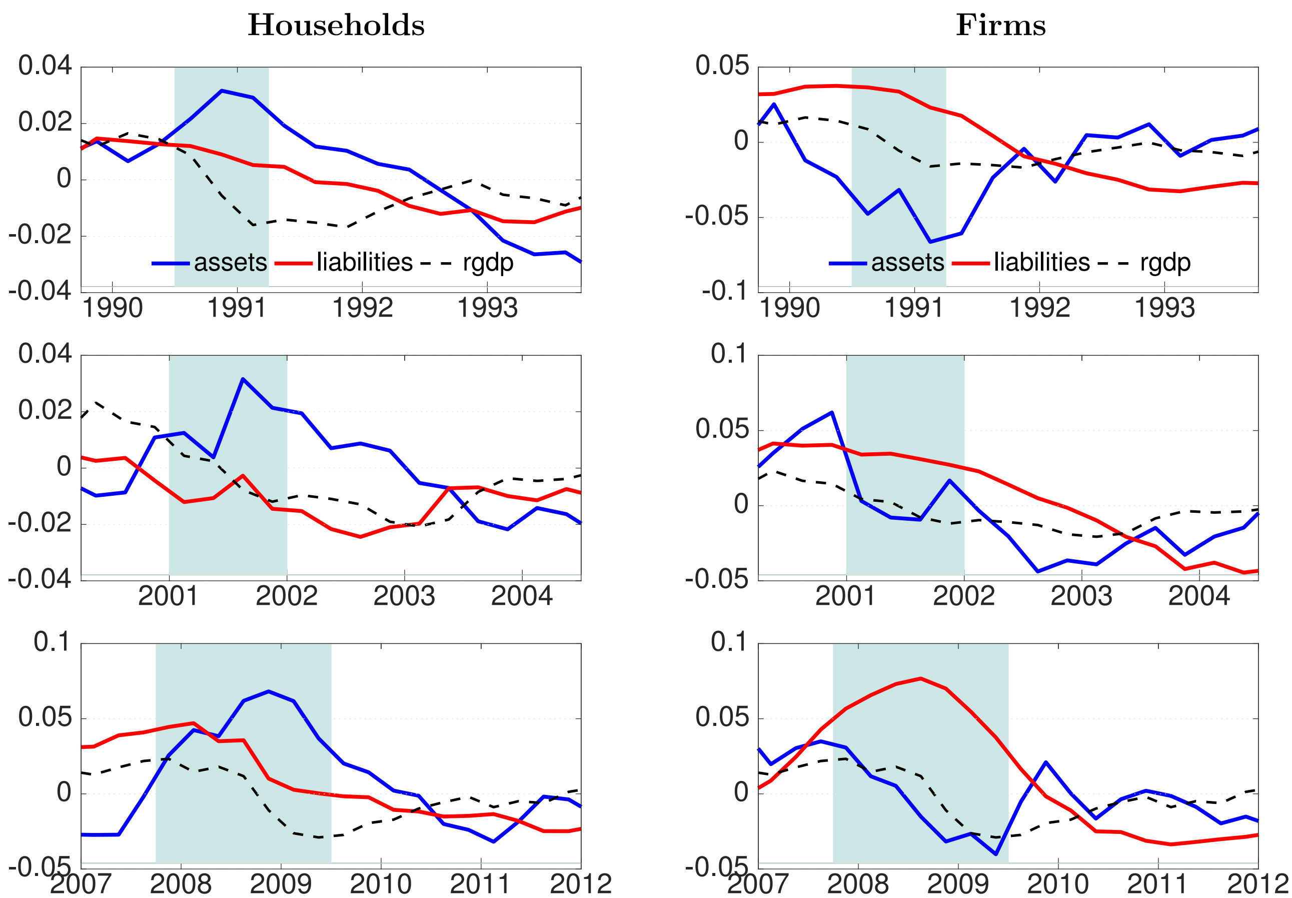

Figure 4
Evolution of Assets and Liabilities During Recessions.
The cyclical component is obtained using a Hodrick-Prescott filter with a filtering parameter of 1600 as it is customary for quarterly frequency data.

3 Model

Time is infinite and indexed by t. The economy is populated by two type of agents: households and firms. There is a final good that can be used for consumption or investment purposes and will play the role of the numeraire. There are also two physical assets: houses owned by households and capital owned by firms. The household side incorporates a housing decision into an otherwise standard problem of idiosyncratic income fluctuations. In the productive side, the presence of decreasing returns to scale, time varying productivity shocks, and borrowing constraints, deliver a motive to save in order to take advantage of high productivity shocks. Finally, there is a reduced form of financial intermediation that allows agents to save and borrow funds by pledging the physical assets they own as collateral. I describe in turn the household's problem, the firm's problem, the market structure and the notion of equilibrium.

3.1 Households

There is a unit mass of households. Each household is infinitely lived, supplies labor inelastically, and derives utility from consumption according to the instantaneous utility function $u(c,h)$, where the variable $h \in \{0,1\}$ indicates the housing status.

Each household enters period t with total wealth given by $\omega_{H,t}$ and decides consumption c_t, asset holdings a_{t+1} and housing status h_{t+1}, so as to satisfy the following budget constraint:

$$c_t + a_{t+1} + \mathbf{q}_t h_{t+1} \leq \omega_{H,t} \tag{1}$$

where $\mathbf{q}_t$ denotes the price of houses in period t. Households can borrow against the collateral value of their houses, in which case a_{t+1} can take on negative values. This implies that the asset holding decision must satisfy the following borrowing constraint:

$$\mathbf{R}_t a_{t+1} + \phi_{H,t} \mathbf{q}_{t+1} h_{t+1} \geq 0 \tag{2}$$

where $\mathbf{R}_t$ denotes the gross interest rate in period t . This equation says that if a household decides to be a renter ($h_{t+1} = 0$), then it will have no access to credit. In contrast, if it decides to be a homeowner ($h_{t+1} = 1$), it will be able to borrow up to the collateral value of the house, which is equal to a fraction $\phi_{H,t}$ of the market value $\mathbf{q}_t$. The parameter $\phi_{H,t}$ is assumed to be uniform across households.

At this point, it is important to remain agnostic regarding what ϕ_H is supposed to stand for. Although it appears correct to interpret it as a loan to value ratio and associate it with the creditworthiness of the borrower, it might as well stand for a measure of how loose credit standards are. Hence, a contraction in ϕ_H intended to capture a worsening of households' borrowing capacity must account for changes in all factors that affect households' access to credit, regardless of whether they are supply or demand driven. Because of this, it is preferable to think of it as a reduced form parameter.

The law of motion for household's wealth is given by:

$$\omega_{H,t+1}(a_{t+1}, h_{t+1}, \theta_{t+1}) = \theta_{t+1}\mathbf{w}_t + \mathbf{R}_t a_{t+1} + \mathbf{q}_t h_{t+1} + \mathbf{d}_{t+1} \tag{3}$$

where $\mathbf{w}_t$ represents the wage per efficiency units, θ_t denotes an idiosyncratic shock that hits the household at the beginning of each period and determines the number of efficiency units of labor they can offer to the market, and $\mathbf{d}_t$ corresponds to the dividend payments that households receive from firms. The implicit assumptions regarding these dividend payments are that households own these firms through a mutual fund so that they can completely diversify idiosyncratic risk, all households own the same amount of mutual fund shares, and mutual fund shares are not traded.

The individual state for the household in period t consists of the triple $(\omega_{H,t}, \theta_t, h_t)$. Each period, households choose plans (c_t, a_{t+1}, h_{t+1}) that are contingent on their individual state so as to solve the right hand side of the following functional equation:

$$V_t(\omega_{H,t}, \theta_t, h_t) = \max_{c_t, a_{t+1}, h_{t+1}} u(c_t, h_t) + \beta \mathbb{E}_t \left[V_{t+1}(\omega_{H,t+1}, \theta_{t+1}, h_{t+1}) \mid \theta_t \right] \tag{4}$$

subject to (1), (2), (3), a non-negativity constraint for c_t and $h_{t+1} \in \{0, 1\}$.

3.2 Firms

There is a unit mass of firms. Each firm has access to a production technology that transforms k units of installed capital and l units of labor into y units of the final good according to the following production function:

$$y = F(z, k, l) = (zk)^{\alpha_1} l^{\alpha_2} \tag{5}$$

where z represents an idiosyncratic productivity shock. The production technology displays decreasing returns to scale in capital and labor, e.g. $\alpha_1 + \alpha_2 < 1$. As it is customary, I will refer to $\alpha_0 \equiv 1 - \alpha_1 - \alpha_2$ as the span of control.

Firms start each period with total assets m_t, installed capital k_t and knowing their current productivity shock z_t. At the beginning of the period, each firm demands labor and production takes place. The labor demand decision solves the following problem:

$$\Pi(k_t, z_t) = \max_{l_t \geq 0} (z_t k_t)^{\alpha_1} l_t^{\alpha_2} - \mathbf{w}_t l_t \tag{6}$$

This is an unconstrained static decision in the sense that firms face no constraint for financing the wage bill. The assumption is that the pledgeability of cashflows is high enough so that the asynchrony between receipts and outlays does not impose a problem regarding short term financing. Once revenues are collected, the total resources available to the firm are given by:

$$\omega_{F,t} = \Pi(k_t, z_t) + (1 - \delta) k_t + \mathbf{R}_{t-1} m_t$$

where δ denotes the depreciation and $\mathbf{R}_t$ corresponds to the gross interest rate . Each firm then decides how to distribute these resources among dividends d_t, next period capital k_{t+1} and savings m_{t+1}, in order to satisfy the flow of funds constraint given by:

$$d_t + k_{t+1} + m_{t+1} \leq \omega_{F,t} \tag{7}$$

At the end of the period, the shock z_{t+1} that determines the productivity the following period is revealed. This timing implies that when firms make their investment and savings decisions, they do not know how much resources they will have available next period. This uncertainty introduces a motive to save for precaution, in order to be able to invest at the appropriate scale at every period.

Each firm has the possibility to leverage up their physical investment by borrowing external funds. This borrowing capacity is constrained by the stock of installed capital, which is the only resource they can pledge. The collateral constraint for the firm has the form:

$$\mathbf{R}_t m_{t+1} + \phi_{F,t}(1-\delta)k_{t+1} \geq 0 \tag{8}$$

where the parameter ϕ_F measures the pledgeability of the undepreciated capital stock and it is assumed to be uniform across firms[7].

The law of motion for firms' total resources is given by:

$$\omega_{F,t+1}(k_{t+1}, m_{t+1}, z_{t+1}) = \Pi(k_{t+1}, z_{t+1}) + (1-\delta)k_{t+1} + \mathbf{R}_t m_{t+1} \tag{9}$$

The problem of the firm consists of maximizing the net present value of dividends. I setup this problem recursively by adopting a cash in hand formulation. Let the individual state of firm at the beginning of the period to be the pair $(\omega_{F,t}, z_t)$. Each period firms choose plans $(d_t, l_t, k_{t+1}, m_{t+1})$ that are contingent on their individual state so as to solve the right hand side of the following functional equation:

$$J_t(\omega_{F,t}, z_t) = \max_{d_t, l_t, k_{t+1}, m_{t+1}} d_t + \mathbb{E}_t\left[\eta_{t+1} J_{t+1}(\omega_{F,t+1}, z_{t+1}) \mid z_t\right] \tag{10}$$

[7] The collateral constraint can be derived formally as an enforcement constraint along the lines of Jermann and Quadrini (2012), assuming that upon default, lender and borrower renegotiate the terms of a new lending agreement. Interpret ϕ_F as the scrap value of capital and suppose that lenders have no bargaining power in the renegotiation stage. Let $b' = -m'$ denote the debt balance, which is assumed to be positive ($m' < 0$). At the beginning of the next period, the debt obligation will be $\mathbf{R}b'$. Thus, a risk neutral lender that discount future cash flows at rate $\mathbf{R} - 1$ would be indifferent between liquidating the firm and get $\phi_F(1-\delta)k'$ or renegotiating debt for a payment of $\phi_F(1-\delta)k' - \mathbf{R}b'$ today, and a promise of $\mathbf{R}^2 b'$ one period after. Let $\mathbb{E}[\eta J]$ denote next period's present value of future dividends. Hence, the value of the firm after defaulting is given by:

$$\mathbb{E}[\eta J] - (\phi_F(1-\delta)k' - \mathbf{R}b')$$

The level of debt b' is enforceable if the ex-ante value of the is weakly larger than its ex-post value:

$$\mathbb{E}[\eta J] \geq \mathbb{E}[\eta J] - \left(\phi_F(1-\delta)k' - \frac{b'}{R}\right)$$

This expression can be rearranged to obtain (8) in the main text.

subject to (7), (8), (9) and a non-negativity constraint for d_t and k_{t+1}[8]. Notice that I have used the factor η_{t+1} to discount the value of the firm the following period. Since dividends are distributed to households, the discount factor η must somehow take into account their preferences. I assume that it is equal to the average inter-temporal marginal rate of substitution across all households in period t:

$$\eta_{t+1} = \beta \mathbb{E}\left[\frac{u_1(c_{t+1}, h_{t+1})}{u_1(c_t, h_t)}\right] \tag{11}$$

where u_1 denotes the derivative of the function u with respect to the first argument and the expectation is taken with respect to the probability distribution of households over their individual state.

3.3 Markets

There are four markets in this economy: the asset market, the labor market, the housing market and the final good market. Let $\psi_{H,t}$ and $\psi_{F,t}$ denote the period t measure of households and firms over their respective individual state. Notice that the recursive formulation is implicitly assuming that the economy starts off after the labor market and the housing market have cleared in period 0 and this must be taken into account when writing the market clearing conditions.

Since both types of agents participate in the asset market, the corresponding market clearing condition must be written as follows:

$$\int a_{t+1}(\omega_{H,t}, \theta_t, h_t) d\psi_{H,t}(\omega_{H,t}, \theta_t, h_t) + \int m_{t+1}(\omega_{F,t}, z_t) d\psi_{F,t}(\omega_{F,t}, z_t) = \overline{B}_t \quad , \forall t \geq 0 \tag{12}$$

where $\bar{B}_t$ is an exogenously given supply of bonds. In the case of the labor market, since households supply labor inelastically, the market clearing condition is given by:

$$\int l_t(\omega_{F_t}, z_t) d\psi_{F,t}(\omega_{F,t}, z_t) = 1 \quad , \forall t \geq 1 \tag{13}$$

I also assume an inelastic supply of houses, which implies that market clearing is given by:

$$\int h_{t+1}(\omega_{H,t}, \theta_t, h_t) d\psi_{H,t}(\omega_{H,t}, \theta_t, h_t) \quad = \quad \overline{H}_t \quad , \forall t \geq 1 \tag{14}$$

where $\overline{H}_t$ can be interpreted as the home ownership rate in period t. The assumption of a fixed supply of houses implies that the only effect of a financial shock is reallocation of

[8]Note that z remains as a state variable as long as it affects current expectations regarding next period shock. In other words, if these productivity shocks were *iid* over time, then z would carry no information beyond ω_F and it would have to be dropped as state variable.

houses among households. As a consequence, the model generates a high sensitivity of house prices household to credit conditions. However, this modeling choice is justified empirically. At cyclical frequencies, the market value of household's real estate is driven mostly by price variations (XX% of overall cyclical variation is driven by prices).

Finally, by Walras' Law, the market clearing condition for the final good is satisfied whenever conditions (13)-(14) hold.

3.4 Recursive Competitive Equilibrium

This formulation suggests a straightforward definition of equilibrium. To this end, let $\mathcal{C}_H$ denote the set of continuous functions mapping $\mathbb{R}_+ \times \mathbb{R} \times [0,1]$ into $\mathbb{R}$, and $\mathcal{C}_F$ denote the set of continuous functions mapping $\mathbb{R}_+ \times \mathbb{R}$ into $\mathbb{R}_+$. Let $\mathcal{S}_H$ and $\mathcal{S}_F$ denote the Borel sigma algebra defined respectively over $\mathcal{C}_H$ and $\mathcal{C}_F$. A generic element of $\mathcal{S}_H$ (resp. $\mathcal{S}_F$) is a set $S \equiv (S_\omega, S_\theta, S_h)$ (resp. $S \equiv (S_\omega, S_z)$). Finally, let Δ_H and Δ_F be the set of all probability measures defined over $\mathcal{S}_H$ and $\mathcal{S}_F$.

The initial position of the economy is given by the pair $\psi_{H,0} \in \Delta_H$ and $\psi_{F,0} \in \Delta_F$ representing the initial measures of households and firms over their respective individual state. The measures $\psi_{H,t} \in \Delta_H$ and $\psi_{F,t} \in \Delta_F$ then evolve according to:

$$\psi_{H,t+1}(S) = \Pr(\theta_{t+1} \in S_\theta) \int \mathbf{I}(\omega_{H,t+1} \in S_\omega)\, d\psi_{H,t}(\omega_{H,t}, \theta_t) \quad ,\forall t \geq 0 \tag{15}$$

$$\psi_{F,t+1}(S) = \Pr(z_{t+1} \in S_z) \int \mathbf{I}(\omega_{F,t+1}(\omega_{F,t}, z_t) \in S_\omega)\, d\psi_{F,t}(\omega_{F,t}, z_t) \quad ,\forall t \geq 0 \tag{16}$$

for any set S belonging alternatively to $\mathcal{S}_H$ and $\mathcal{S}_F$. Equilibrium is then defined as follows:

Definition 1 *Given a deterministic sequence $\{\phi_{H,t}, \phi_{F,t}, \overline{B}_t, \overline{H}_{t+1}\}_{t=0}^{\infty}$ and a pair of initial distributions over individual states $\{\psi_{H,0}, \psi_{F,0}\}$, a Recursive Competitive Equilibrium consists of value functions $\{V_t\}_{t=0}^{\infty} \subset \mathcal{C}_H$ and $\{J_t\}_{t=0}^{\infty} \subset \mathcal{C}_F$, decision rules for the firm $\{d_t, k_{t+1}, m_{t+1}\}_{t=0}^{\infty} \subset \mathcal{C}_F$ and for the household $\{c_t, a_{t+1}, h_{t+1}\}_{t=0}^{\infty} \subset \mathcal{C}_H$, aggregate prices $\{\mathbf{R}_t, \mathbf{w_{t+1}}, \mathbf{q_{t+1}}\}_{t=0}^{\infty}$ and probability measures $\{\psi_{H,t}\}_{t=0}^{\infty} \subset \Delta_H$ and $\{\psi_{F,t}\}_{t=0}^{\infty} \subset \Delta_F$, satisfying:*

1. *Firm Optimality: given prices, $\{J_t\}_{t=0}^{\infty}$ satisfies the functional equation (10) and $\{d_t, k_{t+1}, m_{t+1}\}$ solve the problem in the right hand side of it, for all t.*

2. *Household Optimality: given prices, $\{V_t\}_{t=0}^{\infty}$ satisfies the functional equation (4) and $\{c_t, a_{t+1}, h_{t+1}\}_{t=0}^{\infty}$ solve the problem in the right hand side of it, for all t.*

3. *Market Clearing: given the decision rules and the probability measures, $\{\mathbf{R}_t, \mathbf{w_{t+1}}, \mathbf{q_{t+1}}\}_{t=0}^{\infty}$ satisfies conditions (12), (13), and (14) for all t.*

4. *Aggregate Consistency: given the decision rules, $\{\psi_{H,t}, \psi_{F,t}\}_{t=0}^{\infty}$ satisfies (15) and (16), for all t.*

This definition is ruling out any sort of aggregate uncertainty. In order to perform comparative statics, it is useful to consider the case in which the sequence $\{\phi_{H,t}, \phi_{F,t}, \overline{B}_t, \overline{H}_{t+1}\}_{t=0}^{\infty}$ is constant over time. In such a case, the equilibrium specializes to the following definition:

Definition 2 *Given $\{\phi_H, \phi_F, \overline{B}, \overline{H}\}$, a Stationary Recursive Competitive Equilibrium consists of value functions $V \in \mathcal{C}_H$ and $J \in \mathcal{C}_F$, decision rules for the firm $\{d, k', m'\} \in \mathcal{C}_F$ and for the household $(c, a', h') \in \mathcal{C}_H$, aggregate prices $(\mathbf{R}, \mathbf{w}, \mathbf{q})$ and probability measures $\psi_F^* \in \Delta_F$ and $\psi_H^* \in \Delta_H$, satisfying:*

1. *Firm Optimality: given prices, J is a fixed point of the functional equation (10) and (d, k', m') solves the corresponding problem in the right hand side.*

2. *Household Optimality: given prices, V is a fixed point of the functional equation (4) and and (c, a', h') solves the corresponding problem in the right hand side.*

3. *Market Clearing: given the decision rules and the probability measures, $(\mathbf{R}, \mathbf{w}, \mathbf{q})$ satisfies conditions (12), (13), and (14).*

4. *Stationarity: given the decision rules, (ψ_H^*, ψ_F^*) are fixed points of (15) and (16), respectively.*

In the quantitative section, I will study both types of equilibrium. However, if stationarity is not required, I will restrict attention to equilibria in which $\phi_{i,t} = \mathbf{I}(t < T)\overline{\phi}_i + \mathbf{I}(t \geq T)\underline{\phi}_i$ for $i \in \{H, F\}$. As long as $\overline{\phi}_i > \underline{\phi}_i$, this is supposed to represent a situation in which credit tightens along the equilibrium path. To analyze the case in which such credit tightening is unanticipated, the equilibrium will correspond to the first definition with $\{\phi_{H,t}, \phi_{F,t}, \overline{B}_t, \overline{H}_{t+1}\}$ being constant over time as in the second definition, but with the economy starting off at an arbitrary initial condition $(\psi_{H,0}, \psi_{F,0})$, which is often interpreted as the "old steady state" stationary distribution.

3.5 Liquidity

In the model, the aggregate stock of debt can be interpreted as a source of *liquidity*, in the sense that it allows agents to save and concentrate their spending in those periods in which they need it the most. Firms hold an option to save in order to correlate their capital stock with the realization of their idiosyncratic productivity shock. The value of this option is positively related to the interest rate, which in turn implies a positive relation between the interest rate and productive efficiency. As a result, the interest rate can affect aggregate output in two opposite direction. On one hand, it makes borrowing more expensive and reduces aggregate capital. On the other hand, it facilitates wealth accumulation and promotes efficiency in the allocation of capital. It turns out that which of these two forces prevail depends entirely on the asset position of the productive sector. More precisely, I find numerically that output and interest rate are positively related only if the productive sector is a net lender to the rest of the economy. This in turn indicates that if the model is matched to aggregate data, a contraction in the borrowing capacity of the productive sector is a necessary condition to obtain a qualitative response of output in line with the data.

4 Baseline Economy

In this section I discuss the parameterization of the baseline economy. I follow Justiniano et al. (2013) and calibrate a stationary equilibrium that matches some key statistics for the period of relative stability of the 1990s.

4.1 Preliminaries

A time period in the model corresponds to a quarter in the data. I assume the following functional form for the utility function:

$$u(c,h) = \frac{((1+\gamma h)c)^{1-\nu}}{1-\nu}$$

In addition, I assume that the idiosyncratic shocks θ_t and z_t both follow a Markov chain that approximates an AR(1) process in logs, and calibrate directly the persistence and the volatility of perturbations of each autoregressive process. This delivers four additional parameters to setup in the calibration: $(\rho_\theta, \rho_z, \sigma_\theta, \sigma_z)$. Comment on natural borrowing limit.

4.2 Fixed Parameters

A stationary equilibrium takes as given the vector $\{\phi_H, \phi_F, \overline{B}, \overline{H}\}$. The values for the financial conditions (ϕ_H, ϕ_F) are set in the next section. The exogenous supply of houses $\overline{H}$ is set equal to .66 which corresponds to the average home ownership rate in the U.S. The exogenous supply of debt $\overline{B}$ is obtained as a residual, given a fixed annualized interest rate net of inflation of 2%.

Given these choices, there are two groups of parameters left: those associated with preferences and technology $(\beta, \gamma, \nu, \alpha_1, \alpha_2, \delta)$, and those associated with the stochastic properties of the idiosyncratic shocks $(\rho_\theta, \rho_z, \sigma_\theta, \sigma_z)$. For the first group, I set $\nu = 2$, $\alpha_1 = .25$. $\alpha_2 = .65$,

Table 3
Parameters for Baseline Economy

Parameter	Symbol	Value
1. Preferences and Technology		
Preference shifter	γ	.04
Risk Aversion	σ	2
Discount factor	β	.994
Span of control	α_0	.1
Depreciation rate	δ	.02
2. Financial Conditions		
Pledgeability of houses	ϕ_H^S	.52
Pledgeability of capital	ϕ_F^S	.26
3. Stochastic Properties		
Persistence of labor income shock	ρ_θ	.9
SD of labor income shock	σ_{ϵ_θ}	.12
Persistence of productivity shock	ρ_θ	.8
SD of productivity shock	σ_{ϵ_z}	.0549

and $\delta = .02$, which are standard in the literature. For the second group, I fix the values of the persistence parameters and calibrate the volatility of the perturbations. The estimates for the persistence of the income process in the literature depend on the underlying model structure, and one can find estimates as low as .8 (cf. Guvenen) and as high as .99 (see Storesletten). I take the mid point of these two estimates, expressed at quarterly frequency. The estimates for the persistence of the productivity shocks are more scarce. It seems that a reasonable lower bound for it is .7 in annual terms (Moll and references therein). I fixed these persistence parameters and will calibrate the volatility parameters.

4.3 Calibrated Parameters

It is customary to set the value of the discount factor β so as to match the interest rate in the data. Here instead I assume that the exogenous supply of debt $\overline{B}$ will adjust to restore equilibrium. In other words, given the value for the interest rate, $\overline{B}$ can be obtained as a residual. As a result, the discount factor β remains as a free parameter, with the only requirement that $\beta\mathbf{R} < 1$, as it is usual in models with heterogeneous agents to guarantee equilibrium existence. In the baseline economy, we set $\beta = .994$ rather arbitrarily and do a sensitivity analysis in the appendix to show how the calibration and the comparative statics change if we consider other values for β.

There are five parameters remaining, $(\sigma_\theta, \sigma_z, \gamma, \phi_H, \phi_F)$, and they are calibrated to match the following statistics in the data: the market value of housing structures over GDP, house-

Table 4
Targets and Model Performance

Target	Data	Model
Value of Houses / GDP	1.76	1.76
Household Financial Assets / GDP	61.9%	61.3%
Household Liabilities / GDP	77.5%	77.9%
Firm Financial Assets / GDP	57.0%	56.9%
Firm Liabilities / GDP	11.5%	11.5%

holds' and firms' financial assets over GDP, and households' and firms' liabilities over GDP. By matching these targets we are also matching the NFA asset position of both sectors in the data. These parameters regulate the precautionary saving motive of each side of the economy and shape the stationary distribution of asset holdings. For a given β, there are as many targets as free parameters which makes possible to match all of them almost perfectly. Table 4 shows the model performance and Table 3 reports the all the calibrated parameters

5 Results

In this section, I consider the effect of a contraction in the borrowing capacity of economic agents. I report first the effect of these contractions when they occur in isolation, and then when they interact with features such as downward rigid borrowing interest rates and higher idiosyncratic uncertainty. For each case, I analyze the consequences of credit crises when they affect households, producers and both, assuming that the exogenous supply of liquidity, e.g. $\overline{B}$, remains constant.

5.1 Comparative Statics

5.2 Pure credit tightening

Table 5 displays the effect of a pure credit tightening on aggregate variables. The second column shows the aggregate variables following a contraction of 50% in the borrowing capacity of households. As it can be seen, a credit tightening in the household side doubles its net financial asset position. There is a substantial contraction in the level of household debt, but importantly, there is no household asset depletion whatsoever. In fact the gross asset position of the household sector increases across steady states. This suggests that equilibrium can only be restored by having producers issuing more debt or depleting assets. In this case, they happen to do the latter, provided that the increase in $\overline{B}$ already compensates for most of households'

Table 5
Steady state effects of a credit tightening
The first column displays the baseline economy. The second column considers a 50% decline in the borrowing capacity of households with respect to the baseline economy. The third column considers a 14% decline in the borrowing capacity of producers while keeping households' borrowing capacity intact. The last column considers combines the previous two cases.

	Baseline	**Household**	**Producer**	**Both**
NFA (% of Output)				
Households	0.28	0.59	0.24	0.49
Producers	−0.08	−0.19	0.17	−0.08
Exogenous	0.20	0.40	0.41	0.41
Prices				
Price of houses	4.19	3.27	4.21	3.24
Interest rate	0.51	0.42	0.48	0.26
Aggregates (% of Baseline)				
Households Assets	–	1.23	0.95	1.05
Households Debt	–	0.37	1.05	0.41
Producers Assets	–	0.90	1.04	0.82
Producers Debt	–	1.00	0.83	0.83
Output	–	1.00	0.99	0.99
Capital	–	1.01	0.98	0.99
Efficiency	–	0.98	0.94	0.89

deleveraging. Finally, one can see that this type of crisis generates no response in output and a modest decline in the interest rate.

The results of assuming a credit tightening only on the productive sector do not look better. The net asset position of the household sector barely moves, but one can observe a substantial increase in that of the productive sector to the point of making it a net lender. Both results are counterfactual, as it was shown in Figure 1. Although there is a decline in output of about 1%, the change in equilibrium prices make doubtful that this type of tightening could be the only driver of aggregate activity. There is an modest decline in the interest rate and an increase in the price of houses. This response in the price of houses can be explained by noticing that the contraction in producers' debt needs to be compensated by other agents issuing more debt or depleting financial assets. Higher house prices contribute to this end because they increase the value of households' collateral and relax their borrowing constraints. In other words, had I assumed no increase in $\overline{B}$, this type of credit crisis would have required extra liquidity to be generated by the household sector, which can only occur if the collateral value of their pledgeable assets increase, via higher price of houses.

The results from a two-sided credit tightening look more promising. All variables move in the right direction and in reasonable magnitudes. There is debt contraction in both sides of

Table 6
Steady state effects of a credit tightening and higher intermediation costs
This table considers contractions in borrowing capacity while keeping the borrowing interest rate unchanged at the baseline equilibrium level. The second column considers a 50% decline in the borrowing capacity of households with respect to the baseline economy. The third column considers a 17% decline in the borrowing capacity of producers. The last column combines both effects.

	Baseline	**Household**	**Producer**	**Both**
NFA (% of Output)				
Households	0.28	0.60	0.23	0.49
Producers	−0.08	−0.20	0.18	−0.08
Exogenous	0.20	0.40	0.41	0.41
Prices				
Price of houses	4.19	3.23	4.17	3.11
Interest rate	0.51	0.41	0.45	0.19
Aggregates (% of Baseline)				
Households Assets	–	1.23	0.93	1.02
Households Debt	–	0.35	1.03	0.36
Producers Assets	–	0.87	1.00	0.74
Producers Debt	–	0.98	0.79	0.76
Output	–	1.00	0.99	0.98
Capital	–	1.00	0.98	0.98
Efficiency	–	0.97	0.92	0.86

the economy, and asset depletion in the productive side but not in the household side. Since producers NFA position remains constant by construction, this means household deleveraging was fully compensated by the change in $\overline{B}$. Regarding output and prices, not only we observe a drop in aggregate production of about 1%, but the decline in the price of houses and in the interest rate are both larger than in any of the previous two cases.

These results are encouraging and suggest that if we preclude the role of other factors, aggregate data indicates that the borrowing capacity of households was most likely cut by half, whereas that of producers declined by about 14% during the recent crisis. It is important to emphasize that, in making these claims, I am being agnostic regarding what is that the parameters ϕ_H^S or ϕ_F^S are supposed to capture. To be more precise, although it is intuitively correct to interpret them as loan to value ratios, it is preferable to think of them as being reduced form parameters. Interpreting them too literally as LTV ratios would suggest that, in the case of households, the appropriate modeling of a crisis requires to set ϕ_H^S equal to 0.75 for the post crisis period (see for instance Justiniano et al. (2013)). However, this choice would fail to take into account the fact that a lower ϕ_H^S must capture not only tighter credit constraints but also harder lending standards. For this reason, the approach in this paper is to consider a

Table 7
Steady state effects of a credit crisis and higher idiosyncratic volatility
This table considers contractions in borrowing capacity with a simultaneous increase in idiosyncratic volatility. The second column considers a 60% decline in households' borrowing capacity and a 10% in households idiosyncratic volatility. The third column considers a 27.5% decline in the borrowing capacity of producers and a 10% in producers idiosyncratic volatility. The last column considers consider all perturbations taking place simultaneously.

	Baseline	**Household**	**Producer**	**Both**
NFA (% of Output)				
Households	0.28	0.76	−0.08	0.49
Producers	−0.08	−0.36	0.49	−0.08
Exogenous	0.20	0.40	0.41	0.41
Prices				
Price of houses	4.19	3.20	4.74	3.18
Interest rate	0.51	0.23	0.31	−0.24
Aggregates (% of Baseline)				
Households Assets	–	1.45	0.67	1.01
Households Debt	–	0.25	1.59	0.33
Producers Assets	–	0.76	1.18	0.69
Producers Debt	–	1.01	0.70	0.71
Output	–	1.00	0.99	0.99
Capital	–	1.02	0.96	0.98
Efficiency	–	0.94	1.03	0.90

wider variation in these parameters when trying to match the data.

5.3 Intermediation costs and idiosyncratic uncertainty

The main conclusion from the previous analysis is that the evolution of aggregate variables can only be explained if we consider a credit tightening affecting both sides of the economy. Without weighing in other factors, aggregate data supports a credit tightening of about 50% and 14% in the borrowing capacity of households and producers respectively. The purpose of this section is to consider the possibility that a credit crisis could also display larger intermediation costs and a contemporaneous increase in idiosyncratic uncertainty. I consider these two factors first in isolation and then together.

Hall (2011) has documented the increase in intermediation spreads during the recent crisis and relates them to time varying financial frictions. Downward rigid borrowing interest rates can be interpreted as an increase in the cost of intermediation at the moment of the crisis. To entertain this case, I fix the borrowing interest rate to its value in the baseline economy and and I allow the saving interest rate to adjust to the changes in the precautionary motives

Table 8
Steady state effects of a credit crisis with downward rigidity and higher idiosyncratic volatility
This table considers contractions in borrowing capacity with downward rigid borrowing interest rates and a simultaneous increase in idiosyncratic volatility. The second column considers a 50% decline in households' borrowing capacity and the third column considers a 21.5% decline in the borrowing capacity of producers. The last column considers all perturbations taking place simultaneously.

	Baseline	**Household**	**Producer**	**Both**
NFA (% of Output)				
Households	0.28	0.71	0.10	0.49
Producers	−0.08	−0.30	0.31	−0.08
Exogenous	0.20	0.40	0.41	0.41
Prices				
Price of houses	4.19	3.42	4.24	3.21
Interest rate	0.51	0.28	0.26	−0.17
Aggregates (% of Baseline)				
Households Assets	–	1.41	0.76	1.03
Households Debt	–	0.35	1.16	0.37
Producers Assets	–	0.76	1.06	0.67
Producers Debt	–	0.97	0.73	0.69
Output	–	1.00	0.99	0.98
Capital	–	1.00	0.96	0.96
Efficiency	–	0.95	1.03	0.93

of both economic agents. The results are displayed in Table 6 and one can see that they look very similar to those displayed in Table 5. Namely, the model performs better when we assume that credit crises affected both sides of the economy. The response of the interest rate is larger in this case, which is what one would expect to induce more asset depletion. There is a larger output drop in this case, which can be associated to a lower capital stock and a poorer allocation of it as compared to the previous case. The magnitude of the contractions that generate these responses are very similar to the previous case: 50% for households and 17% for producers. With downward rigid borrowing interest rates, deleveraging must be larger, which in turn imposes a larger need for asset depletion. However, since the drop in the interest rate was only moderate in the pure credit tightening case, I only obtain a modest additional drop drop from assuming that, on top of the credit tightening, the borrowing interest rates remained rigid.

Arguably, recessions, irrespectively of their origin, are times that coincide with an increase in perceived uncertainty. To incorporate this feature, I consider an additional layer of perturbation coming from a simultaneous increase in the volatility of the labor income shocks and the productivity shocks. One could think of the increase in perceived uncertainty in the household side as standing for higher unemployment risk. In turn, the increase of uncertainty in the productive side could be interpreted as lower probability of making sales in the context of a model with goods market frictions. For simplicity, I assume a uniform 10% increase in both sides of the economy and present the results in Table 7.

In order to match a decline in the price of houses of 30% and the evolution of NFA positions, this case requires a contraction in the borrowing capacity of 60% and 27.5% for households and producers respectively. This produces a sizable drop in the interest rate and a contraction in aggregate output of about 1%. The table also makes clear that considering credit crises affecting only one side of the economy do not seem to fit the bill to understand the recent crisis. To understand why the increase in idiosyncratic uncertainty requires tighter borrowing constraints to match the data, one should notice that more uncertainty alone would only put an upward pressure to the price of houses, regardless of the side in which it occurs. This must be compensated by tighter constraints on the household side so that the demand for houses subsides. However, since tighter constraints also imply a stronger precautionary motive, the downward pressure on the interest rate is also stronger than in the baseline case. These results suggest that the increase in perceived uncertainty and its effect on the precautionary savings motive of economic agents is an important piece of the story to understand the recent crisis.

For the sake of completeness, Table 8 combines all the different layers of bad shocks considered in this section. Bringing downward rigid interest rates back to the picture moderates the effect on prices obtained in the previous table, although the outcome looks quite similar. Overall, the results presented so far stress the importance of borrowing constraints coupled with idiosyncratic uncertainty and higher intermediation costs to explain aggregate trends. Moreover, assuming an increase in idiosyncratic uncertainty of about 10% in both sides of the economy, the results estimate a decline in the access to credit of about 50% in the household side and 21.5% in the productive side of the economy. With these estimates in hand, the next section performs the counterfactual exercise of assuming that the exogenous supply of debt, e.g. $\overline{B}$ remained constant throughout the crisis.

5.4 Irresponsive government debt

In the previous sections I assumed that the exogenous supply of debt doubled across steady states. In reality, this was mostly due to the increase in government debt. With the estimates for the contraction in the borrowing capacity in hand, this section performs the counterfactual exercise of assuming that outside liquidity remained constant from one steady state to the other. The results are displayed in Table 9 and they suggest that the main effect of the increase

Table 9
Steady state effects with irresponsive government debt
The first column corresponds to the baseline economy. The remaining columns show the response of the economy assuming that $\overline{B}$ remains unchanged and the magnitude of the credit tightening in both sides of the economy was as described in each of the previous tables.

	Baseline	**Tightening**	**Rigidity**	**Uncertainty**	**All**
NFA (% of Output)					
Households	0.28	0.40	0.38	0.39	0.41
Producers	−0.08	−0.20	−0.18	−0.19	−0.20
Exogenous	0.20	0.20	0.20	0.21	0.21
Prices					
Price of houses	4.19	3.26	3.27	3.00	3.17
Interest rate	0.51	0.12	0.08	−0.09	−0.40
Aggregates (% of Baseline)					
Households Assets	–	0.93	0.89	0.85	0.89
Households Debt	–	0.45	0.47	0.34	0.38
Producers Assets	–	0.72	0.70	0.59	0.55
Producers Debt	–	0.84	0.80	0.71	0.68
Output	–	0.99	0.99	0.98	0.98
Capital	–	1.00	1.00	0.99	0.96
Efficiency	–	0.87	0.85	0.77	0.90

in government debt was crowding-out producer's debt. That is, it only prevented prices from falling any further, but it did not have any effect on output response. Had government debt remained the same, producers would have benefited from lower interest rates and leveraged their investment decisions further, which would have compensated the tighter financial constraints. Notice that this result obtains in spite of the economy without intervention having lower capital stock and being less efficient in the allocation of it. The reason for this result must be that although lower interest rates hinder efficiency, they also reduce dispersion, which improves measure TFP. The numbers displayed in this table indicate that this latter effect dominates the previous two.

6 Conclusions

I presented a parsimonious heterogenous agents model with two-sided heterogeneity to study the effect of credit crises on aggregate activity. I used the model to infer how much credit tightening from each side of the market the data seems to be calling for. This approach stands in contrast with most of the literature, which takes too literally the interpretation of the financial parameters in this type of models as loan to value ratios. I address credit crises from three different perspectives: as a contraction in the ability to pledge real assets, as an increase in intermediation costs, and as an increase in idiosyncratic volatility. My findings indicate that households' borrowing capacity was cut by 50%, whereas producers' by 21.5% during the recent credit crisis. Only then, the evolution of aggregate variables is consistent with what is observed in the data. Changes in the level of perceived uncertainty appear to be a necessary ingredient for attaining this result. In contrast, downward rigid interest rates do not seem to play a big role in the model.

Using these estimates regarding the magnitude of the credit tightening, I assess the consequences of government intervention in the form of more public debt being issued to compensate for the decline in private debt. The results presented here suggest that the only effect of government debt was to crowd out debt issued by the productive sector. Had government debt remained constant, the decline in interest rates would have been larger, allowing producers to leverage their investment and compensate for tighter financial constraints. I other words, the response of aggregate output would have been the same with or without government intervention.

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A Data Construction

The first goal is to calculate a meaningful statistic for the Net Financial Asset (NFA hereafter) position of both sectors. In order to do that, I reconstruct the excess demand time series using FoF data and show that it is practically zero (up to measurement error) for all the period under analysis. I consider the following aggregate sectors: households, non financial firms, government, financial firms, and the rest of the world. For each sector, I consider only debt-like securities in the balance sheet.

Households Assets: Deposits (L.101.2) + Debt Securities (L.101.7) + Loans (L.101.13). Liabilities: Debt Securities (L.101.26) + Loans (L.101.27).

Firms Assets: Currency, Deposits and Money Market Fund Shares (L.102.2-L.102.5) + Debt Securities (L.102.7) + Loans (L.102.12). Liabilities: Debt Securities (L.102.20) + Loans (L.102.24).

Government Assets: Deposits and Money Market Fund Shares (L.105.3-L.105.5) + Debt Securities (L.105.7) + Loans (L.105.13). Liabilities: Debt Securities (L.105.26) + Loans (L.105.29).

Financial Sector Assets: Currency, Deposits and Money Market Fund Shares (L.108.5-L.108.9) + Debt Securities (L.108.11) + Loans (L.108.17). Liabilities: Currency, Deposits, Money Market Fund Shares and Interbank Liabilities (L.108.29-L.108.32) + Debt Securities (L.108.34) + Loans (L.108.38).

Rest of the World Assets: Currency, Deposits and Money Market Fund Shares (L.132.4-L.132.6) + Debt Securities (L.132.8) + Loans (L.132.16). Liabilities: Deposits (L.132.23) + Debt Securities (L.132.25) + Loans (L.132.28).