Financial Frictions: Macro vs Micro Volatility

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Abstract

We examine the impact of frictional financial intermediation in a HANK model. An incentive problem restricts banking sector leverage and gives rise to an equilibrium spread between the returns on savings and debt. The size of this spread impacts on the wealth distribution and movements in it subject borrowers and savers to different intertemporal prices. The model generates a financial accelerator that is larger than in a representative agent setting, derives mainly from consumption rather than investment, and works through a countercyclical interest rate spread. Credit policy can mute this mechanism while stricter regulation of banking sector leverage inhibits households' ability to smooth consumption in response to idiosyncratic risk. Thus, although leverage restrictions stabilize at the aggregate level, we find substantial welfare costs.

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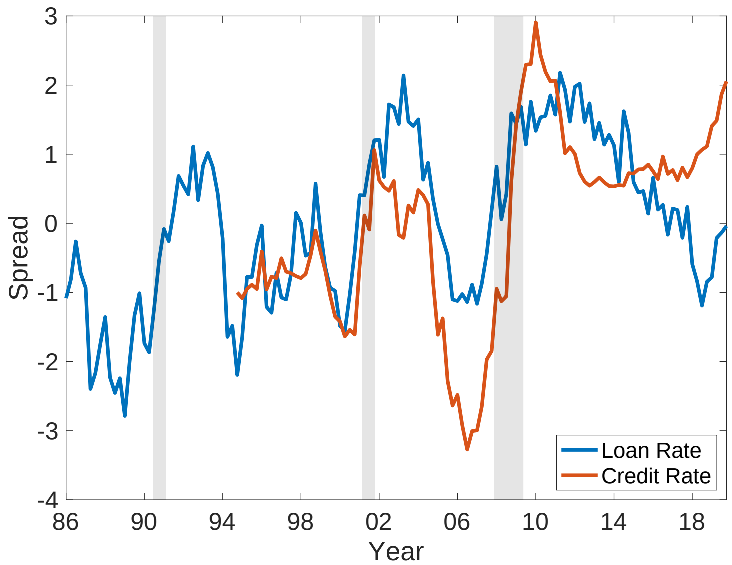
Since the Global Financial Crisis (GFC) much research effort has gone into examining the consequences of imperfections in financial markets for the functioning of the economy. This paper contributes to this literature by showing how wealth inequality deriving from market incompleteness and idiosyncratic risk matters for the impact of frictions in financial intermediation. When households differ in wealth, the financial accelerator mainly works through consumption, and macroprudential regulation involves a trade-off between macroeconomic stabilization and microeconomic volatility. These properties are fundamentally different from those in representative agent economies in which the financial accelerator impacts mainly on investment and macroprudential regulation involves a trade-off between the level of income and macroeconomic volatility. Our results highlight the importance of the spread between the interest rates on household savings and debt for consumption dynamics across the wealth distribution.

Frictionless financial markets allow resources to flow to their most productive uses and provide the economy with immunity to the propagation of shocks deriving from cross-agent differences in their evaluation of intertemporal trade-offs. This cornerstone of economic theory serves as a useful benchmark but a number of its key implications stand in stark contrast with empirical evidence. The frictionless model, for example, implies that households are perfectly insured against idiosyncratic income risk. An extensive empirical literature has challenged this implication and documented that household consumption is sensitive to household-specific income shocks.[1] The frictionless model also implies that central bank purchases of assets should be neutral, an implication that seems strongly challenged by the evidence of the impact of unconventional policies in the aftermath of the GFC.[2]

Such findings have motivated extensive research examining the impact of financial frictions. One line of work has considered aggregate fluctions in settings with idiosyncratic risk, incomplete markets, and frictional goods and/or labor market. In this line of work, frequently referred to as HANK, lack of insurance markets and borrowing constraints inhibit agents' ability to smooth out adverse income shocks, which makes the distribution of marginal propensities to consume a key statistic. Another line of work has instead investigated frictional financial intermediation. This literature typically retains the representative agent assumption, focusing on how agency problems in the financial sector impact on macroeconomics outcomes. A key result is that financial intermediaries matter for macroeconomic (in)stability. In particular, financial frictions may amplify the impact of shocks on the economy due to a financial accelerator that leads to exaggerated investment responses. Moreover, financial intermediaries may be a source of instability due to shocks to their balance sheets.

[1]See, for example, Cochrane (1991), Mace (1991), Blundell et al. (2008), or recently Fagereng et al. (2019).

[2]See, for example, Gagnon et al. (2011), Krishnamurthy and Vissing-Jørgensen (2011), Chen et al. (2012) or Gambacorta et al. (2014).



Notes: Demeaned spread in percentage points. Loan Rate: Rate on personal loans at commercial banks (2 year loan) minus 2-year Treasury rate. Credit Rate: Commercial bank rate on credit card plans minus 3-month T-Bill rate. Retrieved from FRED, Federal Reserve Bank of St. Louis. Shaded areas correspond to recessions according to the NBER.

Figure 1: Borrowing Penalty

In this paper, we shift the attention of the financial frictions literature to its impact on consumption when households differ in wealth. For this purpose, we introduce financial intermediation into a heterogeneous agents new Keynesian (HANK) setting. The economy is composed of a financial sector, a corporate sector, a household sector and a government. There are nominal rigidities on the supply side, while households are subject to uninsurable idiosyncratic income risk. Banks intermediate between savers (households) and borrowers which are either firms or households. This intermediation is hampered by an agency problem which limits banks' investment in assets.

A central aspect of our analysis is the importance of movements in the spread between the savings and lending rates facing households. In our analysis, this spread derives from banks' incentive problem that limits their investment in assets to a certain fraction of their net worth as well as from a resource cost of issuing unsecured consumer debt. Figure 1 shows two (demeaned) measures of this spread, the difference between the interest rate on personal loans and the two-year Treasury rate and the difference between the interest rate on credit card debt and the three-month T-bill rate. NBER recessions are indicated by the shaded grey areas. Both measures of the spread increase abruptly and significantly in recessions and tend to decline during expansions. Such countercyclical movements in the spread are consistent with the predictions of our model to the extent that banking sector net worth is procyclical, a property that we show holds in response to recessionary technology shocks, monetary policy shocks, and "capital quality" shocks.

Such movements in the spread induce a key role for consumption in the transmission mechanism. In fact, we show that the model generates a financial accelerator that mainly works through consumption rather than investment. To see why, note that movements in the spread between savings and lending rates imply a differential impact of shocks on households depending on their net asset positions. First, due to potentially binding borrowing constraints or kinks in the budget constraints, marginal propensities to consume differ across the wealth distribution. Secondly, an increase in the interest rate on debt relative to the return on savings will hold back indebted households' consumption relative to wealthier households. For indebted households, recessions will therefore tend to induce strong consumption reductions which we show dominate in the aggregate because wealthy households are able to smooth out income shocks.

Consider the response of the economy to declining net worth of banks. Lower net worth means that banks have less capacity to invest in the corporate sector inducing an increase in the spread of the return on bank assets over the deposit rate. The deflationary pressures lead the central bank to cut deposit rates which gives households with positive net asset positions less incentive to save. Poorer households, however, face increasing interest rates on consumption loans due to the higher spread forcing these households to reduce their consumption. Similarly, adverse productivity shocks or contractionary monetary policy shocks reduce banking sector net worth that through the interest-rate-spread channel differentially impacts on households according to their net assets. In each of these cases, the increase in the spread implies that more households remain at the kink in their budget constraints where their marginal propensities to consume are very high. Because of the large consumption responses, we show that the output response to shocks are amplified relative to representative agent economies. Hence, while the model has a financial accelerator, it derives from consumption mainly.

Another key insight of our analysis is the impact of macro prudential regulation that limits bank leverage. The literature usually argues that such regulation trades off increased stability of the economy with lower average activity. We show that the trade off is different in the heterogeneous agent economy. Because of the impact on leverage, stricter macro prudential regulation increases the spread between consumer debt and the return on deposits. A higher spread means that a larger share of households find themselves at the kink in the budget constraint at zero wealth, that debt is costlier for households with negative net asset positions, and that it is more attractive for households with positive net asset positions to avoid becoming indebted. Through each of these channels, household consumption becomes more sensitive to idiosyncratic risk thus inducing micro volatility. Hence, we find that such policies are associated with a trade-off between micro and macro volatility, a trade-off that is felt throughout the wealth distribution including by less wealthy households who are proportionally more harmed by higher cost of borrowing. We find that the average welfare loss from a 25% reduction in banking sector leverage is 1.5% of life-time consumption.

Our analysis adds to the rapidly expanding HANK literature.[3] This literature has so far concentrated upon examining how frictions in goods and labor markets, such as nominal rigidities or matching frictions, combine with incomplete markets to produce new insights about macroeconomic fluctuations and economic policy. Parts of this literature has included further frictions such as asset illiquidity or differences in the returns on debt and savings (see, for example, Bayer et al. (2019); Kaplan et al. (2018)), but this literature has not considered the impact of financial intermediation. Our model with frictional banking makes the cost of borrowing endogenous and this has fundamental consequences for the transmission mechanism. Such endogenous changes in the spread between interest rates changes the fraction of households with high marginal propensities to consume. This is a key sufficient statistic for many shocks and policies, see for example Auclert (2019) or Auclert et al. (2018). In addition to this, movements in the spread imply that households are differently exposed to shocks depending on their net asset position. Our analysis also adds to the the literature on financial frictions. The latter has highlighted the importance of the financial accelerator for business cycles.[4] We show that the financial accelerator becomes more powerful in a model with consumer credit by directly affecting consumption. The key role of banks' net worth for the propagation of shocks has led to the literature on macro prudential regulation. We add to this literature by showing that tighter regulation of banks negatively affects household insurance, which has first order effects on welfare.[5]

Complementary to our work, Fernández-Villaverde et al. (2020) combine a financial sector à la Brunnermeier and Sannikov (2014) with heterogeneous households. They show that the interaction between the demand of bonds by the financial sector and the precautionary supply of bonds by households produces significant endogenous aggregate risk when solved globally. Our focus is very different and shows instead how financial frictions interact with the wealth distribution through the interest rate spread.

The remainder of the paper is structured as follows. We present the model in the next

[3]See, for example, Auclert (2019); Bayer et al. (2019); Broer et al. (2019); Gornemann et al. (2012); Guerrieri and Lorenzoni (2017); McKay et al. (2016); Kaplan et al. (2018); Ravn and Sterk (2017).

[4]See Bernanke et al. (1999) for a survey and more recently, for example, Gertler and Kiyotaki (2010); Gertler and Karadi (2011); Brunnermeier and Sannikov (2014).

[5]See Galati and Moessner (2013) for a survey and more recently, for example, Farhi and Werning (2016) or Jeanne and Korinek (2020).

Section. Thereafter, we discuss the calibration and some implications for the links between the financial sector and the wealth distribution in Section 2. Section 3 investigates the transmission mechanism of the model. Section 4 looks into the impact of macroprudential regulation. Finally, we conclude in Section 5.

1 Model

The economy is composed of a financial sector, a corporate sector, a household sector and a government sector. The model combines nominal rigidities on the supply side, incomplete markets and idiosyncratic risk amongst the households, and financial frictions in the financial sector. We will show that this model has important implications for the transmission mechanism and for the impact of macro prudential regulation.

1.1 Households

There is a continuum of measure one of ex-ante identical households indexed by i. Households are infinitely lived, have time-separable preferences and derive utility from consumption c_{it} and disutility from working l_{it}. Households switch randomly between being workers or rentiers. Workers supply labor competitively and are subject to idiosyncratic earnings risk. Rentiers receive a share of the profits made by the corporate and the financial sectors but do not participate in the labor market. The rentiers delegate all intertemporal firm decisions to risk neutral managers. We assume that the claims to the pure rents cannot be traded as an asset.

Preferences are time separable and given as:

$$\mathbf{U}_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{c_{it}^{1-\mu}}{1-\mu} - \chi \frac{l_{it}^{1+1/\gamma}}{1+1/\gamma} \right] \tag{1}$$

where $\mathbb{E}_s x_{it}$ denotes the expectation of x_{it} conditional on all information available at date $s \leq t$. β is the subjective discount factor, $\mu \geq 0$ is the inverse of the intertemporal elasticity of substitution, $\chi > 0$ is a constant, and $\gamma \geq 0$ is the Frisch labor supply elasticity.

Households maximize subject to sequences of budget constraints and borrowing constraints:

$$c_{it} + b_{it+1} \leq \mathbf{R}\left(b_{it}, R_{S,t}, R_{L,t}\right) b_{it} + (1-\tau)\left(w_t h_{it} l_{it} + \mathbb{I}_{h_{it}=0} \mathcal{F}_t\right), \tag{2}$$

$$b_{it+1} \geq -\underline{\mathbf{b}} \tag{3}$$

b_{it+1} denotes financial net assets chosen in period t. Households can save by either purchasing risk-free government bonds, $b_{G,it+1}$, or by making bank deposits, $b_{D,it+1}$. If the household wishes to borrow, it can take out a bank loan, $b_{L,it+1}$, but only up to the borrowing limit, $-\underline{\mathbf{b}} \leq 0$. The interest rate schedule is given as:

$$\mathbf{R}\left(b_{it}, R_{S,t}, R_{L,t}\right) = \begin{cases} R_{S,t} & \text{if} \quad b_{it} = b_{D,it} + b_{G,it} \geq 0 \\ R_{L,t} & \text{if} \quad b_{it} = b_{L,it} < 0 \end{cases} \tag{4}$$

where $R_{S,t} = R_{S,t}^N/\pi_t$ is the gross saving rate, $R_{S,t}^N$ is the gross nominal interest rate and $\pi_t = P_t/P_{t-1}$ is the gross inflation rate (P_t is the price of the consumption good). The gross real interest rate on outstanding debt is given by $R_{L,t} \geq R_{S,t}$. Note that since $R_{L,t} \geq R_{S,t}$, a household will never want to hold assets and have debt simultaneously.

All households pay the same constant proportional tax rate τ on their income. Rentiers' income is given by their share of the profits from firms and banks, $\mathcal{F}_t$. Working households' labor income is given by $w_t h_{it} l_{it}$ where w_t is the real wage per efficiency unit of labor and $h_{it} l_{it}$ is effective labor supply. h_{it} denotes idiosyncratic labor productivity which evolves according to a log-AR(1) process (conditional upon the worker having had the same labor force status last period):

$$h_{it} = \begin{cases} \exp\left(\rho_h h_{it-1} + \varepsilon_{h,it}\right) & \text{with probability } 1-\zeta & \text{if} \quad h_{it-1} \neq 0, \\ 1 & \text{with probability } \iota & \text{if} \quad h_{it-1} = 0, \\ 0 & \text{otherwise.} \end{cases} \tag{5}$$

where $\rho_h \in (-1, 1)$. $\varepsilon_{h,it}$ is assumed to be iid normally distributed with variance σ_h^2. Here $\zeta \in (0, 1)$ denotes the probability that a worker becomes a rentier while $\iota \in (0, 1)$ is the probability rentiers become workers.[6] A rentier that reverts to becoming a household start with median productivity, $h_{it} = 1$.

Suppose that $\zeta \simeq 0$. In this case, workers choose assets and labor supply according to the first-order necessary conditions:

$$l_{it}^{1/\gamma} = \frac{1}{\chi} c_{it}^{-\mu} \left(1-\tau\right) w_t h_{it} \tag{6}$$

$$c_{it}^{-\mu} = \begin{cases} \beta \mathbb{E}_t c_{it+1}^{-\mu} R_{S,t+1} & \text{if} \quad b_{i,t+1} > 0, \\ \beta \mathbb{E}_t c_{it+1}^{-\mu} R_{L,t+1} & \text{if} \quad b_{i,t+1} \in \left(0, -\underline{\mathbf{b}}\right). \end{cases} \tag{7}$$

Constrained households, $b_{it+1} = -\underline{\mathbf{b}}$, or at the kink, $b_{it+1} = 0$, instead choose consumption

[6]Hence the share of rentiers amongst households is given as $\zeta / \left(\zeta + \iota\right)$. We will assume that this is very small.

as

$$c_{it} = \mathbf{R}(b_{it}, R_{S,t}, R_{L,t})b_{it} + (1-\tau)\, h_{it} w_t l_{it} \tag{8}$$

Hence, consumption choices differ across households depending on their net assets. Those constrained by the borrowing limit or with zero assets will have unit marginal propensities to consume. Borrowers and savers will have different intertemporal marginal rates of substitution due to the wedge between interest rates on savings and on debt. Indebted households will for that reason choose higher consumption growth than savers (i.e. lower current consumption relative to resources). These differences in consumption spill over to labor supply with poorer more indebted households supplying more labor (relative to current income) than their richer cousins.

1.2 Firms

There are three types of firms in the economy: (a) intermediate goods producers who hire labor services and rent capital to produce goods, (b) final goods producers who differentiate intermediate goods and sell them to goods bundlers, and (c) capital goods producers, who turn bundled final goods into capital goods.

When profit maximization decisions in the firm sector require intertemporal decisions (i.e. in price setting and in producing capital goods), we assume for tractability that the rentiers delegate the decision power to a mass-zero group of risk neural managers who are compensated by a share in profits.[7] They do not participate in any asset market and have the same discount factor as all other households. Since managers are a mass-zero group in the economy, their consumption does not show up in any resource constraint and all profits go to the rentiers (whose $h = 0$).

1.2.1 Final Goods Producers and Goods Bundlers

Households, capital producers and the fiscal authority purchase bundled goods from competitive firms. These firms and assemble the good using inputs of final goods. Their technology is:

$$Y_t = \left(\int_j y_{jt}^{1-1/\eta} dj \right)^{1/(1-1/\eta)} \tag{9}$$

where y_{jt} denotes the input of final good of variety j which is purchased at price p_{jt}. $\eta > 1$ is the elasticity of substitution between the final goods. The demand for final goods variety

[7] Since we solve the model by a first-order perturbation in aggregate shocks, the assumption of risk-neutrality only serves as a simplification in terms of writing down the model. With a first-order perturbation we have certainty equivalence and fluctuations in stochastic discount factors become irrelevant for price setting.

j is therefore given as:

$$y_{jt} = (p_{jt}/P_t)^{-\eta} Y_t \tag{10}$$

where $P_t = \left(\int_j p_{jt}^{1-\eta} dj\right)^{1-\eta}$ is the price index. The resource constraint is then:

$$Y_t = C_t + I_t + G_t + Y_t^{ad} \tag{11}$$

where $C_t = \int_i c_{it} di$ is aggregate consumption, I_t denotes investment, and G_t is government consumption. Y_t^{ad} denotes some further resource costs specified below.

Final goods are produced by a continuum of monopolistically competitive firms. Producer j buys the intermediate good at the nominal price MC_t. We assume price adjustment frictions à la Rotemberg (1981). Under this assumption, the firms' managers maximize the expected present value of real profits:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t Y_t \left\{ \left(\frac{p_{jt}}{P_t} - mc_t\right) \left(\frac{p_{jt}}{P_t}\right)^{-\eta} - \frac{\eta}{2\kappa_Y} (\log \frac{p_{jt}}{p_{jt-1}})^2 \right\}, \tag{12}$$

Here $mc_t = MC_t/P_t$ are real marginal costs, $\kappa_Y > 0$ captures price adjustment costs with $\kappa_Y \to \infty$ denoting flexible prices. We focus on symmetric equilibria in which all firms set the same prices. Imposing symmetry, the first-order necessary condition for optimal prices is given as:

$$\log(\pi_t) = \beta \mathbb{E}_t \log(\pi_{t+1}) \frac{Y_{t+1}}{Y_t} + \kappa_Y \left(mc_t - \tfrac{\eta-1}{\eta}\right), \tag{13}$$

where π_t is the gross inflation rate of final goods and $\frac{\eta}{\eta-1}$ is the target markup.

1.2.2 Intermediate Goods Producers

Intermediate goods producers are competitive and operate constant returns technologies given as:

$$M_t = \mathcal{Z}_t H_t^{\alpha} (\xi_t K_t)^{1-\alpha}, \tag{14}$$

where $\mathcal{Z}_t$ is total factor productivity which follows an autoregressive process in logs. ξ_t denotes the quality of capital so that $\xi_t K_t$ is the effective quantity of capital at time t. ξ_t also follows an autoregressive process. $\alpha \in (0, 1]$ is the labor share of income and H_t is the effective labor input:

$$H_t = \left(\int_i l_{it} h_{it} di\right) \tag{15}$$

Let mc_t be the relative price at which the intermediate good is sold to final goods producers. Labor is rented period-by-period on a competitive spot market. Labor demand satisfies the first-order condition:

$$w_t = \alpha m c_t \mathcal{Z}_t \left(\frac{\xi_t K_t}{H_t} \right)^{1-\alpha} \tag{16}$$

After production, the firms have $(1-\delta)\, K_t$ units of capital left which sell at the normalized (relative) price of 1 per unit, where $\delta \in (0,1)$ is the depreciation rate. All profits and the remaining capital stock are then paid to the firms' owners. Then the firm acquires new units capital, K_{t+1}, at the price Q_t per unit which are used for production the next period. Capital purchases are financed through issuing $b_{F,t}$ units of equity at the price of Q_t each, i.e.:

$$Q_t K_{t+1} = Q_t b_{F,t} \tag{17}$$

After production, the firms pay out all remaining value in the firm to their equity owners. The return offered to the current equity holders is given as:

$$R_{K,t} = \frac{(r_{K,t} + Q_t - \delta)\, \xi_t}{Q_{t-1}} \tag{18}$$

where $r_{K,t}$ is the marginal product of capital:

$$r_{K,t} = \alpha m c_t \mathcal{Z}_t \left(\frac{H_t}{\xi_t K_t} \right)^{\alpha} \tag{19}$$

1.2.3 Capital Goods Producers

New capital goods are produced by competitive firms. They purchase I_t of bundled goods and transform these into ΔK_{t+1} units of new capital goods according to:

$$I_t = \frac{\psi_k}{2} (\Delta K_{t+1}/K_t)^2 K_t + \Delta K_{t+1}. \tag{20}$$

where $\psi_k \geq 0$ captures adjustment costs.

The first-order necessary condition is:

$$\frac{\Delta K_{t+1}}{K_t} = \frac{Q_t - 1}{\psi_k}, \tag{21}$$

so that the capital stock is rising (falling) whenever $Q_t > 1$ $(Q_t < 1)$.[8]

[8] We assume that capital goods producers are each small and thus ignore their externality on the future cost of capital goods production.

1.3 Banks

Our modeling of the banking sector extends Gertler and Karadi (2011) to include unsecured consumer lending but otherwise follows their setup. A continuum of banks of measure Z, indexed by $z \in (0, Z)$ provides financial intermediation services. Banks are owned by the rentiers but they delegate management to risk neutral bankers who discount future utility at the rate of β. Bankers start life with a start-up fund and build up net worth during their banking careers. Every period a fixed fraction $\theta \in (0, 1)$ of the managers die and replaced by new ones. As in Gertler and Kiyotaki (2010), an agency problem constrains bankers ability to leverage net worth and induces interest rate wedges.

Banks intermediate between households and the corporate sector and between different types of households. The activities of the banks can be summarized in two stages. In the first stage, banks raise deposits ($b^z_{D,t+1}$) from savers. In the second stage, banks use the deposits and their net worth (n^z_t) to invest in equity ($b^z_{F,t}$), bought at price Q_t per unit, and make loans to households ($b^z_{L,t+1}$). The bank's balance sheet follows as:

$$Q_t b^z_{F,t} + b^z_{L,t+1} = n^z_t + b^z_{D,t+1} \tag{22}$$

The gross interest rate on deposits, $R_{D,t+1}$, has to equal the return on government bonds, $R_{S,t+1}$. The return on equity purchases is $R_{K,t+1}$. Bankers can freely choose whether to invest in consumption loans or in corporate sector equity and there is no default risk associated with either asset. The return to banks from consumer loans therefore needs to be $R_{K,t+1}$. Hence, the law of motion of net worth is given as:

$$n^z_{t+1} = (R_{K,t+1} - R_{S,t+1}) \left(Q_t b^z_{F,t} + b^z_{L,t+1} \right) + R_{S,t+1} n^z_t \tag{23}$$

We assume that banks face additional costs of supplying loans to households. In particular, making loans to households induces an additional cost that we assume is proportional to the number of units of loans issued. One can think of these as costs of checking whether the size of the loan requested by a household is compatible with the borrowing limit. These costs are passed on to borrowers, i.e.:

$$R_{L,t} = \varphi R_{K,t} \tag{24}$$

where $\varphi \geq 1$.

As in Gertler and Kiyotaki (2010), the banker can divert a fraction $\lambda \in (0, 1)$ of its assets. Should this happen, depositors declare bankruptcy, the bank closes, and the depositors recover the remaining fraction of $1 - \lambda$ of assets. Thus, bankers will refrain from diversion only if the following constraint is satisfied:

$$\mathbf{V}_t^z \geq \lambda \left(Q_t b_{F,t}^z + b_{L,t+1}^z \right) \tag{25}$$

where $\mathbf{V}_t^z$ denotes the value of the bank given as:

$$\mathbf{V}_t^z = \max \mathbb{E}_t \sum_{i=0}^{\infty} (1-\theta)\, \theta^i \beta^{i+1} n_{t+1}^z \tag{26}$$

$\mathbf{V}_t^z$ can be expressed as:

$$\mathbf{V}_t^z = \upsilon_{b,t} \left(Q_t b_{F,t}^z + b_{L,t+1}^z \right) + \upsilon_{n,t} n_t^z \tag{27}$$

where

$$\begin{aligned} \upsilon_{b,t} &= \mathbb{E}_t \left[(1-\theta)\, \beta \left(R_{K,t+1} - R_{S,t+1} \right) + \beta \theta x_{t,t+1} \upsilon_{b,t+1} \right] \\ \upsilon_{n,t} &= \mathbb{E}_t \left[(1-\theta) + \beta \theta g_{t,t+1} \upsilon_{n,t+1} \right] \end{aligned} \tag{28}$$

$\upsilon_{b,t}$ is the value of a marginal extra unit of bank assets, and $\upsilon_{n,t}$ is the value of a marginal unit of net worth. $x_{t,t+1} = \left(Q_t b_{F,t}^z + b_{L,t+1}^z \right) / \left(Q_{t-1} b_{F,t-1}^z + b_{L,t}^z \right)$ is the growth rate of bank assets and $g_{t,t+1} = n_{t+1}^z / n_t^z$ is the growth rate of net worth. Both $x_{t,t+1}$ and $g_{t,t+1}$ are identical across banks (see below) and therefore not indexed by z. Thus, $\upsilon_{b,t}$ and $\upsilon_{n,t}$ are also equalized across banks.

We will assume that the incentive constraint is binding so that banks will be unable to invest sufficiently to close the gap between the return on assets and the interest they offer on savings, ie. $R_{K,t} \geq R_{S,t}$. Imposing that the constraint binds, implies that:

$$Q_t b_{F,t}^z + b_{L,t+1}^z = \phi_t n_t^z \tag{29}$$

where ϕ_t is given by

$$\phi_t = \frac{\upsilon_{n,t}}{\lambda - \nu_{b,t}} \tag{30}$$

It then follows that:

$$n_{t+1}^z = \left(\left(R_{K,t+1} - R_{S,t+1} \right) \phi_t + R_{S,t+1} \right) n_t^z \tag{31}$$

and therefore $x_{t,t+1} = \left(\phi_t / \phi_{t-1} \right) g_{t,t+1}$ and $g_{t,t+1} = \left(\left(R_{K,t+1} - R_{S,t+1} \right) \phi_t + R_{S,t+1} \right)$ which both are the same across banks as conjectured.

Let $\omega / (1-\theta)$ be the fraction of banking sector value that is injected to new bankers.

Aggregating across banks, banking net worth, $N_t = \int_z n_t^z dz$, then obeys the law of motion:

$$N_t = \theta \left[\left(R_{K,t} - R_{S,t} \right) \phi_{t-1} + R_{S,t} \right] N_{t-1} + \omega \left(Q_t b_{F,t-1} + b_{L,t} \right) \tag{32}$$

1.4 Government

1.4.1 Monetary Policy

We assume that monetary policy is conducted by setting the nominal interest rate according to a Taylor-type rule:

$$R_{S,t+1}^N = \overline{R}_S^N \left(\frac{\pi_t}{\overline{\pi}} \right)^{\kappa_\pi} \exp\left(\epsilon_t^m \right) \tag{33}$$

where $\overline{R}_S^N$ is the long-run level of the short term nominal interest rate, $\overline{\pi}$ is an inflation target, and $\kappa_\pi > 0$ is the interest rate response to deviations of inflation from its target. ϵ_t^m is a monetary policy shock. It follows an AR(1) process with persistence $\rho_m \in (0, 1)$ and iid innovations that are normally distributed with mean 0 and variance σ_m^2.

1.4.2 Fiscal Policy

The fiscal authority manages government debt, purchases of final goods and is in charge of tax collection. The government budget constraint is given as:

$$B_{G,t+1} = R_{S,t} B_{G,t} + G_t - T_t + DC_t$$

where $B_{G,t+1}$ is the amount of debt issued in period t and T_t are tax revenues:

$$T_t = \tau \left(w_t H_t + \mathcal{F}_t \right)$$

DC_t denotes the net costs of carrying out credit policy which are specified below.

In order to anchor government debt and impose government solvency, we assume that government purchases of goods are governed by the feedback rule:

$$\frac{G_t}{\overline{G}} = \left(\frac{G_{t-1}}{\overline{G}} \right)^{\rho_G} \left(\frac{B_{G,t}}{\overline{B}_G} \right)^{-\gamma_G}$$

where $\overline{G} > 0$ is a constant denoting the long-run level of government spending, and $\rho_G \in (-1, 1)$ allows for partial adjustment of government spending. The last term captures how deviations of government debt from its target, $\overline{B}_G$, triggers spending adjustments. We assume that $\gamma_G > 0$ so that the government cuts spending when debt is rising in order to improve the primary budget balance with the aim of stabilizing debt dynamics.

1.4.3 Credit Policy

The central bank may also facilitate lending, which we call credit policy. Let S_t^g be the value of assets intermediated via government assistance and let S_t be the total value of intermediated assets: i.e.,

$$S_t = S_t^p + S_t^g \tag{34}$$

where $S_t^p = Q_t b_{F,t} + b_{L,t+1}$ is the total value of privately intermediated assets. To conduct credit policy, the central bank issues government debt to households that pays the deposit interest rate $R_{S,t+1}$ and then lends the funds to non-financial firms and households at the market lending rates $R_{K,t+1}$ and $R_{L,t+1}$, respectively. Importantly, the government always honors its debt but it involves an efficiency costs.

In particular, the central bank credit involves an efficiency cost of τ_I per unit supplied. Hence, the government does not have an incentive to completely replace banks.

Suppose that central bank funds the fraction of ψ_t of intermediated assets: i.e.,

$$S_t^g = \psi_t S_t \tag{35}$$

The cost of this policy is $\tau_I \psi_t S_t$. Its net earning from intermediation in any period t equals to $(R_{K,t+1} - R_{S,t+1})B_{G,t}^C$.[9] Considering this government activity with banks intermediation, we can rewrite equation (34) to obtain

$$S_t = \phi_t N_t + \psi_t S_t = \phi_{c,t} N_t \tag{36}$$

where ϕ_t is the leverage ratio for privately intermediated funds and $\phi_{c,t}$ is the leverage ratio for total intermediated funds.

$$\phi_{c,t} = \frac{1}{1-\psi_t}\phi_t \tag{37}$$

The central bank injects credit in response to movements in credit spreads as the following feedback rule:

$$\frac{\psi_t}{\bar{\psi}} = \left[\frac{R_{K,t+1} - R_{S,t+1}}{\bar{R_K} - \bar{R}_S}\right]^v. \tag{38}$$

According to this rule, the central bank expands credit as the spread increases relative to its steady state value.

[9] The surcharge on consumer loans is wasted.

1.5 Market clearing

Let $\Theta_t(b,h)$ denote the joint distribution of assets and productivity across households. The market clearing condition for the savings market reads:

$$\int_{b^*>0} b^*(b,h)\,\Theta_t(b,h)\,\mathrm{d}b\mathrm{d}h = B_t = B_{D,t+1} + B_{G,t+1} \tag{39}$$

where $b^*(b,h)$ is the policy function that solves the households' savings problem, $B_{D,t+1}$ and $B_{G,t+1}$ denote aggregate supply of bank deposits and government bonds, respectively.

The credit market clearing condition is:

$$N_t + B_{D,t+1} = Q_t K_{t+1} + \int_{b^*<0} b^*(b,h)\,\Theta_t(b,h)\,\mathrm{d}b\mathrm{d}h$$

which states that credit supply from banks and saving households are equal to the credit demand from firms and borrowing households. The market for capital goods has to clear:

$$\frac{\Delta K_{t+1}}{K_t} = \frac{Q_t - 1}{\psi_k}$$

Clearing of goods market implies that:

$$\left(1 - \frac{\epsilon}{2\kappa_Y}(log(\pi_t))^2\right) Y_t = C_t + I_t + G_t + \tau_I \psi_t S_t + B_{L,t} A_t$$

where τ_I is the cost parameter from the government intermediation and $A_t = (\varphi - 1)R_{K,t}$ is the wasted intermediation cost. The government budget constraint, taking into account credit policy,

$$G_t + R_{S,t} B_{G,t} + \tau_I \psi_t S_t = T_t + B_{G,t+1} + (R_{K,t} - R_{S,t})\psi_{t-1} S_{t-1}$$

is then satisfied by the Walras' law whenever the credit, deposit, goods, labor, capital and capital service markets clear.

2 Calibration

We solve the model by first-order perturbation, using the method of Bayer and Luetticke (2018). We calibrate the model so that one period corresponds to a quarter. Table 1 contains the parameter values of the calibration.

Calibrated Parameters	Description	Value
Households		
β	Discount factor	0.986
χ	Disutility weight of labor	7
μ	Relative risk aversion	1
γ	Frisch elasticity of labor supply	1
ρ_h	Persistence of income shocks	0.98
σ_h	Variances of income shocks	0.06
Production		
α	Labor share	0.67
Capital		
ψ_k	Capital adjustment cost	6.0
δ	Capital depreciation	0.02
Final Goods		
κ	Price stickiness	0.09
μ^Y	Markup	0.05
Intermediation		
λ	Divertible fraction of capital	0.381
θ	Bank survival ratio	0.972
ω	Transfer to the entering bankers	0.002
τ_I	Government intermediation cost	0.001
φ	Consumer loan cost	1.015
Monetary and Fiscal Rules		
κ_π	Reaction to inflation	1.5
γ_G	Reaction to debt	0.1
ρ_G	Persistence in fiscal rule	0.9
Aggregate Shocks		
ρ_{CQ}, σ_{CQ}	Persistence, standard deviation	0.66, 0.01
ρ_{TFP}, σ_{TFP}	Persistence, standard deviation	0.90, 0.01
ρ_{MP}, σ_{MP}	Persistence, standard deviation	0.50, 0.001

Table 1: Model Parameterization

		Baseline
Households (%)		
(At kink)	(%)	8.9
(Borrowers)	(%)	24.3
Return on capital	(R_K,% quarterly)	1.14
Saving interest rate	(R_S,% quarterly)	0.75
Lending interest rate	(R_L,% quarterly)	2.69
Spread	(bp, quarterly)	194

Table 2: Steady state statistics

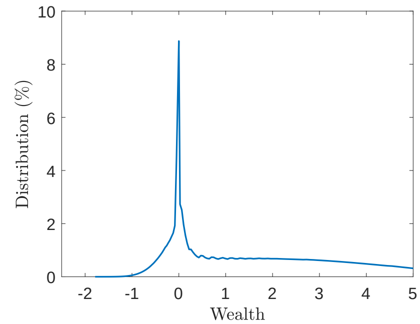


Figure 2: Distribution of wealth (with wealth reported as: b / Y)

We assume that the intertemporal elasticity of substitution is equal to 1, a value in the range of empirical estimates from studies of household consumption such as Attanasio and Weber (1993) or studies of aggregate data such as Eichenbaum et al. (1988). We set the Frisch elasticity equal to one, a standard value in macro literature even if slightly above the consensus view from the labor literature. We calibrate χ, the weight on the disutility of labor to target a value of labor supply equal to one third. The intertemporal discount factor is calibrated by targeting an annual capital-output ratio of 2.5. Together with other parameters, this implies $\beta = 0.986$ indicating that households engage in quite substantial amounts of precautionary savings.

We assume that the output elasticity to labor, α, is equal to 67 percent. The depreciation rate is assumed to be two percent per quarter while capital adjustment costs, ψ, are calibrated to target a volatility of investment to output of 3 in response to TFP shocks. The parameter η, the elasticity of substitution between goods varieties, is calibrated to induce a long-run mark-up of five percent. The price stickiness parameter κ is calibrated by exploiting that the slope of the Phillips curve in the Rotemberg model can be related to the average price contract length implied by this slope in a Calvo model. Using this, we calibrate κ so that it is consistent with an average contract length of four quarters.

We follow the calibration of Gertler and Karadi (2011), assuming that bankers can divert around 38 percent of the bank's assets and that the survival rate is 97.2 percent per quarter (so that their planning horizon is approximately 10 years). This implies a leverage ratio of 3.5. Even though some banks in the data have higher leverage ratios, which often comes from housing finance, the leverage ratio for corporate and non-corporate business sectors is closer to two in the data. We also follow Gertler and Karadi (2011) in assuming that the transfer to new banks correspond to 0.2 percent of the banking assets.

The inflation coefficient in the Taylor rule is 1.5, a standard value in the literature. We assume that the central bank pursues price stability and set $\overline{\pi} = 1$. To ensure government solvency, government spending reacts to debt, $\gamma_G = 0.1$, and also features inertia, $\rho_G = 0.9$. We set the level of long-run government debt, $\overline{B}_g$, to target a ratio of bank deposits to total gross savings in bonds and deposits to 0.85. This value is consistent with the equivalent share in the Survey of Consumer Finances.

We then target moments of the wealth distribution when calibrating the borrowing limit $\underline{\mathbf{b}}$ and the spread on unsecured consumer loans determined by φ. In the Survey of Consumer Finances, roughly 20 percent of households are borrowers and 10 percent of households have close to zero wealth (putting them at the kink in their budget constraint). To match these we set $\underline{\mathbf{b}}$ equal to 2 times average income and φ so that the spread of the interest rate on consumer loans over the deposit rate is 1.94 percent point per quarter while the spread over the return on equity is 1.55 percent point per quarter. At the annual rate, the calibrated spread over the savings rate is 8.1 percent point which is marginally lower than e.g. the calibration of Kaplan et al. (2018) who assume a spread of 10 percent. The spread implies issuing a consumption loan induces a resource cost of 1.5 percent of the loan amount which is passed on to the households.

For the idiosyncratic income risk, we assume that $\rho_h = 0.98$ and $\sigma_h^2 = 0.06^2$. These values correspond to estimates for net household (after tax and transfers) income from the Survey of Income and Program Participants (for the 1984-2013 sample), see Bayer et al. (2019).[10]

These parameter values imply the following wealth distribution and interest rate schedule, see Table 2 and Figure 2. It is noticeable that there is a mass point in the wealth distribution at zero wealth that derives from the kink in the budget constraint of households induced by the spread of the lending rate over the savings rate. It is also clear that there is a considerable mass of households with close to zero wealth. This is induced by the relatively high variance of idiosyncratic income shocks which induce movements to/from the zero wealth state. The left tail of the wealth distribution is very thin due to the utility cost suffered by households who are prevented from taking on additional debt. Indeed, there are almost no households at the borrowing limit in the stationary distribution. Thus, the high MPC households all derive from the interest rate spread rather than mechanically from the borrowing constraint.

The economy is subject to 3 aggregate shocks, which are TFP, monetary policy, and capital quality shocks. TFP shocks are persistent with an autocorrelation of 0.9 and have a standard deviation of 1%. Monetary shocks are less persistent with an autocorrelation of 0.5 and have a standard deviation of 10 basis points. Capital quality shocks are somewhat persistent with an autocorrelation of 0.66 and have a standard deviation of 1%.

[10] These estimates control for purely transitory income shock and for a deterministic component.

3 The Transmission Mechanism

We first investigate whether the set-up has new implications for the impact of shocks on the economy. We look at three shocks: Two shocks that has attracted much attention in the business cycle literature, technology shocks and monetary policy shocks, and a capital quality shock that the financial frictions literature has focused attention on. We also examine the stabilizing role of central bank provided credit supply.

We show that the model introduces a new mechanism which has been overlooked in the literature: The impact of endogenous movements in the spread of the interest rate on consumer credit relative to the savings rate. This spread moves countercyclically in response to each of these shocks because of the impact on banking sector net worth. Such countercyclical movements in the spread imply that households face different trade-offs depending on their net wealth position giving rise to divergent consumption responses to shocks along the wealth distribution. Moreover, a higher spread increases the consumption response to shocks deriving from households with zero (or close to zero) net wealth. Through these channels, consumption account for a larger fraction of aggregate adjustments to shocks.

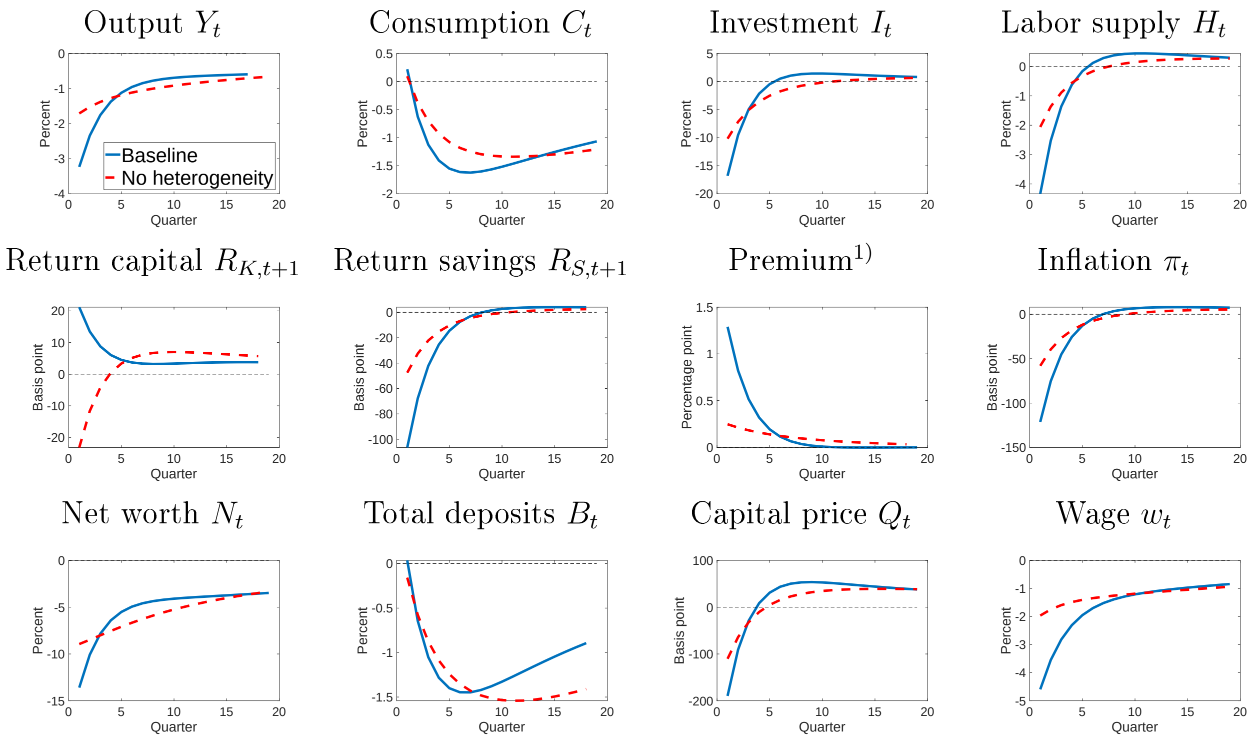
Hence, we move the attention from the spread between the return on corporate debt and savings rates, much studied in the financial frictions literature, to the spread between the interest on consumer debt and deposit rates. This spread matters when agents differ in wealth and face uninsurable idiosyncratic risk.[11]

Capital quality shocks:

We first look at the capital quality shock that Gertler and Karadi (2011) argue was an important factor in the Great Financial Crisis. Figure 3 illustrates the impact of a one percent shock to ξ_t which simultaneously lowers productivity and increases the depreciation rate. In order to understand the importance of household heterogeneity, we show both the impact of the shock in the baseline model (in blue) and in a representative agent economy (RANK) where there is no idiosyncratic earnings risk, the wealth distribution is degenerate, and all households are savers (red dotted line).

The decline in capital quality sets off fire-sales of capital and produces a sudden steep decline in the price of new capital, Q_t. The drop in the price of capital worsens banks' balance sheets, and because of their leveraged positions, forces them to cut back on investment in equity and in consumer loans. This sets in motion a process through which reductions in banks' investments lowers the capital price which lower banking sector net worth inducing a further fall in investment etc. In equilibrium, the price of capital falls by approximately two percent and net worth by 14 percent on impact. Both of these responses are substantially

[11] We provide robustness checks to other formulations of the lending rate in Appendix B.



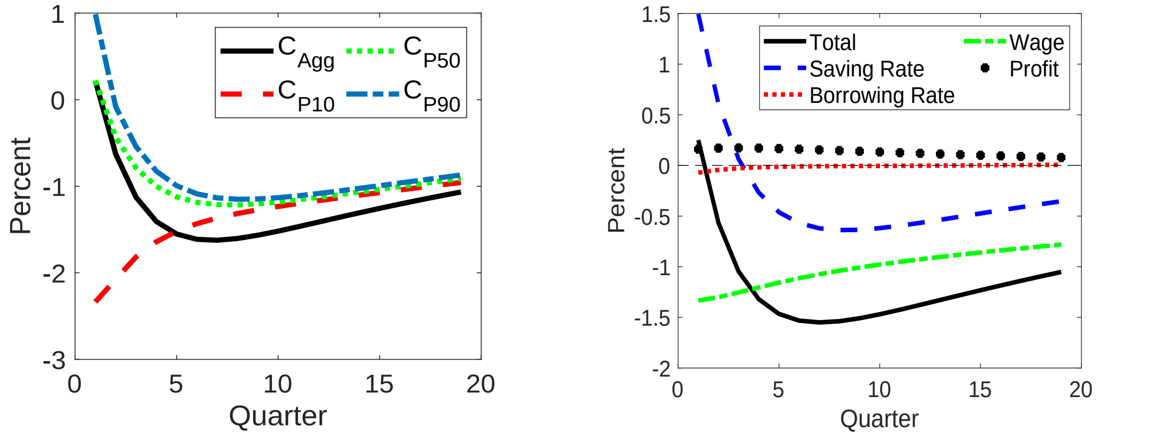
1) $E_t(R_{L,t+1} - R_{S,t+1})$ in Baseline and $E_t(R_{K,t+1} - R_{S,t+1})$ with No heterogeneity.

Figure 3: Aggregate effects of a capital quality shock

larger than in the model without heterogeneity in which the capital price declines by around one percent and net worth by close to 10 percent.

The capital quality shock has a large and persistent impact on the economy. In the initial period, output declines 3.2 percent and 6 quarters later, aggregate output is still one percent below its steady-state value. The decline of output in the first period is amplified by a factor of two in the HANK economy relative to the RANK economy. It is also noticeable that while aggregate investment accounts for why output falls in the very first period, thereafter consumption accounts for much more of the fall in aggregate spending.

Recall that declining net worth in the banking sector implies that the return on its assets (equity and consumption loans) must rise relative to the price of funding (the return on savings). The savings rate is dictated by the Taylor rule and the deflationary impact of the capital quality shock leads the central bank to cut nominal and real returns on savings. In a representative agent economy, the increase in the spread is accomplished by the interest on corporate loans falling less than the interest rate on consumer deposits. Allowing for household heterogeneity changes this. In particular, the interest rate on consumption loans has to rise because, otherwise, the bank would stimulate the demand for credit forcing it to cut further back on corporate loans. Thus, not only does the spread between the return on



A) Consumption responses by wealth   B) Decomposition of aggregate consumption

Notes: Panel A plots the consumption response for households at 10th, 50th, 90th percentile of the wealth distribution.

Panel B plots the decomposition of aggregate consumption into the effect of each price sequence by using household policy functions.

Figure 4: Transmission to consumption: Capital quality shock

bank assets and the price of funds increase, but the interest rates on savings and on loans move in opposite directions.

These movements in interest rates impact differentially on households across the wealth distribution. Figure 4, Panel A, illustrates the consumption paths for households in the 10th percentile (who are indebted), 50th percentile, and 90th percentile of the wealth distribution, together with aggregate per capita consumption. The impact on the median and wealthy households' consumption is very mild. These households have savings allowing them to smooth consumption in response to the decline in real wages. Moreover, the drop in the return on savings motivates these households to substitute towards current consumption. In combination, this implies that richer households' consumption moves little. Indebted households instead get hit not only by lower real wages but also have to pay higher interest rates on their debt inducing a strong decline in consumption. Moreover, the negative wealth effect spurs an increase in labor supply which reinforces the drop in real wages that derive directly from the shock. Lower real wages hit poorer households hard also because many of these households have low productivity. For the 10th percentile, consumption drops by almost two-and-a-half percent.

In Figure 4, Panel B, we decompose the aggregate response of consumption into the impact of the savings rate, the lending rate, the wage rate, and profits. While the saving rate contributes positively to consumption, the lending rate contributes negatively to consumption. The wage rate is the main channel that makes consumption fall accounting for a large

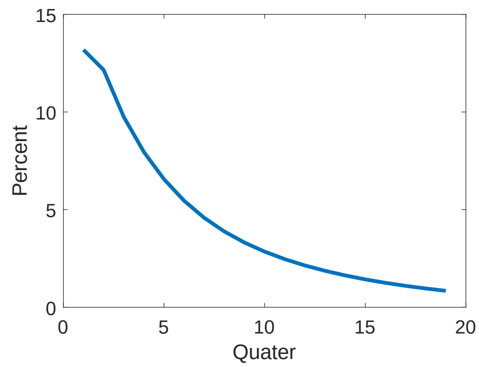


Figure 5: Impulse response of the average MPC to capital quality shock

fraction of the decline in consumption at all horizons.

Added to this, the increase in the spread induces a rise in the share of zero wealth households who have high marginal propensities so consume. Figure 5 shows that the average MPC of the economy increases by 13% in response to the capital quality shock. This together with the direct impact on borrowers implies that aggregate consumption falls significantly more in the heterogeneous agent model than in the representative agent economy.

An additional way to quantify the importance of borrowing households for aggregates is to look at a counterfactual economy with zero borrowing limit. In this economy all households supply deposits and are barred from taking out consumer loans. Figure 6 compares our baseline economy to such an economy without borrowing. The counterfactual economy behaves similar to the RANK model and induces a much smaller output response to the shocks and a much milder reduction in consumption. Thus, our results derive from allowing households to demand loanable funds from banks.

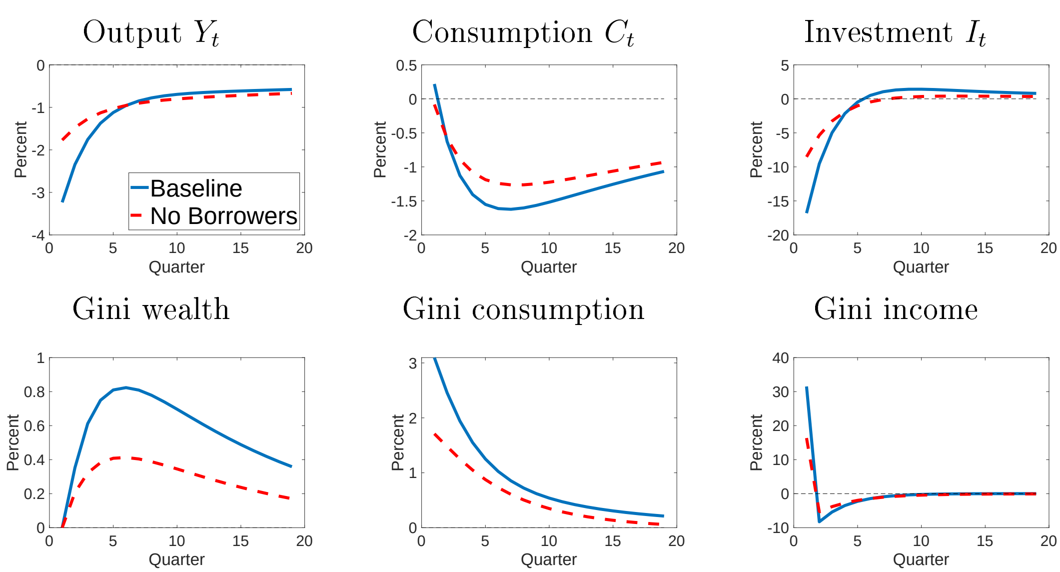
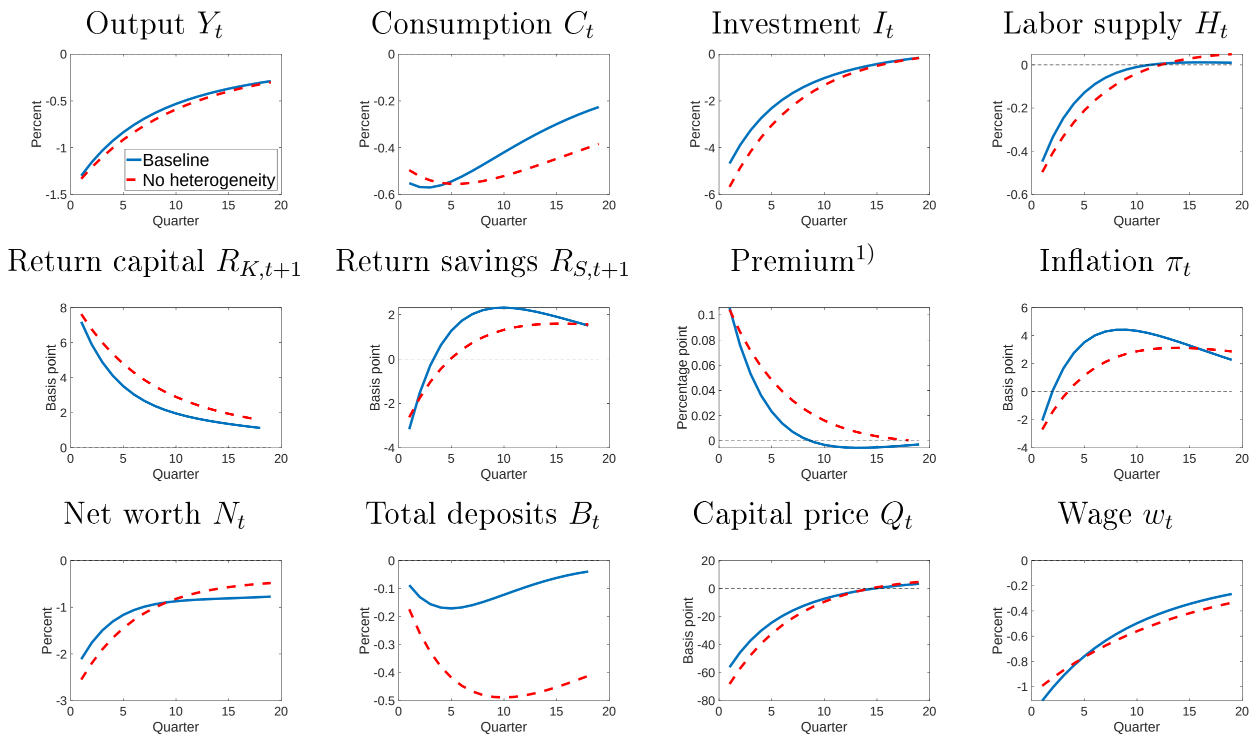


Figure 6: Aggregate and distributional effects of a capital quality shock w/o borrowers

Finally, it is worth noticing that the countercyclical lending rate also matters for inequality, see Figure 6. With borrowers, the Gini coefficient of consumption increases by three percent and stays elevated for three years. Without borrowers, in contrast, the Gini coefficient of consumption only increases by less than two percent.

Technology shocks:



1) $E_t(R_{L,t+1} - R_{S,t+1})$ in Baseline and $E_t(R_{K,t+1} - R_{S,t+1})$ with No heterogeneity.

Figure 7: Aggregate effects of a TFP shock

The key insights from above carry over to the impact of technology shocks. Figure 7 shows the adjustment of the economy to a one percent decline in TFP. This shock is recessionary, lowers the productivity of labor and of capital, and produces a fall in the price of new capital. Aggregate output falls and along with it the economy sees declining investment and consumption. As in the standard financial frictions model, the impact of technology shocks are mildly amplified due to the rise in the interest rate premium that follows from the declining banking sector net worth.

At the level of the aggregate output, the introduction of incomplete markets has little impact on the financial accelerator. However, introducing household heterogeneity again introduces a more important role for consumption in the macroeconomic adjustment process, and especially so in the shorter run. The roots of this derive again from the countercyclical

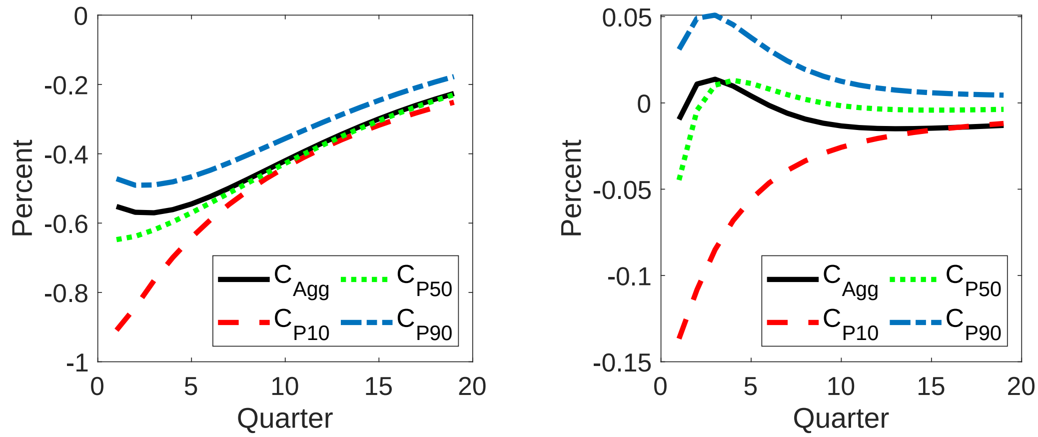


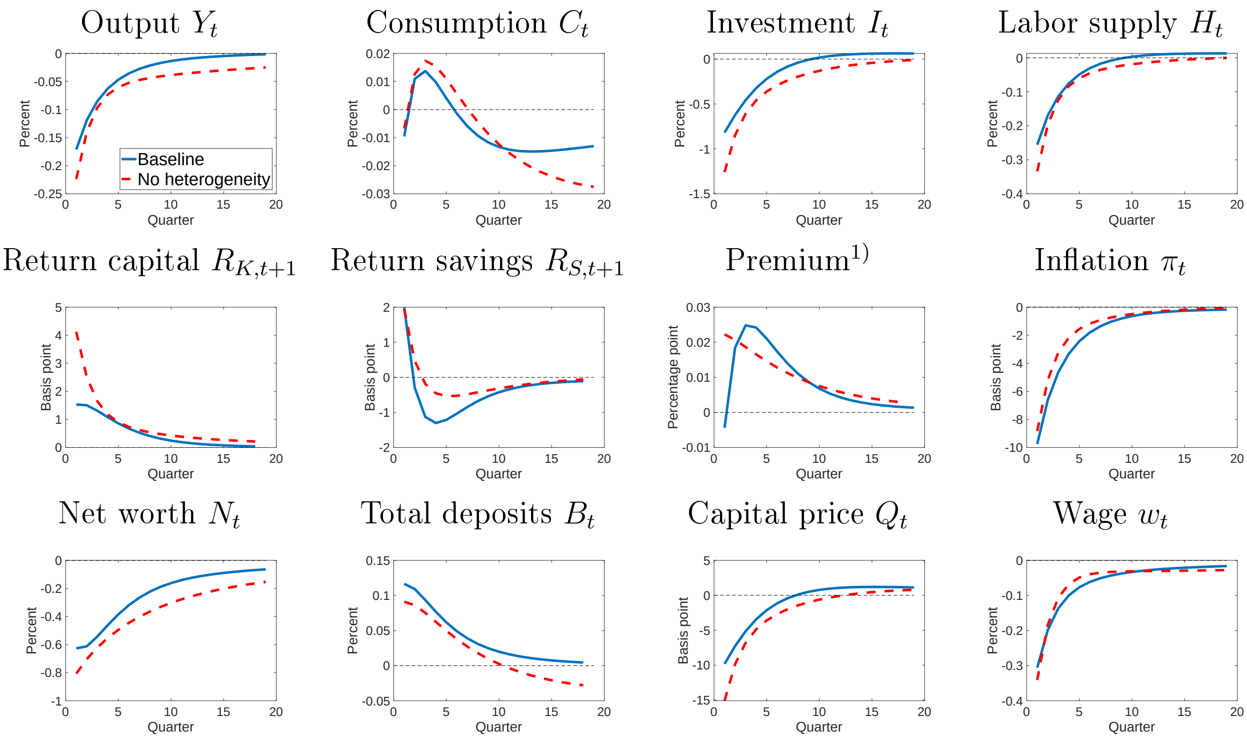
Figure 8: Consumption impulse responses by wealth percentiles

spread between savings and lending rates, and the impact thereof on consumption adjustments along the wealth distribution. Declining net worth in the banking sector induces lower interest rates on deposits but higher interest rates on loans. The results of this, see Figure 8 Panel A, is a sharp drop in consumption for indebted households that is almost twice the size of the aggregate decline. This result derives from poorer households suffering from both poorer credit conditions and from lower income forcing them to reduce consumption strongly while richer households smooth out the income shock and are induced to substitute towards current consumption due to the drop in the real return on savings.

Monetary policy shocks: Concerns about differential impact of shocks along the wealth distribution that we have pointed to above are common as far as popular discussions of monetary policy are concerned. Yet arguments are often centered around how common changes in interest rates impact differentially on households according to their portfolio composition. We add to this that the spread in interest rates faced by borrowers and savers also increases when the central bank raises short term nominal interest rates.

Figure 9 illustrates the response of the economy to a contractionary monetary policy shock assuming that the shock follows an autoregressive process with persistence 0.5. The impact of monetary policy shocks on aggregate output in the heterogeneous agents economy are very close to those that arise in the representative agent model but we confirm again that much of the adjustment mechanism is accounted for aggregate consumption rather than investment.[12] The contractionary monetary policy shock increases the cost of funds for banks

[12] In a different setup with household portfolio choice, Luetticke (2018) finds consumption to be more responsive to monetary shocks as well because of the positive (negative) covariance between the distributional consequences and marginal propensities to invest (consume).



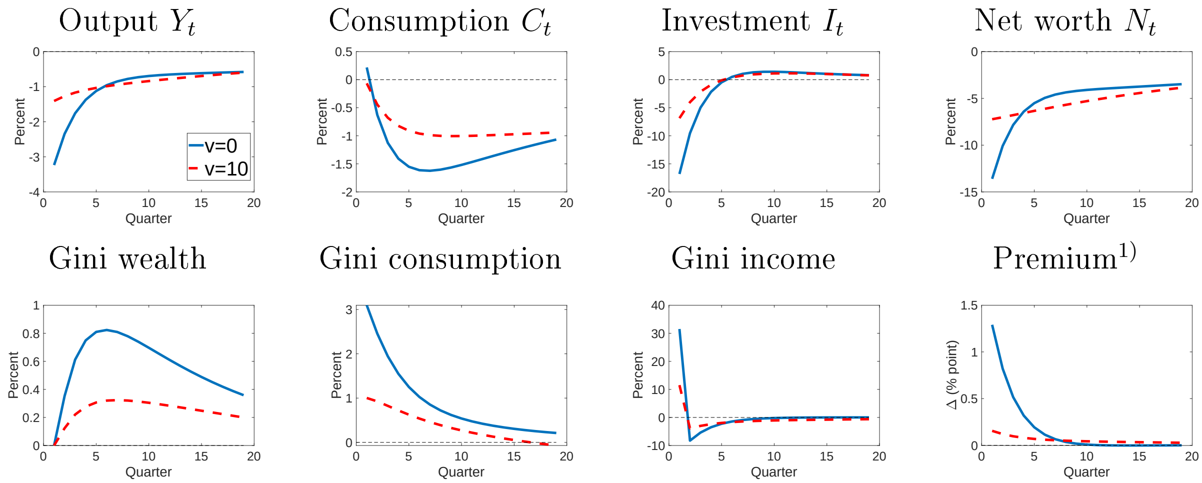
1) $E_t(R_{L,t+1} - R_{S,t+1})$ in Baseline and $E_t(R_{K,t+1} - R_{S,t+1})$ with No heterogeneity.

Figure 9: Aggregate effects of a monetary policy shock

by forcing up the short term real interest rate on deposits. The price of capital falls, banks see their net worth decline and this forces the spread to increase.

Thus, relative to standard intuition, the model adds the insight that borrowers are harder hit by the increase in interest rates than in models without financial frictions. The product of this is that households are affected differently by the monetary policy shock. Richer households earn higher real returns on their savings. The consumption of the median household is approximately unaffected by the contraction in the economy (see Figure 8, Panel B) and at the 90th percentile consumption actually rises. In contrast, indebted households face higher cost of credit leading to a strong reduction in their consumption. On average, the impact on richer households dominate the aggregate response yet consumption accounts for more of the macroeconomic adjustment than in the representative agent economy.

Credit policy: Given the results above, it is interesting to ask whether credit policy can help alleviate the amplification of shocks that occur through the countercyclical movements in the spread between savings and lending rates. Gertler and Karadi (2011) show that such a policy can mute the financial accelerator by stabilizing the impact of shocks on the spread which in their setting amplifies shocks through the investment response. As we have argued above, in the incomplete markets setting, much of the adjustment process occurs through consumption. Hence credit policy, while still stabilizing, may have different effects.



Notes: $v = 0$ corresponds to baseline and $v = 10$ corresponds to active credit policy with a semi-elasticity of credit supply to the spread set equal to 10.
1) $E_t(R_{L,t+1} - R_{S,t+1})$.

Figure 10: Aggregate and distributional effects of credit policy

Here we focus on the impact of credit policy after a capital quality shock. As above, we feed in a one percent decline in ξ_t. Our specification of credit policy implies that the central bank provides more liquidity when the corporate lending rate increases relative to the savings rate. Hence, as the shock hits the economy and spreads rise due to declining banking sector net worth, the central back steps in with credit supply. We show the impact of this in Figure 10 in which we illustrate the impulse responses for both the baseline economy (without credit policy) and for a specification where the semi-elasticity of credit supply to the spread, v, is set equal to 10.

We find that credit policy has a large stabilizing role in this economy. The impact effect on aggregate output is more than halved when the central bank supplies credit in response to the widening interest rate spread. The spread itself declines very significantly as does the fire sales of bank assets (and therefore banking sector net worth). The policy stabilizes both the decline in investment produced by the capital quality shock and, importantly, removes the large amplification that derives from aggregate consumption.

The credit policy stabilizes the interest rate spread. Therefore, it restores lending to households after an adverse capital quality shock which enables indebted households to avoid having to cut their consumption dramatically. Moreover, this policy also mutes the increase in the share of hand-to-mouth households that arise in the absence of this policy. When there is insurance against idiosyncratic risk, as in the representative agent economy, credit policy only stabilizes due to investment being less adversely affected by the shock to banking sector net worth. We find that the stabilization is much larger in the HANK economy, which shows the importance of the spread between the interest rates on savings and borrowing facing households.[13]

Finally, it is noticeable that the smaller recession with credit policy translates into a smaller response of inequality. The Gini coefficient of consumption increases by 70% less. The effects on wealth inequality are similar.

4 Macroprudential Regulation

The credit supply policy discussed above is an effective means of dampening the amplification of shocks through financial accelerator-type mechanisms. Such policies, however, imply resource costs on the part of the central bank and may also induce further incentive problems if banks ex-ante take into account how excessive risk taking on their part may be mitigated by central bank actions.

An alternative option is to regulate the banking sector in such a way that the amplification mechanism is neutralized. Here we will consider on such macroprudential regulation implemented through limiting banks' ability to leverage their net worth. By restricting leverage, shocks to the economy have less impact on banking sector net worth that stabilizes the impact of shocks.

The standard trade-off from introducing such regulation is that stabilization of the financial accelerator comes at the cost of lower steady-state output (since banks become more restricted in their investment activities). Here we will show that the trade-off is very different in the incomplete markets set-up. It involves a different trade-off between "micro volatility" and "macro stability" while long run steady-state output costs may be close to zero.

Long-run effects:

We first consider the long-run impact of regulating the banking sector. To be specific, we suppose that the regulator restricts ϕ, banking sector leverage, by 25 percent relative to its baseline value (3.47). This policy corresponds to what the market would impose on financial intermediaries that can divert 55.8 percent of the banks' capital (as compared to 38.1 percent in the baseline). Thus, the regulator imposes much stricter standards than the market forces.

Table 3 reports the long-run impact of this regulation on both aggregate variables as well as on distributional indicators. For a point of comparison, we also report the impact of the regulation in a counterfactual representative agent economy. The most direct effect of the

[13] See Appendix Figure 15 for the impact of this policy in the counterfactual representative agent economy.

	Heterogeneity		No Heterogeneity	
	Baseline	Low Leverage	Baseline	Low Leverage
Leverage	3.47	2.60	3.47	2.60
	Interest rates			
Return on capital (R_K, %)	1.14	1.17	1.60	1.74
Return on savings (R_S, %)	0.75	0.47	1.40	1.40
Lending interest rate (R_L, %)	2.69	2.73	-	-
	Aggregates			
Output	1.120	1.125	0.941	0.923
Capital	11.20	11.11	8.19	7.73
Labor	0.360	0.364	0.324	0.324
Consumption	0.738	0.733	0.652	0.640
	Household distribution			
At kink (%)	8.9	16.9	-	-
Borrowers (%)	24.3	30.9	-	-
Gini Wealth	0.921	0.961	-	-
Gini Consumption	0.259	0.273	-	-
Gini Income	0.320	0.325	-	-

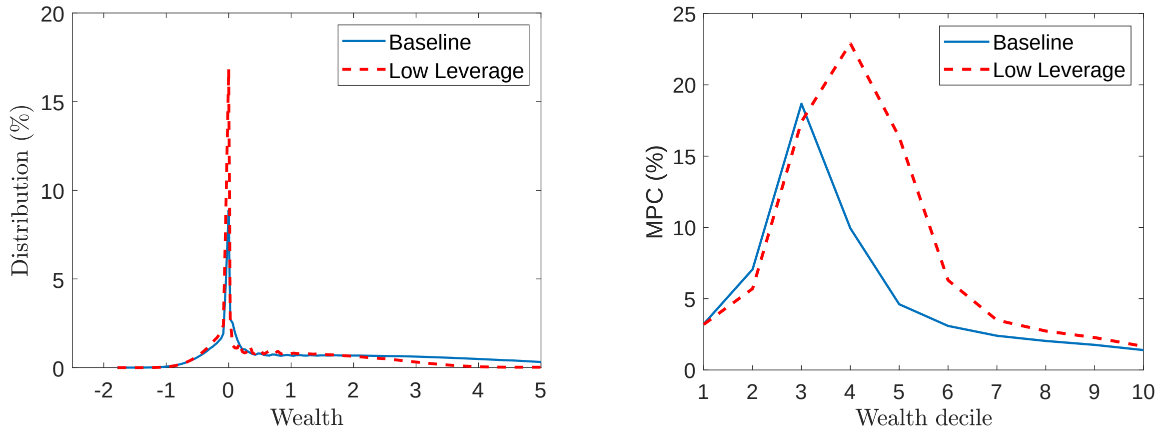
Notes: We compare the baseline steady state to one with low leverage (a high divertibility parameter $\lambda = 0.558$). The last two columns do so for the model with a representative household.

Table 3: Steady state: Baseline and low leverage

macroprudential regulation is to increase the spread between the return on bank investments and the deposit rate because of constraints imposed on the intermediary in its attempts to profit from high returns on investment opportunities. In equilibrium, the spread between the interest rate on loans and the deposit rate increases by 128 basis points (annualized) for consumer loans and 124 basis points for corporate loans.

The increase in the spread has distributional consequences because it exaggerates the kink in the budget constraint for zero wealth households. Figure 11 shows the long-run wealth distributions in the baseline economy and in the low leverage economy. It is noticeable that the spike at zero wealth is much higher when leverage is restricted. Indeed, we find that the share of households with zero wealth increases from just below 9 percent in the baseline to almost 17 percent in the low leverage economy. The share of borrowing households also increases (from 24 percent to 31 percent) but this is mainly due to transitions from zero wealth to marginally negative wealth produced by the mass point of households with zero assets.

Interestingly, the regulation of banks' leverage has no output costs. On the contrary, we



A) Distribution of wealth (b / Y)   B) MPC distribution

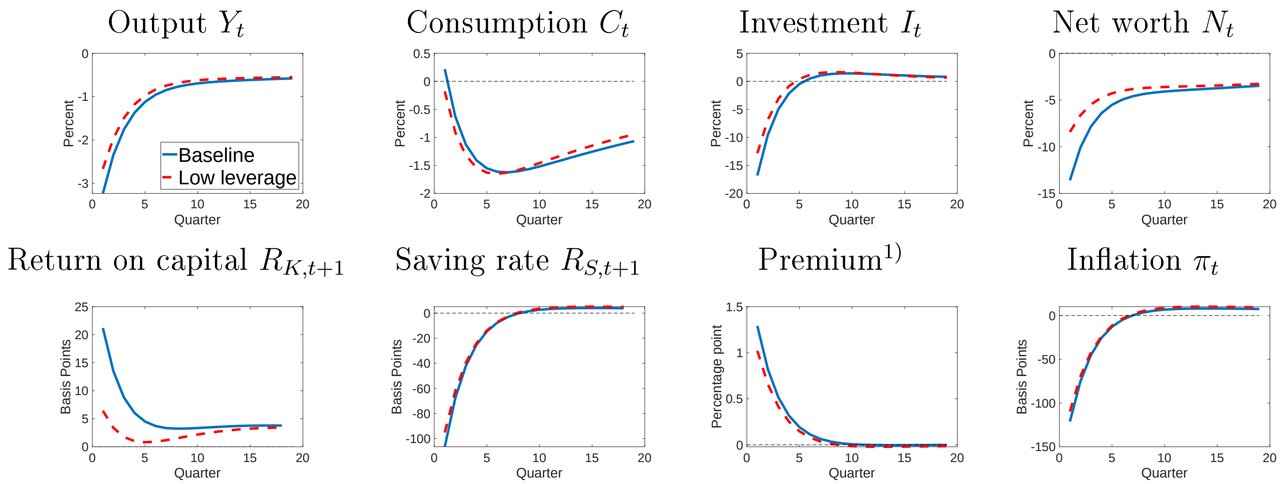
Figure 11: Distributions: Baseline and low leverage

find a small increase (0.4 percent) in aggregate output that derives from a combination of an increase in labor supply of 1.1 percent and a minor fall in the aggregate capital stock of 0.8 percent. This contrasts with the representative agent model in which there is a significant drop in output (of 2 percent) produced by a drop in the capital stock of almost 6 percent (induced by a decline in banks' financing of investment projects). In this economy, the return on savings in the steady-state is determined by the rate of time preference, $\beta^{-1} - 1$. Thus, a higher spread is reflected in the return on capital only and for that reason the macro prudential regulation induces a lower capital stock.

These effects are very different under incomplete markets. Here, the higher risk of being stuck at zero wealth gives households with positive wealth a precautionary savings motive, which puts downward pressure on the return on savings. Moreover, lower wealth households increase their labor supply, which increases the return on capital. In equilibrium these forces imply that although the spread increases, the impact on the aggregate capital is marginal and aggregate output rises. Given the savings desire of wealthier households, the increase in the spread is, in contrast to the representative agent economy, accomplished by the combination of a strong decline in the savings rate and marginally higher returns on equity investment and on consumer loans.

Thus, the common wisdom about the long-run output costs of macroprudential regulation is challenged in this model because of labor supply responses amongst poorer households and savings choices made by wealthier households.

Volatility: The aim of the macroprudential regulation is to lower the sensitivity of the economy to shocks. In Figure 12 we illustrate the impulse response functions of the economy to a one percent capital quality shock comparing the regulated economy with the baseline



1) $E_t(R_{L,t+1} - R_{S,t+1})$.

Figure 12: Impulse responses to capital quality shock with low leverage

calibration. Restricting banks' leverage stabilizes aggregate output especially in the short run because net worth falls much less in response to the shock. This also implies a much smaller impact of the capital quality shock on aggregate investment. Yet, consumption falls more in the first 6 quarters.

Table 4 quantifies these effects by reporting selected 2nd moments of the economy computed from simulations of the model in response to all three aggregate shocks (and idiosyncratic shocks). The regulatory intervention lowers aggregate output volatility as measured by the standard deviation by almost 10 percent and the relative volatility of investment by 14 percent. The relative volatility of consumption, by contrast, increases by 7 percent. These numbers are similar to those that arise in the representative agent economy thus indicating that macroprudential regulation appears to be as effective at stabilizing the economy against the financial accelerator as in the earlier literature.

However, this macro stabilization comes at a large cost in terms of micro volatility. The increase in the spread induced by the more restrictive regulatory framework induces a large increase in the sensitivity of household consumption to income shocks. Recall that households at the borrowing limit and at zero wealth have unit marginal propensities to consume. Because of income shocks and wealth mobility, households will move in and out of these high MPC states. Figure 11 Panel B shows the average MPC for each wealth decile in the baseline economy and in the economy with lower leverage.[14] The macroprudential regulation induces a large increase in the MPCs for a significant fraction of households. For the median wealth households, the MPC rises from approximately 5 percent to close to 25

[14] The MPCs are computed by examining the response of consumption to a one percent (of income) transfer across the wealth distribution.

	Baseline (A)	Low Leverage (B)	(B/A - 1)
Heterogeneity			
STD(Y) (%)	4.00	3.62	-9.5%
STD(C)/STD(Y)	0.98	1.05	7.1%
STD(I)/STD(Y)	3.18	2.74	-13.9%
No Heterogeneity			
STD(Y) (%)	3.79	3.57	-5.8%
STD(C)/STD(Y)	1.08	1.11	2.8%
STD(I)/STD(Y)	3.08	2.83	-8.1%

1) We report standard deviations of aggregate variables as $100 * \log(X/X^{SS})$ in response to TFP, monetary, and capital quality shocks.
2) We target an output volatility of 4%, which corresponds to the volatility of US real output per capita (1954-2015) (after taking logs and controlling for a linear trend). We adjust the standard deviation of the CQ shock to 0.5% to hit this target.

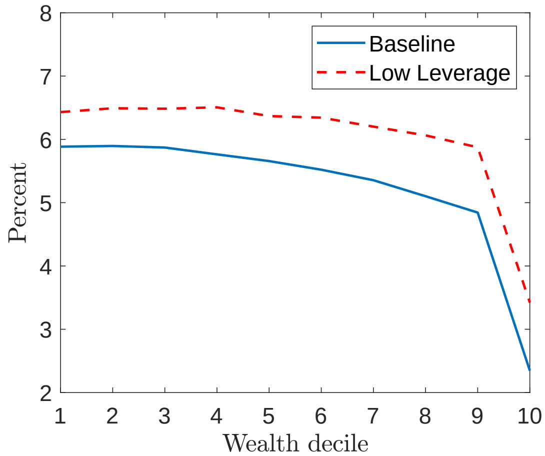
Table 4: Volatility of aggregate variables

percent.

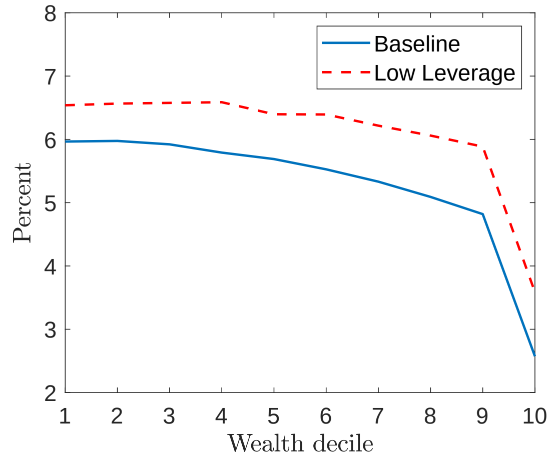
It follows from Figure 11 Panel B that a by-product of macroprudential regulation is to increase volatility at the micro level. Figure 13 shows the volatility of household consumption computed as the standard deviation of consumption over a 5 years horizon.[15] Panel A reports this measure in the absence of aggregate shocks while Panel B allows for aggregate shocks as well. Regardless of whether one allows for aggregate shocks or not, household consumption volatility increases sharply across the wealth distribution when banking sector leverage is lower. The irrelevance of aggregate shocks for this picture derives from the much higher variance of idiosyncratic income shocks than aggregate shocks. Quantitatively, the increase in consumption volatility is very large with the mean household experiencing a 10 percent increase in household consumption volatility, with even larger increases for wealthier households.

Welfare: Given these results, we then ask whether macroprudential regulation is beneficial for welfare or not. We compare the welfare across quintiles of the wealth distribution for the baseline calibration and for the economy in which banking sector leverage is lowered by 25 percent. To capture the effects of aggregate volatility on welfare we solve the model by second order perturbation. We do not take into account transitional costs but it so turns out that this is not so relevant for our analysis because of the moderate impact on the aggregate

[15]The figure shows the average standard deviation of quarterly growth rates of household consumption for a simulation of length five years computed over 100.000 individuals and then averaged over wealth deciles.



A) Only idiosyncratic shocks



B) Aggregate and idiosyncratic shocks

Notes: Volatility refers to the average standard deviation of quarterly growth rates of household consumption for a simulation of length five years computed over 100.000 individuals.

Figure 13: Micro consumption volatility by wealth deciles

capital stock that we discussed above.

We report the results in Table 5 that shows the welfare gains/losses for households across the wealth distribution from moving to a world with less leverage. We report the results both with and without aggregate shocks. In the absence of aggregate shocks, the average welfare loss is 1.1% of life-time consumption. All households prefer the steady state with higher leverage because it implies a lower lending rate and a higher saving rate. The welfare losses are largest for households in the top 20% of the wealth distribution because of the lower return on their savings. With aggregate shocks, the average welfare loss is 1.4% of life-time consumption. The difference between the regime with low and high leverage hence becomes even larger in the presence of aggregate shocks. While low leverage reduces the volatility of aggregate output, the relative volatility of aggregate consumption increases and the absolute volatility of consumption for some households increases as well.

For poor households, macroprudential regulation requires a trade-off: Higher costs of borrowing vs. less aggregate volatility. It turns out that in our calibration, poor households prefer less regulation. The benefit of lower output volatility does not translate into lower consumption volatility, because the fraction of households with high marginal propensities to consume increases markedly, see Figure 11 Panel B. Hence, consumption responds more to aggregate and idiosyncratic shocks for the majority of households.

The reason why we find welfare costs of macroprudential regulation is that it increases the interest rate spread which exaggerates the kink in the budget constraint and hinders households' ability to smooth out adverse shocks. Thus, the policy involves a trade-off between

	Consumption Equivalent Variation	
	only idiosyncratic shocks	aggregate and idiosyncratic shocks
1. Wealth quintile	0.53%	0.82%
2. Wealth quintile	0.56%	0.71%
3. Wealth quintile	0.62%	0.74%
4. Wealth quintile	0.78%	0.96%
5. Wealth quintile	3.15%	3.88%
Aggregate	1.10%	1.39%

We report the fraction of life-time consumption that households are willing to give up to stay in the baseline economy relative to a counterfactual economy with 25% less leverage.

Table 5: Welfare costs of macroprudential regulation

stabilizing the aggregate economy but destabilizing at the household level. Credit policy based stabilization does not involve such a trade-off and therefore appears more palatable.

5 Conclusion

In this paper we have considered the impact of frictional financial intermediation in a HANK setting. Heterogeneity between households implies that banks intermediate not only between the household sector and the corporate sector, as in most analyses of financial intermediation, but also between different types of households some of whom are savers others borrowers. We adopted commonly used arguments for incentive problems in the banking sector that induce an inverse relationship between banking sector net worth and the spread between the interest earned on the banks' assets (corporate investments and household loans) and liabilities (household deposits).

The spread between the return on household savings and the interest on household debt affect the long-run wealth distribution. This happens primarily through the spread generating a mass point in the wealth distribution at zero wealth. Thus, financial sector efficiency has long-run implications beyond those emphasized in the representative agent literature, which mostly relate to aggregate investment.

We have derived three major results. First, with household heterogeneity, the financial accelerator works through consumption and tends to be larger than in representative agent settings. This result derives from countercyclical movements in the savings-lending interest rate spread that induces differential consumption responses of households with positive and negative net assets. Contractionary shocks harm indebted households not only because of lower income but also because the interest rate on their debt increases. Furthermore, higher spreads exaggerate the mass point in the wealth distribution of households that have large marginal propensities to consume. In combination, these forces introduce a key role for consumption in the adjustment of the economy to shocks.

Secondly, credit policy – central bank purchases of assets when the interest rate spread rises – is shown to be a very effective tool for stabilizing the financial accelerator. Such a policy stabilizes the countercyclical movements in the spread and removes the amplification of shocks that derive from the consumption adjustments. Indeed, we find that such a policy is much more effective in the heterogeneous agents economy than in the representative agent economies usually focused upon in the financial intermediation literature.

Third, we show that macroprudential regulation has very different effects than usually emphasized in the literature. We consider regulation of banking sector leverage with the aim of muting the financial accelerator. The standard trade-off considered from such regulation is that it comes at the cost of lower average activity. This does not necessarily happen in the incomplete markets setting because savings respond to the policy. Indeed, we find little impact on aggregate output. Instead, the cost of this regulation is that it hampers households' ability to smooth out idiosyncratic risk (because of the rising interest rate spread). We find that this induces significant welfare costs.

Our work suggests several promising avenues for future research. First, we introduce a wedge between the return on household debt and corporate investments by assuming a simple resource cost of issuing household loans. It would be interesting to consider the implications of household default risk as a source of this spread. It would also be interesting to examine long-term debt such as mortgage contracts. The short term pass-through to mortgage rates from policy rates may be smaller especially because mortgages often are issued with fixed rates. On the other hand, due to household leverage, the mechanisms that we have described may be even stronger in such a setting.

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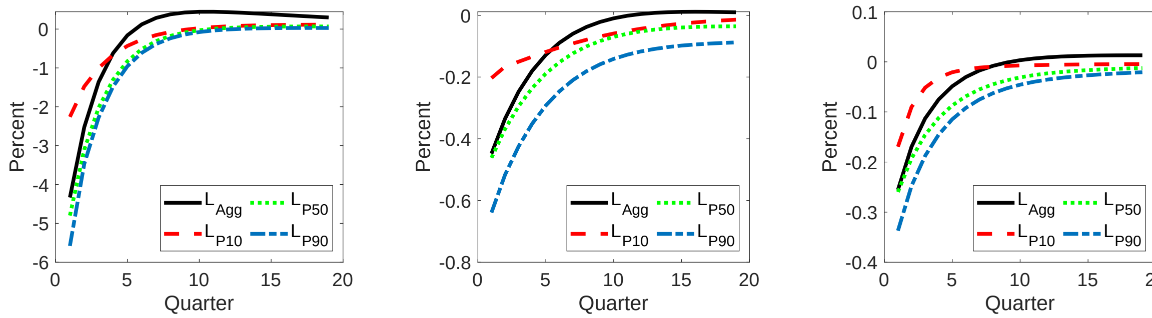
A Further Impulse Responses

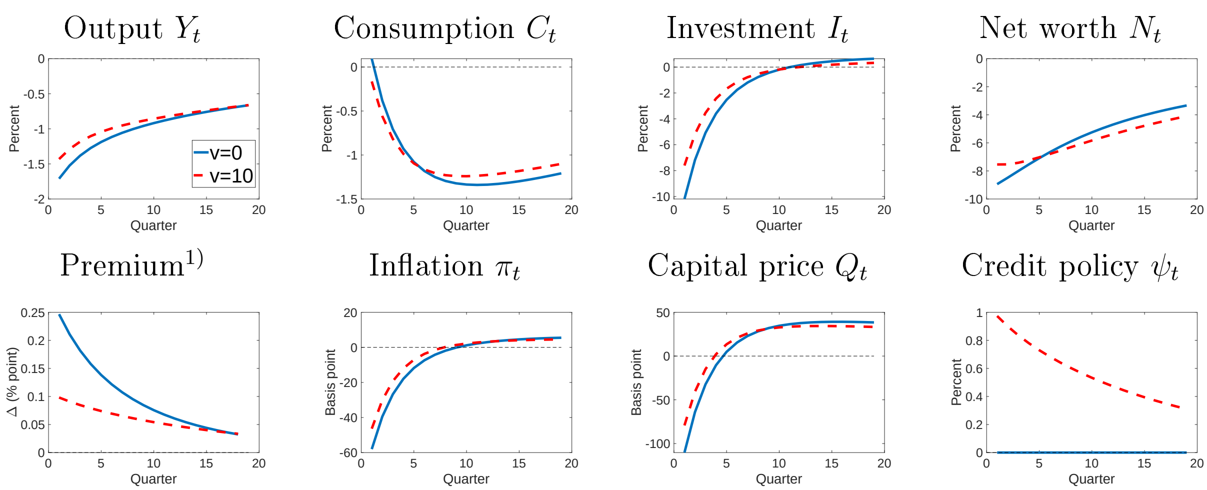
Figure 14 reports the labor supply response of households at the 10th, 50th, and 90th percentile of the wealth distribution.



(a) Capital quality shock (b) TFP shock (c) Monetary shock

Figure 14: Labor supply responses by percentiles

Figure 15 reports the aggregate effects of credit policy in response to a capital quality shock for the economy without household heterogeneity.



1) $E_t(R_{K,t+1} - R_{S,t+1})$.

Figure 15: Aggregate effects of credit policy without household heterogeneity

B Alternative Models of the Lending Rate

We consider two alternative formulations of the borrowing penalty that applies to household borrowing. We consider 1) an additive penalty that does not depend on the banking premium, and 2) the case of a penalty that is proportional to the banking premium. Our results are qualitatively robust and amplified in the latter case.

B.1 Additive Borrowing Penalty

In this section, we assume that borrowing penalty is constant and added return on capital.[16] This means, we specify:

$$\mathbf{R}\left(b_{it}, R_{S,t}, R_{K,t}\right) = \begin{cases} R_{S,t} & \text{if} \quad b_{it} = b_{D,it} + b_{G,it} \geq 0 \\ R_{K,t} + A & \text{if} \quad b_{it} = b_{L,it} < 0 \end{cases} \tag{B.1}$$

Table 6 presents the steady state distributions and interest rates for the baseline calibration and the low leverage calibration. We choose A such that we have the same lending rate as in the baseline model and hence the baseline steady state is unchanged. The low leverage steady state and its impact on consumption volatility are almost identical to the main text, see Figure 16 and 17.

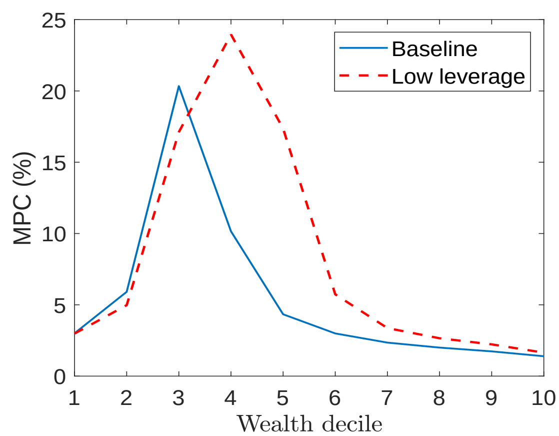


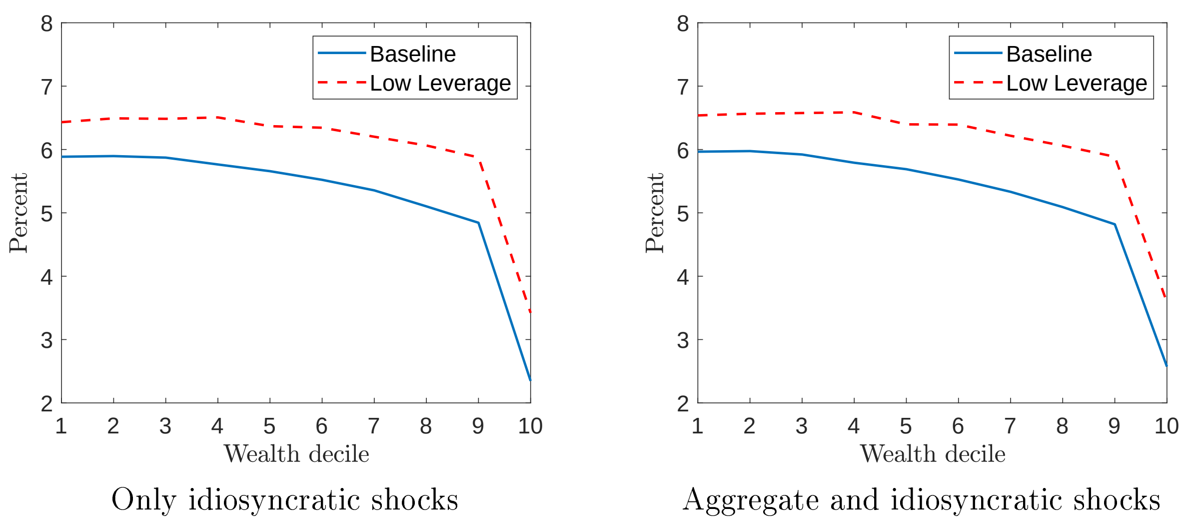
Figure 16: MPC by wealth decile and leverage

[16]We assume that this cost is wasted, thus, banks obtain the same lending interest rate $R_{K,t}$ from both firms and borrowing households.

	Baseline	Low Leverage	
		Additive penalty	Proportional penalty
Leverage	3.47	2.60	2.60
		Interest rates	
Return on capital (R_K, %)	1.14	1.17	1.17
Return on savings (R_S, %)	0.75	0.47	0.47
Lending interest rate (R_L, %)	2.69	2.73	3.97
		Aggregates	
Output	1.120	1.125	1.120
Capital	11.20	11.11	11.07
Labor	0.360	0.364	0.362
Consumption	0.738	0.733	0.734
		Household distribution	
At kink (%)	8.9	16.9	43.2
Borrowers (%)	24.3	30.9	0.8
Gini Wealth	0.921	0.961	0.940
Gini Consumption	0.259	0.273	0.269
Gini Income	0.320	0.325	0.321

Notes: We compare the baseline steady state to one with low leverage (a high divertibility parameter $\lambda = 0.558$).

Table 6: Steady state: Baseline and low leverage with additive penalty



Notes: Volatility refers to the average standard deviation of quarterly growth rates of household consumption for a simulation of length five years computed over 100.000 individuals.

Figure 17: Micro consumption volatility by wealth deciles

B.2 Borrowing Penalty Proportional to Spread

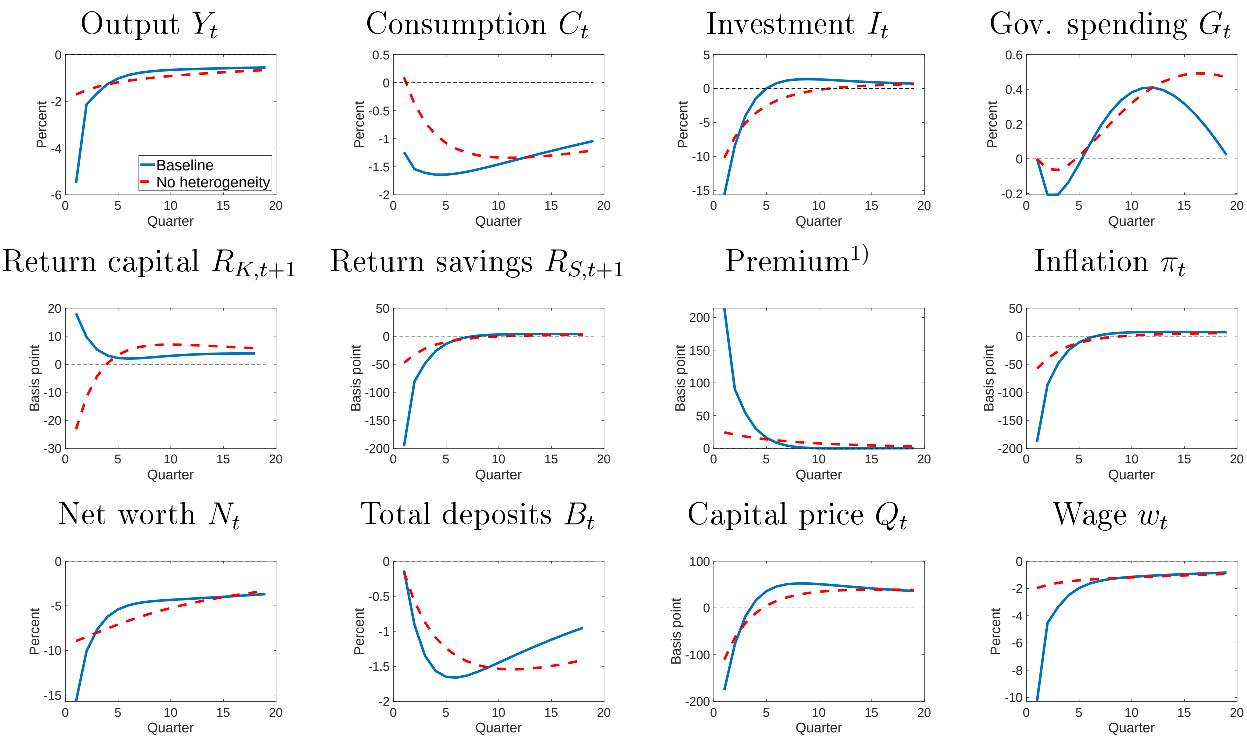
In this section, we assume that the borrowing penalty is proportional to the premium charged by banks, which is the difference between the interest rates on deposits and capital.[17] This means, we specify:

$$\mathbf{R}\left(b_{it}, R_{S,t}, R_{K,t}\right) = \begin{cases} R_{S,t} & \text{if} \quad b_{it} = b_{D,it} + b_{G,it} \geq 0 \\ A(R_{K,t} - R_{S,t}) & \text{if} \quad b_{it} = b_{L,it} < 0 \end{cases} \tag{B.2}$$

This formulation captures the idea that the marginal cost of issuing consumer loans might increase with lower leverage. Now, the lending rate responds substantially more to aggregate shocks. As a result, the output response to a capital quality shock almost doubles, see Figure 18. This is driven by a stronger fall in consumption. Aggregate consumption falls by 1.5 percent, and consumption of borrowers falls by 15 percent, see Figure 19 panel A. Looking at the decomposition of aggregate consumption in Figure 19 panel B, the lending rate now explains a sizable fraction of the fall of aggregate consumption. Hence, our results on the transmission mechanism are even stronger.

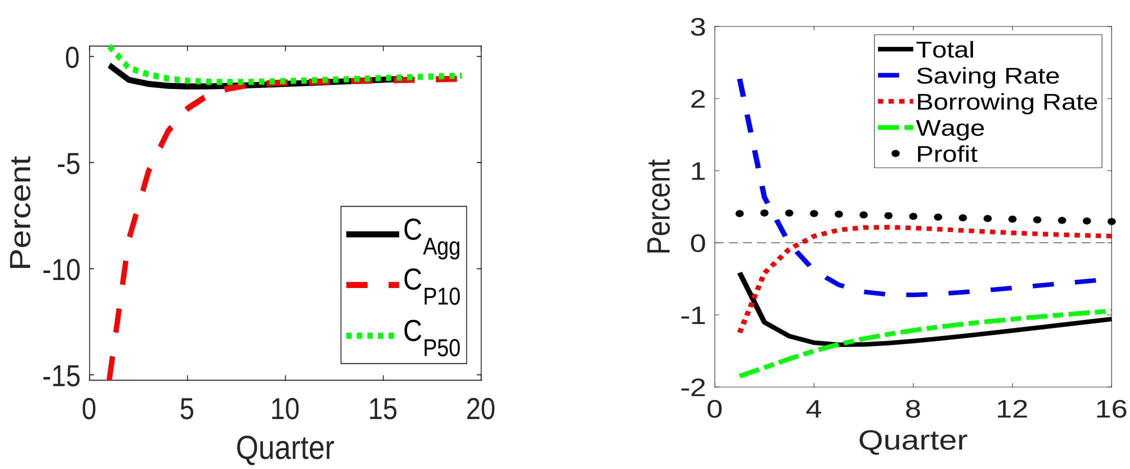
When it comes to macroprudential regulation, a reduction of 25 percent in leverage increases the spread between the interest rates on savings and debt by 616 basis points (annualized), see Table 6. This leads to a sizable increase in marginal propensities to consume, see Figure 20. The volatility of consumption, therefore, increases substantially more across steady states, see Figure 21. However, for poor households, the volatility of consumption with aggregate shocks is lower with low leverage. Aggregate stabilization is more important here because of the strong incidence of aggregate shocks on borrowers.

[17] We assume that this cost is wasted, thus, banks obtain the same lending interest rate R_t^k from both firms and borrowing households.



1) $E_t(R_{L,t+1} - R_{S,t+1})$ in Baseline and $E_t(R_{K,t+1} - R_{S,t+1})$ with No heterogeneity.

Figure 18: Aggregate effects of a capital quality shock



A) Consumption responses by wealth B) Decomposition of aggregate consumption

Figure 19: Transmission to consumption: Capital quality shock

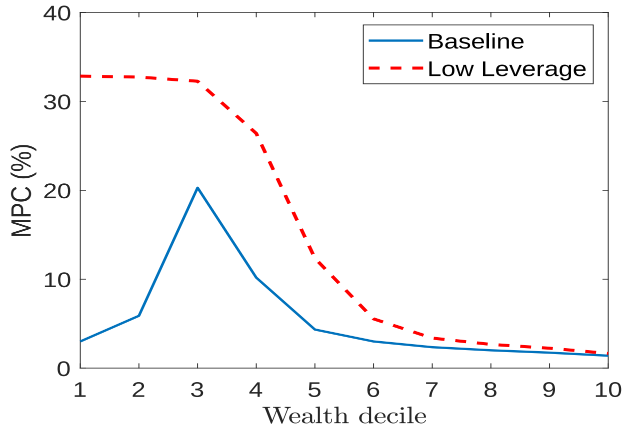
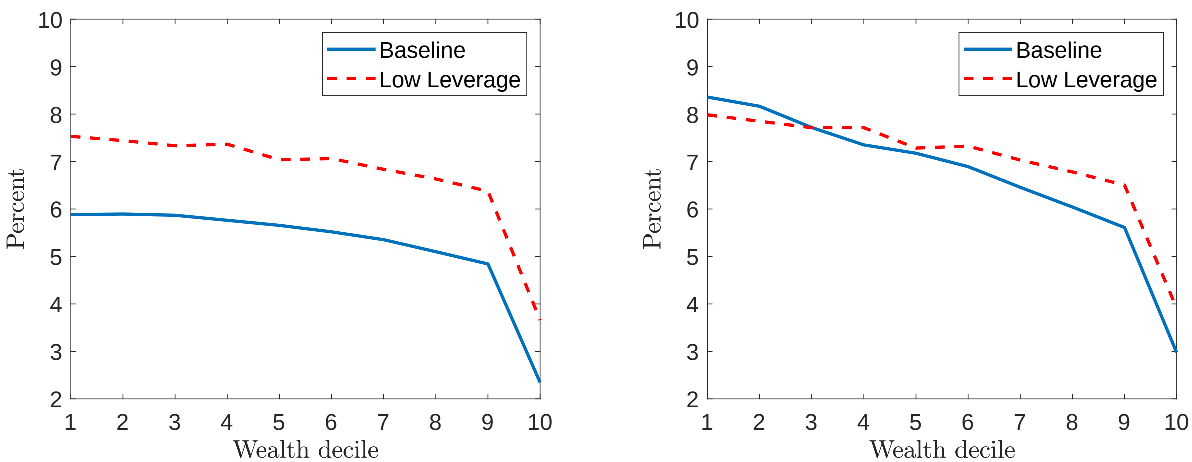


Figure 20: MPC by wealth decile and leverage



Only idiosyncratic shocks   Aggregate and idiosyncratic shocks

Notes: Volatility refers to the average standard deviation of quarterly growth rates of household consumption for a simulation of length five years computed over 100.000 individuals.

Figure 21: Micro consumption volatility by wealth deciles