Financial Frictions: Micro vs Macro Volatility[*]

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Abstract

We introduce frictional financial intermediation into a HANK model. Households are subject to idiosyncratic and aggregate risk and smooth consumption through savings and consumer loans intermediated by banks. The banking friction introduces an endogenous countercyclical spread between the interest rate on savings and on loans. This interacts with incomplete markets because borrowers and savers face different intertemporal prices, and induces a time-varying mass point of high MPC households. Aggregate shocks through their impact on the spread give rise to consumption inequality. We show this mechanism to be empirically relevant. Ex-ante macro prudential regulation reduces welfare by reducing consumption smoothing.

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1 Introduction

In this paper we study the impact of frictional financial intermediation in an incomplete markets model with aggregate and idiosyncratic risk. The aim of our analysis is to understand how financial intermediation impacts on aggregate outcomes *and* its distributional consequences. For this purpose, we formulate a heterogeneous agents New Keynesian (HANK) model in which the financial sector provides not only funds for corporate sector investments, but also consumer loans. We show that frictions in intermediation, on top of introducing a financial accelerator mechanism, have first-order consequences for welfare that derive from limiting households' ability to insure themselves against idiosyncratic risk.

A key channel through which frictional financial intermediation impacts on the economy is the spread between the return on savings offered to agents with excess liquidity and the price of debt faced by borrowers. Much of the macroeconomic literature on financial frictions has focused on the spread between the return on corporate debt and government debt. This spread is countercyclical which introduces an amplification mechanism in standard representative agent models. In a heterogeneous agents setting in which financial institutions also provide consumer loans, the spread between the return on savings and the price of consumer debt also matters because it influences households' ability to self-insure against shocks and implies that common shocks impact differentially on households depending on their net asset positions.

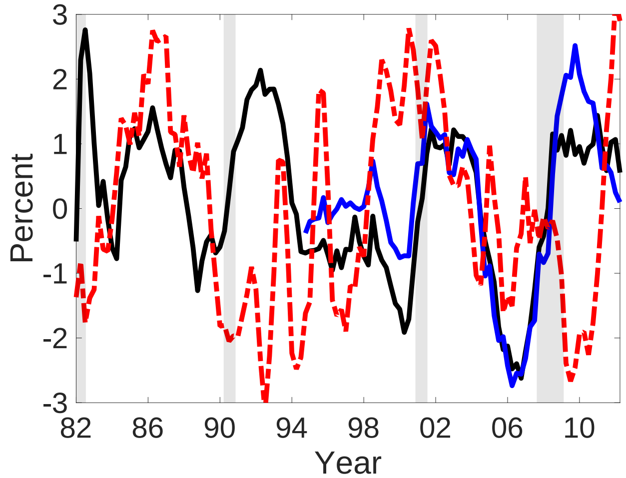
Therefore, to fully understand the macroeconomic consequences of frictional intermediation, it is important to study a setting in which the financial sector simultaneously intermediates between the household sector and the corporate sector *and* between different segments of the household sector. We accomplish this by introducing frictional financial intermediation in the fashion of Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) into a HANK model. Households supply labor and face uninsurable idiosyncratic labor income risk. They can smooth consumption through self-insurance by saving in bank deposits, or borrowing by taking out consumer loans from banks. Consumer credit, however, comes at an interest rate premium relative to the return offered to households who make bank deposits. We will refer to this premium as the consumer loan spread. Consumption goods are purchased from competitive retailers who bundle a differentiated good supplied by monopolistically competitive firms that face nominal rigidities. The monopolistic producers differentiate an intermediate good produced by competitive firms which hire labor from households and purchase capital from competitive capital producers. Capital acquisitions are financed by issuing equity which is purchased by the financial intermediaries. These intermediaries combine bank deposits with their net worth and invest in consumer loans and corporate equity. An agency cost constrains banking sector leverage thereby relating total investments in consumer loans and corporate equity to banking sector net worth. Finally, the government sector is in charge of fiscal policy and monetary policy.

Frictional intermediation introduces endogenous and time-varying interest rate spreads because of the agency problem. As in standard representative agent models, the spread between the return on corporate equity investment and the savings rate induces a financial accelerator through which shocks to the economy are amplified. However, in addition, in our set-up the agency problems also induces countercyclical movements in the consumer loan spread. This spread directly affects households' ability to smooth their consumption streams: First, by inducing a kink in households' budget sets at zero liquid wealth which gives rise to a time-varying mass point in the household wealth distribution, and second, by inducing different intertemporal trade-offs faced by borrowers and savers. Both of these aspects have consequences for the macroeconomic and distributional impact of aggregate shocks. The kink in the budget set limits the ability of households with near-zero liquid wealth to smooth their consumption inducing large marginal propensities to consume of this subset of the households. Moreover, changes in the spread impacts borrowers and savers potentially very differently both because of differences in their net asset position but also because borrowing and savings rates may move in different directions in response to changes in the spread, which affects consumption dispersion via income and substitution effects.

In order to evaluate the quantitative significance of these channels, we carefully calibrate the model to targets of the U.S. wealth distribution including the share of households with limited liquid assets and the size of the stock of consumer debt, as well as standard targets. We solve the model numerically by first and second order perturbation and examine its implications for the transmission mechanism, for the distributional effects of shocks to the economy as well as the potential for stabilization policy implemented through macro prudential instruments.

We show that the HANK cum Banks model can account for a number of empirical regularities and has important positive and normative implications. First, interest rate spreads are countercyclical in the U.S. data and in the model. Countercyclicality of the corporate debt to T-bill spread is well-known, see e.g. Gilchrist and Zakrajsek (2012). Figure 1 illustrates instead the spreads between the personal loan rate or the credit card rate minus the three months T-Bill rate (both detrended). Both measures of interest rate spreads display clear countercyclical movements increasing in NBER recessions and generally declining during expansions. Our model reproduces such countercyclical movements in the consumer loan spread due to the financial friction embedded in the model.

Secondly, consumer credit is volatile and procyclical in the U.S. data. These are moments that have attracted surprisingly little attention in the literature. A notable exception is Nakajima and Rios-Rull (2019) who construct an incomplete markets model with aggregate shocks. They model consumer credit as defaultable debt and introduce many realistic features of the U.S. legal system including bankruptcy. They show that their model is consistent with procyclical consumer debt but not with its high volatility. Our model abstracts from issues related to default and stresses the banking friction instead. We find that it is consistent with both procyclicality and high volatility of



Notes: The figure illustrates the personal loan rate - 3 months T-Bill rate spread in black, the credit card rate - 3 months T-bill rate spread in blue, and the ratio of median consumption to the 10th percentile consumption in red. All data have been logged and detrended with a fourth order time polynomial. Consumption dispersion has also been de-seasonalized using 3 quarterly dummies and smoothed with a centred MA(3). Grey areas are NBER recessions.

Figure 1: Consumer loan spread and consumption dispersion

consumer debt due to the interaction of frictional financial intermediation and incomplete markets.

Third, the HANK model preserves the financial accelerator present in representative agent models that amplifies the impact of aggregate shocks. The main channel through which amplification occurs is the countercyclical movements in spreads which induce strong corporate investment procyclicality relative to models without financial intermediation. In principle, the impact on consumption dispersion can have consequences for the financial accelerator. Our quantitative experiments indicate some but not very large impact through aggregate consumption volatility.

Fourth, the model predicts that cross-sectional consumption inequality is positively related to the consumer loan spread. This features derives from the differential impact on borrowers and savers induced by changes in the consumer loan spread, as well as the impact of the spread on the mass point of high MPC households. Through this channel, the model induces considerable impact of aggregate shocks on inequality as measured by consumption dispersion across the wealth distribution. Figure 1 illustrates this link by plotting a measure of consumption dispersion, the ratio of median household consumption to the 10th percentile consumption from the Consumer Expenditure Survey (the CEX). Visually, there is a relationship between spreads and inequality although consumption dispersion appears to somewhat lag movements in spreads. We provide formal empirical evidence in favor of the link between consumption dispersion and consumer loan spreads using local projection regressions both in terms of the bivariate relationship and conditional on the impact of identified shocks.

Fifth, the HANK model has stark implications for the welfare effects of macro prudential policies.

In particular, we show that bank capital requirements have little long run output costs, a result that contrasts with representative agent models, stabilize the impact of aggregate shocks by muting the financial accelerator, but have significant welfare costs across the entire wealth distribution. The latter result derives from capital requirements increasing the consumer loan spread which harms wealth-poor households' ability to smooth consumption, in addition to the regulation inducing lower return on savings which harms wealth-rich households. We also consider the extent to which cyclical capital requirements can be used for stabilization policy. We find small, but positive, welfare gains for all but the wealthiest households. The potential welfare gains, however, are sufficiently small that any costs of implementing the policy and ex-ante moral hazard on the part of banks could outweigh easily these.

Our paper contributes to the literature on financial frictions, see e.g. Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), Christiano, Motta and Rostagno (2014), Gertler and Karadi (2011) or Gertler and Kiyotaki (2010). We add to this literature incomplete markets and heterogeneous agents which we show have important implications. Moreover, we model banks that intermediate simultaneously both between the corporate sector and between different segments in the household sector while the extant literature has focused upon one of the roles in isolation.

We also contribute to the literature on unsecured consumer credit, see e.g. Athreya (2002), Chatterjee et al (2007), or Nakajima and Rios-Rull (2019). This literature has focused mainly on the impact of consumer default risk while we focus on the implications of the agency problem in the financial sector as in Curdia and Woodford (2011). Our analysis adds to this literature insights into the determinants of the consumer loan rate spread that do not derive from default risk, movements that Dempsey and Ionescu (2021) argue are empirically important for understanding much of the time-variation in the spread faced by a large fraction of borrowers.

Relative to the fast-growing HANK literature, c.f. Bayer et al (2019), Kaplan, Moll and Violante (2018), McKay and Reis (2016), Ravn and Sterk (2017), the paper introduces financial intermediation thereby stressing another aspect of financial frictions on top of the lack of insurance against idiosyncratic risk assumed in this literature. We show that this has important consequences both because it generates a financial accelerator mechanism and because there are ramifications for the distributional impact of aggregate shocks. Fernandez-Villaverde, Hurtado and Nuno (2020) also introduce frictional financial intermediation into a heterogeneous agents framework but focus on a very different question (the impact on aggregate risk), and study a setting which abstracts from goods markets frictions and from household debt.[1]

Finally, by the introduction of incomplete markets and idiosyncratic risk, our analysis adds new insights into the impact of financial regulation, c.f. Bianchi and Mendoza (2010), Farhi and

[1] Wang (2018) studies a model of frictional financial intermediation and household heterogeneity where the latter derives solely from life-cycle issues.

Werning (2016), Lorenzoni (2008), or Stein (2012). Our contribution to this literature lies in the introduction of heterogeneous agents and idiosyncratic risk which adds a new perspective on the impact of regulatory policies which we argue is important for understanding their consequences.

The remainder of the paper is organized as follows. In Section 2 we present the model. Section 3 discusses the calibration. Section 4 examines the implications for the transmission of aggregate shocks and business cycle properties. In Section 5 we examine the link between consumption dispersion and interest rate spreads. In Section 6 we look at macro prudential regulation and stabilization policy. Finally, Section 7 summarizes and concludes.

2 Model

We embed heterogeneous agents and idiosyncratic risk into the Gertler and Karadi (2011) model. Banks intermediate both between the household sector and the corporate sector and between borrowers and savers amongst households.

2.1 Households

There is a continuum of measure one of ex-ante identical households indexed by $i \in [0, 1]$. Households are infinitely lived and maximize the present expected value of their utility streams which depend on consumption, c_{it}, and hours worked, 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 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.

Households have intertemporally separable preferences and discount future utility at the rate $\beta \in (0, 1)$. The flow utility function is given as:

$$\mathbf{u}\left(c_{i,t}, l_{i,t}\right) = \frac{c_{i,t}^{1-\mu} - 1}{1-\mu} - \frac{\chi}{1+1/\gamma} l_{i,t}^{1+1/\gamma} \tag{1}$$

where $1/\mu \geq 0$ is the intertemporal elasticity of consumption, $\gamma \geq 0$ is the Frisch elasticity of labor supply and $\chi > 0$ is a preference weight.

Workers are subject to stochastic idiosyncratic shocks to labor productivity. Supplying one unit of time as labor is compensated at the rate $w_t h_{i,t}$ where w_t denotes the wage per efficiency unit of labor and $h_{i,t}$ is the household's productivity level. The law of motion of $h_{i,t}$ is given as:

$$h_{i,t} = \begin{cases} \exp\left(\rho_h \log h_{i,t-1} + \varepsilon_{i,t}^h\right) & \text{with probability } 1-\zeta \quad \text{if } h_{i,t-1} \neq 0 \\ 1 & \text{with probability } \iota \quad \text{if } h_{i,t-1} = 0 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where $\rho_h \in (-1, 1)$ and $\varepsilon_{i,t}^h \sim n.i.d\left(0, \sigma_h^2\right)$. $\zeta \in (0, 1)$ is the probability that a worker becomes a rentier and $\iota \in (0, 1)$ is the probability that a rentier becomes a worker. The share of rentiers amongst households is therefore $\zeta/(\zeta+\iota)$. We impose that rentiers leave the labor market and assume that a rentier who returns to the labor market starts her working life with the unconditional mean productivity level.

Households can save in two assets, riskless government bonds, $b^G_{i,t+1}$, bank deposits, $b^D_{i,t+1}$, and have access unsecured consumer credit, $b^L_{i,t+1}$. Households cannot go short on government debt and on bank deposits, and face a borrowing constraint on unsecured credit:

$$b^L_{i,t+1} \geq \underline{\mathbf{b}} \tag{3}$$

$$b^G_{i,t+1}, b^D_{i,t+1} \geq 0 \tag{4}$$

where $\underline{\mathbf{b}}$ is tighter than the natural borrowing limit. The interest rate schedule associated with these assets is given by:

$$\mathbf{R}(b_{i,t}, R_{S,t}, R_{L,t}) = \begin{cases} R_{S,t} & \text{if} \quad b_{i,t} = b^G_{i,t} + b^D_{i,t} \geq 0 \\ R_{L,t} & \text{if} \quad b_{i,t} = b^L_{i,t} < 0 \end{cases} \tag{5}$$

Government bonds and bank deposits are perfect substitutes and therefore must have the same real return $R_{S,t} = R^N_{S,t}/\pi_t$, where $R^N_{S,t}$ is the gross nominal interest rate and π_t is the gross inflation rate (denominated in the consumption good). Households taking out a consumer loan pay the real interest rate $R_{L,t}$ charged by the banks. Due to the banking frictions discussed below, consumer loans come with an interest rate premium relative to government bonds and bank deposits, $R_{L,t} \geq R_{S,t}$. Given absence of adjustment frictions, households will choose either to hold bank deposits and government loans, or consumer debt only.[2]

Let $\mathbb{E}_t x_{t+s}$ denote the mathematical expectation as of date t of x_{t+s}, $s \geq 0$, conditional on all information available at date t. A worker's intertemporal problem is then:

$$\begin{aligned} \mathbf{V}^w_i(b_{i,t}, h_{i,t}, S_t) &= \max[\mathbf{u}(c_{i,t}, l_{i,t}) \\ &\quad + \beta \mathbb{E}_t\left((1-\zeta)\mathbf{V}^w_i(b_{i,t+1}, h_{i,t+1}, S_{t+1}) + \zeta \mathbf{V}^r_i(b_{i,t+1}, S_{t+1})\right)] \end{aligned} \tag{6}$$

subject to (3)-(4) and to the flow budget constraint:

$$c_{i,t} + b_{i,t+1} \leq (1-\tau_{h,t}) w_t h_{i,t} l_{i,t} + \mathbf{R}(b_{i,t}, R_{S,t}, R_{L,t}) b_{it} \tag{7}$$

$\tau_{h,t}$ is a proportional income tax rate and S_t is a vector of aggregate state variables. $\mathbf{V}^r_i$ is rentiers' value function which is the solution to:

$$\begin{aligned} \mathbf{V}^r_i(b_{i,t}, S_t) &= \max[\mathbf{u}(c_{i,t}, l_{i,t}) \\ &\quad + \beta \mathbb{E}_t\left((1-\iota)\mathbf{V}^r_i(b_{i,t+1}, S_{t+1}) + \iota \mathbf{V}^w_i(b_{i,t+1}, 1, S_{t+1})\right)] \end{aligned} \tag{8}$$

subject to (3)-(4) and to the flow budget constraint:

$$c_{i,t} + b_{i,t+1} \leq (1-\tau_{h,t}) \mathcal{F}_t + \mathbf{R}(b_{i,t}, R_{S,t}, R_{L,t}) b_{it} \tag{9}$$

[2] When the spread is zero, the three assets are perfect substitutes. In equilibrium, the spread is strictly positive so this case does not arise.

where $\mathcal{F}_t$ is the profit stream at date t enjoyed by the rentiers.

The consumer loan spread is time-varying and endogenously determined through the banking problem characterized below. When the spread is strictly positive, households split into four types. The first are households at the borrowing constraint. The second type are households with zero wealth who are at a kink in the budget set. The consumption levels of these two types of households (assuming they are workers) are given by:

$$c_{i,t}^{k} = (1-\tau_{h,t})\, w_t h_{i,t} l_{i,t} + \mathbf{R}\left(b_{i,t}, R_{S,t}, R_{L,t}\right) b_{it} \tag{10}$$

$$c_{i,t}^{bc} = (1-\tau_{h,t})\, w_t h_{i,t} l_{i,t} + \mathbf{R}\left(b_{i,t}, R_{S,t}, R_{L,t}\right) b_{it} + \underline{\mathbf{b}} \tag{11}$$

where $c_{i,t}^{k}$ denotes consumption for households with zero wealth (for whom $b_{it} = 0$ if they were at the kink in the budget set last period) and $c_{i,t}^{bc}$ is consumption for households at the borrowing constraint (for whom $b_{it} = -\underline{\mathbf{b}}$ if they were at the borrowing constraint last period too). Each of these two types will have unit marginal propensities to consume as long as they remain their respective type. The contribution of $c_{i,t}^{k}$ to aggregate consumption volatility will tend to dominate that of $c_{i,t}^{bc}$ both because those at the kink are wealthier than those at borrowing constraint and because, when the interest rate spread is sufficiently large, the mass point at zero wealth will dominate relative to the share of households at the borrowing constraint.

The other two types of households are on their Euler equations and are either unconstrained savers or borrowers (indicated by 'sa' and 'bo', respectively). Abstracting from transitions between the rentier state and the worker state, their intertemporal consumption allocations satisfy the Euler equations:

$$\left(c_{i,t}^{sa}\right)^{-\mu} = \beta \mathbb{E}_t R_{S,t+1} \left(c_{i,t+1}^{sa}\right)^{-\mu} \tag{12}$$

$$\left(c_{i,t}^{bo}\right)^{-\mu} = \beta \mathbb{E}_t R_{L,t+1} \left(c_{i,t+1}^{bo}\right)^{-\mu} \tag{13}$$

Whenever $R_{S,t+1} < R_{L,t+1}$, the expected consumption growth of the borrowers exceeds that of savers. Variations in the interest rate spread will therefore affect borrowers' and savers' consumption choices differently, and impacts on the share of households with zero wealth.

2.2 Banks

There is a continuum of banks indexed by $z \in [0, Z]$. Banks are owned by rentiers who delegate management to risk neutral bankers. Bankers discount future utility at the rate β and face mortality risk $1 - \theta \in (0, 1)$. When a banker dies, their net worth is transferred to the rentiers and a new banker enters the economy with a start-up fund provided by the rentiers.

Banks intermediate between the household sector and the corporate sector. Bankers invest in corporate sector equity and in consumer credit financed by household deposits and net worth. We focus upon the variations in interest rate spreads that derive from financial intermediation and abstract from default risk associated with lending to firms and to the household sector.[3] As in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), bankers' ability to leverage their positions is limited by an agency problem. Bankers can divert a fraction $\lambda \in (0, 1)$ of the bank's assets in which case depositors declare the bank bankrupt, recover the remaining fraction $1 - \lambda$ of assets, and terminate the bank. This agency problem leads the household sector to constrain the supply of deposits to the banks.

Let n_t^z denote bank z's net worth at the beginning of period t. At the beginning of the period, mortality risk is realized amongst the existing bankers and new bankers enter the economy. Banks then receive deposits $b_{D,t+1}^z$ from savers in the household sector. Next, banks invests their funds - the sum of deposits and net worth - in corporate equity $b_{F,t+1}^z$ at the price Q_t per unit and in consumer loans $b_{L,t+1}^z$. The balance sheet is given as:

$$Q_t b_{F,t+1}^z + b_{L,t+1}^z = n_t^z + b_{D,t+1}^z \tag{14}$$

The interest on deposits has to match the return on government bonds $R_{S,t+1}$ since the bank otherwise would receive no deposits. The return on equity is $R_{K,t+1}$. Since there is no default risk on neither equity nor consumer loans, the return to the *bank* of investing in the two assets both have to equal $R_{K,t+1}$. Banks, however, face costs of checking borrowers' credit situation which they pass on to the households. We assume that these costs are proportional to the size of the loans and given by $\varphi \geq 0$. Thus, the consumer credit rate faced by households is given as:

$$R_{L,t} = (1 + \varphi) R_{K,t} \tag{15}$$

The law of motion of bank z's net worth is then given as

$$n_{t+1}^z = (R_{K,t+1} - R_{S,t+1}) \left(Q_t b_{F,t+1}^z + b_{L,t+1}^z\right) + R_{S,t+1} n_t^z \tag{16}$$

We formulate the banks' problems recursively as in Bocola (2016). Let $\mathbf{V}^b (n_t^z, S_t)$ denote the value of bank z at date t. This value is given as:

$$\mathbf{V}^b (n_t^z, S_t) = \max \mathbb{E}_t \beta \left((1 - \theta) n_{t+1}^z + \theta V^b \left(n_{t+1}^z\right) \right) \tag{17}$$

subject to (16) and to:

$$\lambda a_t^z \leq \mathbf{V}^b (n_t^z, S_t) \tag{18}$$

where $a_t^z = \left(Q_t b_{F,t+1}^z + b_{D,t+1}^z\right)$ denotes the bank's assets. The constraint in (18) imposes that assets cannot exceed $\mathbf{V}^b/\lambda$ since bankers otherwise would choose to divert their assets.

[3] In line with our analysis, studying administrative data, Dempsey and Ionescu (2021) document large spreads in consumer loan rates that are not accounted for by default risk.

Given the linear structure of the problem, we make the guess:

$$\mathbf{V}^b\left(n_t^z, S_t\right) = \varrho_t n_t^z \tag{19}$$

This guess imposes that ϱ_t is independent of the bank identity, a property that is confirmed in the equilibrium below. Subject to this guess, the incentive constraint can be expressed as:

$$l_t^z = \frac{a_t^z}{n_t^z} \leq \frac{\varrho_t}{\lambda} \tag{20}$$

where l_t^z denotes bank z's leverage which, if the incentive constraint is binding, is equalized across banks when the independence of ϱ_t across banks' is confirmed. Using the guess, the first-order necessary conditions and the envelope conditions for the bank's profit maximization problem are given as:

$$\begin{aligned}
\mu_t^z \lambda &= \mathbb{E}_t[\beta\left((1-\theta)+\theta\varrho_{t+1}\right)\left(R_{K,t+1}-R_{S,t+1}\right) && (21)\\
0 &= \mu_t^z\left[\varrho_t n_t^z - \lambda a_t^z\right] && (22)\\
\varrho_t &= \mathbb{E}_t\beta\left((1-\theta)+\theta\varrho_{t+1}\right)R_{S,t+1}+\mu_t^z\varrho_t && (23)
\end{aligned}$$

where $\mu_t^z \geq 0$ is the Kuhn-Tucker multiplier on (18). Were the incentive constraint slack, returns on bank assets and the deposit rate would equalize, $R_{K,t+1} = R_{S,t+1}$, see (21), since the banks would invest in assets as long they deliver a higher return. When the incentive constraint binds, $\varrho_t n_t^z = \lambda a_t^z$, bank assets have higher return than deposits, $R_{K,t+1} > R_{S,t+1}$. The envelope condition implies that:

$$\varrho_t = \frac{\mathbb{E}_t\beta\left((1-\theta)+\theta\varrho_{t+1}\right)R_{S,t+1}}{1-\mu_t^z}$$

which requires that the Kuhn-Tucker multiplier on the incentive constraint to belong to the unit interval, $\mu_t^z \in [0,1)$. Using the incentive constraint, μ_t^z can then be expressed as:

$$\mu_t^z = \max\left(1-\frac{\mathbb{E}_t\beta\left((1-\theta)+\theta\varrho_{t+1}\right)R_{S,t+1}n_t^z}{\lambda a_t^z}, 0\right)$$

Subject to our guess, leverage is equalized across banks when the incentive constraint binds. Therefore, the Kuhn-Tucker multiplier is identical across banks and given as:

$$\mu_t = \max\left(1-\frac{\mathbb{E}_t\beta\left((1-\theta)+\theta\varrho_{t+1}\right)R_{S,t+1}N_t}{\lambda A_t}, 0\right) \tag{24}$$

where $N_t = \int n_t^z dz$, $A_t = \int a_t^z dz$. This also confirms the guess on the value function. Imposing that the incentive constraint binds, then gives us:

$$\begin{aligned}
\varrho_t &= \frac{\mathbb{E}_t\beta\left((1-\theta)+\theta\varrho_{t+1}\right)R_{S,t+1}}{1-\mathbb{E}_t[\beta\left((1-\theta)+\theta\varrho_{t+1}\right)\left(R_{K,t+1}-R_{S,t+1}\right)/\lambda} && (25)\\
l_t &= \frac{\varrho_t}{\lambda} = \frac{\mathbb{E}_t\beta\left((1-\theta)+\theta\varrho_{t+1}\right)R_{S,t+1}}{\lambda-\mathbb{E}_t[\beta\left((1-\theta)+\theta\varrho_{t+1}\right)\left(R_{K,t+1}-R_{S,t+1}\right)} && (26)
\end{aligned}$$

The equilibrium law of motion of an individual bank z's net worth is then:

$$n_{t+1}^{z} = \left(l_t R_{K,t+1} + (1 - l_t) R_{S,t+1}\right) n_t^{z} \tag{27}$$

Finally, assuming that rentiers endow new banks with the share $\omega/(1-\theta)$ of banking sector net worth, the law of motion for aggregate banking sector net worth is given as:

$$N_{t+1} = \theta\left(l_t R_{K,t+1} + (1 - l_t) R_{S,t+1}\right) N_t + \omega\left(Q_{t+1} B_{F,t} + B_{L,t}\right) \tag{28}$$

where $B_{F,t} = \int b_{F,t}^{z} dz$, $B_{L,t} = \int b_{L,t}^{z} dz$.

2.3 The Corporate Sector

There are four types of firms in the corporate sector: 1) Competitive retailers who produce a homogeneous final good that is used for consumption, government spending, and investment; 2) Monopolistically competitive goods producers which transform intermediate goods into differentiated goods and set prices subject to a nominal rigidity; 3) Competitive intermediate goods producers who produce their goods using inputs of capital and labor; 4) Capital producers which convert final goods into new capital.

We assume that whenever firms face intertemporal problems, the rentiers delegate management to a very small set of risk neutral managers which discount future payoffs at the rate β.[4] Managers are compensated by a share of the profits and do not participate in any asset market. 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.

2.4 Retailers

Retailers are competitive and purchase a continuum of differentiated goods, $y_{r,t}$, $r \in (0,1)$, from goods producers which they transform into a single homogeneous final good using a CES technology:

$$Y_t = \left(\int_0^1 y_{r,t}^{1-1/\eta} dj\right)^{1/(1-1/\eta)} \tag{29}$$

where Y_t denotes the quantity of the final good and $\eta > 1$ is the elasticity of substitution. The differentiated goods are purchased at the nominal prices $P_{r,t}^{F}$. Retailers' demand for the differentiated goods is then given as:

$$y_{r,t} = \left(\frac{P_{r,t}^{F}}{P_t}\right)^{-\eta} Y_t \tag{30}$$

where $P_t = \left(\int_0^1 \left(P_{r,t}^{F}\right)^{1-\eta} dh\right)^{1/(1-\eta)}$ is the price index of the final good.

[4]This assumption serves only to simplify the presentation. We solve the model by first-order perturbation in which case there is certainty equivalence making the assumption of risk neutrality is irrelevant.

Final goods are used for consumption, $C_t = \int_i c_{it} di$, government purchases, G_t, and investment, $I_{g,t}$ ($I_{g,t}$ denotes gross investment, the sum of net investment and depreciation replacement):

$$Y_t^n = C_t + G_t + I_{g,t} \tag{31}$$

where $Y_t^n = Y_t - Y_t^{ad}$ where Y_t^{ad} denotes various adjustment costs.

2.5 Good Producers

There is a continuum of mass one of identical monopolistically competitive goods producers. Firms purchase the homogeneous intermediate goods at price P_t^m and differentiate them. The goods producers set the price of their goods subject to a quadratic adjustment costs as in Rotemberg (1981).

The real profit flow (denominated in units of the consumption good) in period t is given as:

$$\upsilon_{h,t} = \left(\frac{P_{r,t}^F}{P_t} - \frac{P_t^m}{P_t} \right) y_{r,t} - \frac{\eta}{2\kappa_Y} \left(\log \left(\frac{P_{r,t}^F}{P_{r,t-1}^F} \right) \right)^2 Y_t \tag{32}$$

The first term on the right hand side is real revenue from sales, $\frac{p_{r,t}^F}{P_t} y_{r,t}$, less real cost of acquiring the intermediate goods, $\frac{P_t^m}{P_t} y_{r,t}$. The second term on the right hand side captures price adjustment costs where $\kappa_Y \geq 0$ parametrizes the extent of nominal rigidities with $\kappa_Y \to \infty$ denoting flexible prices. Let $\mathbf{V}_r^F \left(P_{r,t-1}^F, S_t \right)$ denote the expected present value of real profits of a producer that charged the nominal price $P_{r,t-1}^F$ last period. Goods producers intertemporal maximization problem is then:

$$\mathbf{V}_r^F \left(P_{r,t-1}^F, S_t \right) = \max_{P_{r,t}^F} \left(\upsilon_{r,t} + \beta \mathbb{E}_t \mathbf{V}_r^F \left(P_{r,t}^F, S_{t+1} \right) \right) \tag{33}$$

subject to (30). The first order condition and the envelope condition can be expressed as:

$$\left(1 - \eta \left(1 - \frac{P_t^m}{P_{r,t}^F} \right) \right) \frac{1}{P_t} y_{r,t} = \frac{\eta}{\kappa_Y} \frac{1}{P_{r,t}^F} \log \left(\frac{P_{r,t}^F}{P_{r,t-1}^F} \right) Y_t - \beta \mathbb{E}_t \frac{\partial \mathbf{V}_f^F \left(P_{r,t}^F, S_{t+1} \right)}{\partial P_{r,t}^F} \tag{34}$$

$$\frac{\partial \mathbf{V}_r^F \left(P_{r,t-1}^F, S_{t+1} \right)}{\partial P_{r,t-1}^F} = \frac{\eta}{\kappa_Y} \frac{1}{P_{r,t-1}^F} \log \left(\frac{P_{r,t}^F}{P_{r,t-1}^F} \right) Y_t \tag{35}$$

Combining these and imposing that goods producers choose the same price (i.e. focus on symmetric equilibria) implies that:

$$\log(\pi_t) = \beta \mathbb{E}_t \log(\pi_{t+1}) \frac{Y_{t+1}}{Y_t} + \kappa_Y \left(\frac{P_t^m}{P_t} - \frac{\eta - 1}{\eta} \right) \tag{36}$$

which links inflation to marginal costs as is standard in models with nominal price rigidities.

2.6 Capital Goods Producers

Capital goods producers purchase depreciated capital and refurbish it costlessly. They then produce new capital goods which they sell at the relative price Q_t (which they take for given) using inputs of final goods. Production of new investment goods is associated with adjustment costs.

Letting $I_{n,t}$ denote net investment. Capital producers net revenue in period t is given as:

$$\upsilon_t^K = (Q_t - 1)\, I_{n,t} - \frac{\phi}{2}\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)^2 (I_{n,t}+\psi) \tag{37}$$

where $\phi > 0$ parametrizes adjustment costs and $\psi \geq 0$ is a constant. Let $V^K(I_{n,t-1}, S_t)$ denote expected discounted profits for a capital producer that generated $I_{n,t-1}$ units of new capital goods last period. Capital producers solve the following dynamic problem:

$$V^K(I_{n,t-1}, S_t) = max_{I_{n,t}}\left(\upsilon_t^K + \beta\mathbb{E}_t V^K(I_{n,t}, S_{t+1})\right) \tag{38}$$

The first-order necessary condition and the envelope condition are given as:

$$(Q_t - 1) + \beta\mathbb{E}_t\frac{\partial V^K(I_{n,t}, S_{t+1})}{\partial I_{n,t}} = \phi\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right) + \frac{\phi}{2}\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)^2 \tag{39}$$

$$\frac{\partial V^K(I_{n,t-1}, S_t)}{\partial I_{n,t-1}} = \phi\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi} \tag{40}$$

Combining these gives us:

$$\begin{aligned} Q_t = 1 + \phi\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right) + \frac{\phi}{2}\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)^2 \\ -\beta\mathbb{E}_t\phi\left(\log\left(\frac{I_{n,t+1}+\psi}{I_{n,t}+\psi}\right)\right)\frac{I_{n,t+1}+\psi}{I_{n,t}+\psi} \end{aligned} \tag{41}$$

which determines the price of new capital as a function of net investment.

Since the producers are symmetric, we obtain as the law of motion for aggregate capital:

$$K_{t+1} - (1-\delta)\, K_t = \left[1 - \frac{\phi}{2}\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)^2\right](I_{n,t}+\psi)\,. \tag{42}$$

2.7 Intermediate Goods Producers

There is a continuum of mass one of identical competitive intermediate goods firms indexed by $j \in [0,1]$ that produce a single homogeneous good, $m_{j,t}$, using inputs of capital and labor. At the end of period $t-1$ firms acquire $k_{j,t}$ units of capital at the price of Q_{t-1} per unit. Intermediate goods producers finance these purchases by selling $b_{f,t}$ units of equity at the price Q_{t-1} per unit. Thus:

$$Q_{t-1}k_{j,t} = Q_{t-1}b_{f,t} \tag{43}$$

At the start of period t, all firms are subject to a capital quality shock, $\xi_t > 0$:

$$k_{j,t}^e = \xi_t k_{j,t} \tag{44}$$

where $k^e_{j,t}$ can be interpreted as the effective capital stock. The firm then rents labor at a price w_t per efficiency unit of labor, $n_{j,t} \equiv \int h_{i,t} l^j_{i,t} di$ ($l^j_{i,t}$ denotes the amount of hours household i works for intermediate goods producer j) $n_{j,t}$, and produces output, $m_{j,t}$. The technology is given as:

$$m_{j,t} = Z_t n^{\alpha}_{j,t} \left(k^e_{j,t}\right)^{1-\alpha} \tag{45}$$

where Z_t is an aggregate productivity shock and α is the labor share in the intermediate goods sector.

The choice of labor input is the solution to:

$$\phi_{jt} = \max_{n_{j,t}} \left(P^m_t m_{jt} - w_t n_{jt}\right)$$

which implies that labor demand satisfies:

$$w_t = P^m_t \alpha Z_t n^{\alpha-1}_{j,t} \left(k^e_{j,t}\right)^{1-\alpha} \tag{46}$$

The firm then pays out profits and the market value of its capital stock to its current owners:

$$\varsigma_{j,t} = \phi_{jt} + Q_t \xi_t k_{jt} - \delta \xi_t k_{jt}$$

where $\varsigma_{j,t}$ is the total payout and $\phi_{jt} = (1-\alpha) P^m_t Z_t n^{\alpha}_{j,t} \xi_t \left(\xi_t k_{j,t}\right)^{-\alpha} k_{j,t}$ are revenues net of payments to labor. The term $Q_t \xi_t k_{jt}$ is the market value of firm j's effective capital stock in period t, and $\delta \xi_t k_{jt}$ are costs of replacement of depreciated capital during the period. It follows that the return on equity offered to existing owners is given as:

$$R_{K,t} = \frac{\left(r_{K,t} + Q_t - \delta\right) \xi_t}{Q_{t-1}} \tag{47}$$

where $r_{K,t} = (1-\alpha) P^m_t Z_t n^{\alpha}_{j,t} \left(k^e_{j,t}\right)^{-\alpha}$ is the marginal product of "effective" capital.

2.8 Government

There is a monetary authority that is in charge of monetary policy and a fiscal authority that taxes, spends and ensures government solvency.

2.8.1 Fiscal Policy

The law of motion of government debt is:

$$B^G_{t+1} = R_{S,t} B^G_t + G_t - T_t \tag{48}$$

where B^G_{t+1} is the amount of real government debt issued in period t and G_t denotes government purchases of final goods and T_t are real tax revenues in period t:

$$T_t = \tau_{h,t} \left(w_t H_t + \mathcal{F}_t\right) \tag{49}$$

We assume that spending adjusts to changes in government debt so as to ensure government solvency:

$$\frac{G_t}{\overline{G}} = \left(\frac{B_t^G}{\overline{B}^G}\right)^{-\gamma_G} \tag{50}$$

where $\overline{B}^G$ is a long-run target for government debt and $-\gamma_G$ is the elasticity of government spending to government debt.

2.8.2 Monetary Policy

We assume a simple Taylor style rule for the short-term nominal interest rate:

$$\left(\frac{R_{S,t}^N}{\overline{R}^N}\right) = \left(\frac{R_{S,t-1}^N}{\overline{R}^N}\right)^{\rho_m} \left(\frac{\pi_t}{\overline{\pi}}\right)^{\kappa_\pi(1-\rho_m)} exp\left(\varepsilon_t^m\right) \tag{51}$$

where $\overline{R}^N$ is the long-run level of the short-term nominal interest rate, $\rho_m \in (0,1)$ allows for interest rate smoothing, $\overline{\pi}$ is the inflation target, $\kappa_\pi > 1$ is the interest rate response to deviations of inflation from its target and ε_t^m is a monetary policy shock which follows a first-order autoregressive process with persistence $\rho_m \in (0,1)$ and with innovations that are $n.i.d.\left(0, \sigma_m^2\right)$.

2.9 Market Clearing

Let $\Theta_t(b,h)$ denote the joint distribution of assets (including bank loans) and productivity across households at date t. The labor market clearing condition is:

$$\int_h \int_b l^*(b,h)\, h\Theta_t(b,h)\, dbdh = \left(\frac{w_t}{P_t^m Z_t \alpha}\right)^{1/(\alpha-1)} K_t^e \tag{52}$$

where $l^*(b,h)$ denotes households labor supply policy function and $K_t^e = \int k_{j,t}^e dj$ is the aggregate "effective" capital stock. The savings market clearing condition reads:

$$\int_h \int_{b*>0} b^*(b,h)\, \Theta_t(b,h)\, dbdh = B_{t+1} = B_{D,t+1} + B_{G,t+1} \tag{53}$$

where $b^*(b,h)$ denote households' optimal policy function for assets and bank loans, $B_{D,t+1}$ are aggregate supply bank deposits. The credit market clearing condition is:

$$N_t + B_{D,t+1} = Q_t K_{t+1} + \int_h \int_{b^*<0} b^*(b,h)\, \Theta_t(b,h)\, dbdh \tag{54}$$

which simply imposes that credit supply from banks and saving households equals credit demand from firms and households. The capital market clearing condition is:

$$\frac{\Delta K_{t+1}}{K_t} = \Gamma\left(Q_t - 1, \mathbb{E}_t I_{n,t+1}\right) - \delta K_t \tag{55}$$

where Γ is implicitly defined in conditions (41)-(42). Finally, goods market clearing implies that:

$$\left(1 - \frac{\eta}{2\kappa Y}\log\left(\pi_t\right)^2\right) Y_t = C_t + I_t + G_t + (\phi - 1)\, B_{L,t+1} \tag{56}$$

Table 1: Model parameterization

Parameter	Description	Value	Parameter	Description	Value
Households			Final Goods		
β	Discount factor	0.985	κ^Y	Price stickiness	0.09
χ	Disutility weight of labor	0.7	μ^Y	Markup	0.05
μ	Relative risk aversion	1.5	Intermediation		
γ	Frisch elasticity	0.75	λ	Divertible fraction of capital	0.381
ρ_h	Persistence of income shocks	0.99	θ	Bank survival ratio	0.972
σ_h	Variances of income shocks	0.06	ω	Transfer to the new bankers	0.002
ζ	Transition prob. to rentier	0.0015	τ_I	Government credit cost	0.001
ι	Transition prob. to worker	0.0625	φ	Consumer loan cost	1.013
Technology			Monetary and Fiscal Rules		
α	Labor share	0.67	κ_π	Reaction to inflation	1.5
ψ_k	Investment adjustment cost	2.625	ρ_m	Interest rate smoothing	0.7
δ	Capital depreciation	0.02	γ_G	Reaction to debt	0.25

where the term in parenthesis on the left hand side corrects for price adjustment costs and the last term on the right hand side are the intermediation costs of issuing consumer credit. Added to these is the government budget constraint which holds by Walras' law.

3 Calibration

We solve the model by first-order perturbation for the calibration, using the method of Bayer and Luetticke (2020). We calibrate the model so that one period corresponds to a quarter. Table 1 contains the parameter values of the calibration and Table 2 contains some targets that we use in the calibration for parameters that are not selected externally. All targets correspond to a data sample covering 1973:1-2019:4.

We first calibrate preference parameters. We assume that the intertemporal elasticity of substitution is equal to 1.5 which is in the range of empirical estimates from studies of household consumption such as Attanasio and Weber (1995) or studies of aggregate data such as Eichenbaum, Hansen and Singleton (1988). We set the Frisch labor supply elasticity equal to 0.75 consistent with the range of estimates in the micro literature, see e.g. Chetty et al (2011). In order to calibrate the preference weight on disutility of work, χ, we target a value of labor supply of one third which corresponds roughly to the share of non-sleeping time that U.S. labor market participants devote to labor market activities according to the American Time Use Survey (ATUS). The intertemporal discount factor is calibrated by targeting an annual capital-output ratio of 2.5, which reflects all private capital.[5] Together with other parameters, this implies $\beta = 0.985$.

[5] We hence assume that all private capital is funded by banks. This assumption is innocuous because using a tighter definition of capital affects both the numerator and denominator of the capital-output ratio.

Table 2: Calibration targets

Targets	Model	Data	Source	Parameter
Hours worked	1/3	1/3	ATUS	Preference weight
Capital to annual output	250%	250%	NIPA	Discount factor
Household debt to annual output	6%	6%	FRED	Borrowing limit
Fraction with zero wealth	20%	20%	SCF	Borrowing penalty
Top 10% wealth share	67%	67%	WID	Fraction of entrepreneurs

Next, we calibrate parameters related to the supply side of the economy. We assume that the output elasticity to labor, α, is equal to 67 percent, a standard value in the literature. The capital depreciation rate is assumed to be two percent per quarter while capital adjustment costs, ϕ, are calibrated to target a volatility of investment to output of 3.87 in response to the aggregate shocks in the model. 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^Y so that it is consistent with an average contract length of four quarters.

The parameters pertaining to the financial intermediaries are calibrated following Gertler and Karadi (2011). As these authors, we assume 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. We also follow Gertler and Karadi (2011) in assuming that the transfer to new banks correspond to 0.2 percent of the banking assets.

As for policy parameters, we assume that the inflation coefficient in the Taylor rule is 1.5, a standard value in the literature. We set the degree of interest rate smoothing equal to 0.7 consistent with the estimates of Rudebusch (2002). Also, we assume that the central bank pursues price stability and set $\overline{\pi} = 1$. To ensure government solvency, government spending reacts to debt, $\gamma_G = 0.25$. 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, the share observed in the Survey of Consumer Finances.

Next, we calibrate parameters that impact on moments related to the wealth distribution. The first two moments that we target is the amount of consumer credit and the share of households with close to zero wealth (+/- one week of average income). According to the Flow of Funds, the average of the share of the stock consumer credit to GDP at the annual rate is 6 percent. In the Survey of Consumer Finance, roughly 20 percent of households have wealth that does not exceed one week of average income. In combination, these two targets imply an value of the borrowing limit, $\underline{\mathbf{b}}$, close to five time average quarterly income and of the net resource cost of providing consumer loans, φ, that

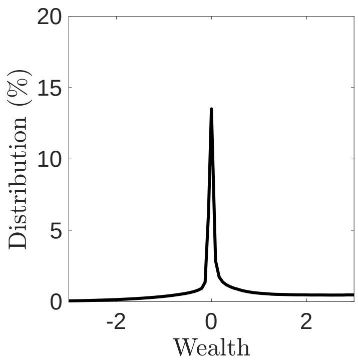


Figure 2: Distribution of wealth
(with wealth reported as: b / Y)

		Baseline
Households (%)		
(Close to kink)	(%)	20.0
(Borrowers)	(%)	23.5
Return on capital	(R_K,%)	1.18
Saving interest rate	(R_S,%)	0.77
Lending interest rate	(R_L,%)	2.44
Consumer Loan Spread	($R_L - R_S$,bp)	167

Table 3: Steady state statistics (quarterly)

corresponds to 1.25 percent of the loan value. This implies a spread of the interest rate charged to households on consumer loans over the return on capital of just below 5.3 percent annually. Given this, the calibration implies a consumer loan rate of 10.1 percent annually, a consumer loan spread of 7 percent annually, and a spread of the return on capital over the deposit rate of 1.7 percent annually, see Table 3. The former of these is very similar to the calibration of Kaplan, Moll and Violante (2018) who assume a loan rate of 10 percent. The spread of the return on capital over the deposit rate is somewhat higher than the 100 basis point calibration of Gertler and Karadi (2011) but closer to the spread of corporate bond yields over 3 months T-Bill rates, 2.4 percent in the U.S. on average during 1954-2021, which is the appropriate spread in terms of our model.

We set the probability to leave the rentier state to the probability to leave the top 1 percent of the income distribution as reported by Guvenen, Ozkan and Song (2014). We then calibrate the fraction of households in the rentier-state to roughly 1 percent to match the fraction of wealth held by the top 10 percent of households, 67 percent, from the World Inequality Database. For the idiosyncratic income risk, we assume that $\rho_h = 0.99$ and $\sigma_h^2 = 0.06^2$ (at quarterly frequency). These values correspond to estimates for net household (after tax and transfers) income from the PSID, see Storesletten, Telmer and Yaron (2004).

These parameter values induce the wealth distribution reported in 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 caused by the consumer loan spread. It is also clear that there is a considerable mass of households with wealth close to this kink. This derives from the relatively high variance of idiosyncratic income shocks which induces movements to/from the zero wealth state. The left tail of the wealth distribution is very thin because households try to avoid ending up at the borrowing limit since it prevents them from smoothing negative income shocks. Thus, the high MPC households almost all derive from the interest rate spread rather than mechanically from the

Table 4: Business cycle moments

Moments	Data	Model	Moments	Data	Model
σ_Y (target)	1.43	1.43	$corr(Y)$	1.00	1.00
σ_C/σ_Y	0.59	0.65	$corr(C,Y)$	0.82	0.55
σ_I/σ_Y (target)	3.87	3.87	$corr(I,Y)$	0.93	0.92
σ_{Credit}/σ_Y	3.45	2.59	$corr(Credit,Y)$	0.44	0.80
σ_{Spread}/σ_Y	0.23	0.34	$corr(Spread,Y)$	-0.53	-0.44

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 1.43% and a relative investment volatility of 3.87, which corresponds to the volatility of U.S. real output and investment per capita over 1973-2015, after HP(1600)-filtering.

borrowing constraint.

The economy is subject to 3 aggregate shocks, which are TFP, monetary policy (MP), and capital quality (CQ) shocks. TFP and capital quality shocks are persistent with an autocorrelation of 0.95 and 0.66. For all impulse responses we show one percent shocks (1 percentage point for monetary shocks). For business cycle moments and the welfare analysis, we calibrate the size of shocks to match U.S. output volatility, see Table 4. We obtain $\sigma_{TFP} = 1.0\%$, $\sigma_{MP} = 20bp$, and $\sigma_{CQ} = 0.5\%$.

4 Aggregate Fluctuations

We initially investigate the model's implications at the level of aggregate fluctuations.

4.1 Business Cycle Moments

We first examine the extent to which the model is consistent with aggregate business cycle moments, a litmus test on whether it provides a reasonable account of aggregate fluctuations.

Table 4 reports key moments of aggregate variables in the U.S. for the post World War II sample, quarterly data filtered with the Hodrick-Prescott filter (with a smoothing parameter of 1600). We report standard deviations of output, consumption, and investment and their cross-correlations with output. We also examine moments for the consumer loan spread, as well as for the quantity of consumer debt. We compute the corresponding model moments by simulating the model for a very long sample period and filtering the model generated data with the Hodrick-Presoctt filter (removing the initial periods that are used for burning in).

In the U.S. data, the standard deviation of output is 1.43 percent at the quarterly frequency, consumption is smoother than output with a standard deviation around 40 percent lower than that of output, while investment is significantly more volatile with a standard deviation around 3.9 times that of output. Both consumption and investment are very procyclical at the business cycle frequencies with cross-correlations with output of 0.82 and 0.93, respectively. These are moments that standard business cycle models match well and so does the HANK model with financial intermediation. In particular, the model matches well the relative standard deviation of consumption[6], and the procyclicality of both consumption and investment with the latter being matched very precisely.

Consumer debt is volatile and procyclical in the U.S. data with a standard deviation around 3.5 times that of output, and a cross-correlation with output of 0.44. The model is consistent with both of these facts implying a volatility of consumer debt around 2.5 times that of output and procyclicality of consumer debt somewhat higher than what is observed in the data (0.80). The consumer loan spread has a quarterly standard deviation of 0.23 percent in the U.S. data and is strongly countercyclical with a cross-correlation of output of -0.53. The model accounts for both the smoothness of the spread (displaying a standard deviation of the spread of 0.34 percent per quarter in the model) and its countercyclicality (with a cross-correlation with output of -0.44).

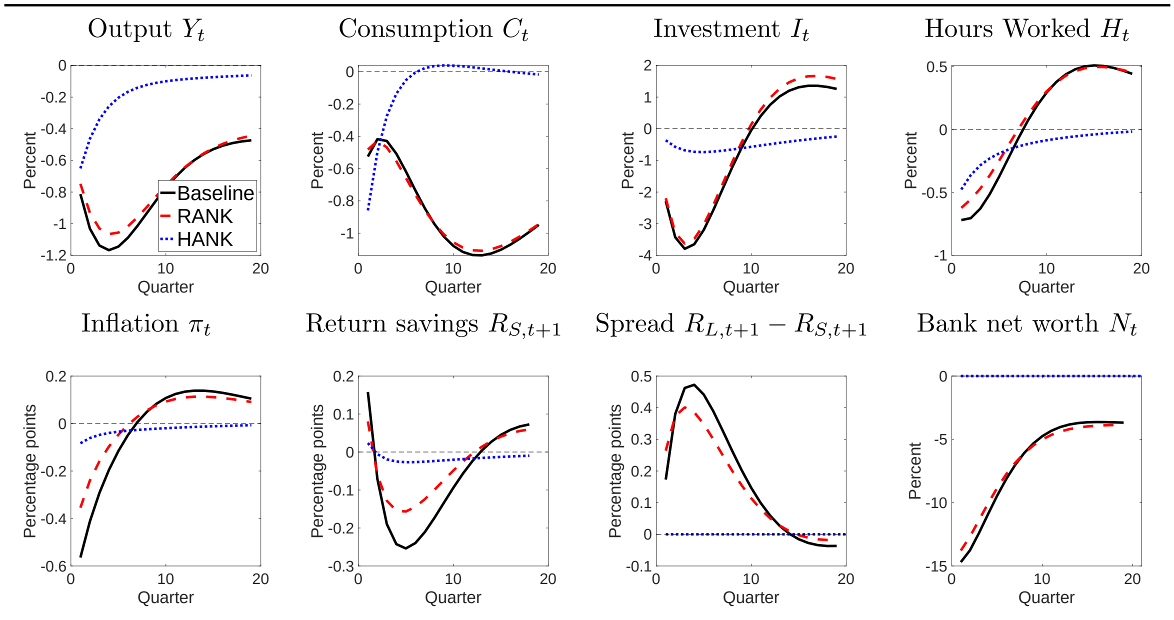
4.2 The Transmission Mechanism

We now investigate the extent to which the model has novel implications for the transmission of aggregate shocks to the aggregate economy. We accomplish this by means of computing impulse response functions to the three aggregate shocks in the model.

In order to understand better the separate roles of heterogeneous agents, which is new to the macro literature on financial frictions, and of frictional financial intermediation, which is new to the HANK literature, we compare the baseline model with two alternative economies. In the first we eliminate idiosyncratic productivity shocks and assume a standard representative agent (RANK) specification of the households but retain the financial intermediation. In this economy, the wealth distribution is degenerate, households are savers, and banks simply transform deposits from the household sector into corporate investment. In the second alternative economy we eliminate the banking sector and let households directly finance corporate investment but retain idiosyncratic shocks and incomplete markets. Since households here directly finance investment, the return on capital matches the return on savings in this economy. We still allow households to access debt markets and we assume a constant consumer loan spread matching the calibrated value for the stationary equilibrium of the baseline model.

We look at the impact of the three aggregate shocks: Technology shocks and monetary policy shocks, standard aggregate impulses to the business cycle studied much in the literature, and the capital quality shock that the financial frictions literature has focused attention on. In each case, we look at a one percent (one percentage point for the nominal interest rate) recessionary shock to the aggregate stochastic variable in question and trace out percentage changes in the aggregate variables

[6] The relative standard deviation of investment is matched by construction because we target it when calibrating the investment adjustment costs.



Impulse responses to a one percent negative capital quality shock. Baseline refers to the baseline model with household heterogeneity and frictional financial intermediation. RANK refers to the representative household model with frictional financial intermediation. HANK refers to the heterogeneous household model without frictional financial intermediation.

Figure 3: Aggregate effects of a capital quality shock

(percentage points for interest rates) for a five year forecast horizon.

4.2.1 Capital Quality Shocks

We first look at the capital quality shock that Gertler and Karadi (2011) argue was an important factor in the Global Financial Crisis. Figure 3 illustrates the impact of a one percent decline in ξ_t. We show the impact of the shock in the baseline model in black, the RANK economy by the red dotted line, and the HANK model without banks with the blue dotted line.

In the baseline model, a one percent negative capital quality shock sets of a sharp fall in output which worsens the first few periods and peaks at a decline of around 1.25 percent one year after the shock. The decline in output is accompanied by a very persistent reduction in aggregate consumption initially by around 0.5 percent but building up over time and reaching a peak decline of 1.2 percent three years after the shock. Aggregate investment also declines strongly, 4.5 percent at its trough which occurs three quarters after the shock, but thereafter recovers strongly. The capital quality shock induces a large reduction in aggregate hours worked of 0.75 percent on impact which reverses only after 2 years.

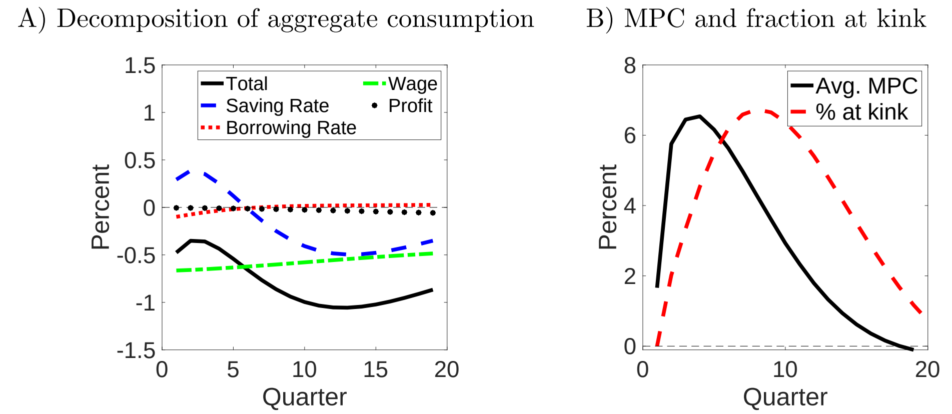
The reduction in capital quality produces fire sales of capital which induces a strong decline in the price of capital. This decline in the value of corporate equity reduces banking sector net worth which, due to the financial friction, is accompanied by an increase in the interest rate spread on consumer loans and an increase in the return on capital relative to the deposit rate. The rise in the spread is quantitative large going above 50 basis point one year after shock and it remains elevated for the first 10 quarters after the decline in capital quality. The deflationary impact of the shock leads the central bank to cut nominal interest rates but, due to interest rate smoothing, this is done in a staggered manner which induces a short lived increase in the real return on bonds and therefore in the deposit rate. As the nominal interest rate reduction is implemented, the short term real interest (savings) rate declines with a one quarter delay.

The capital quality shock is amplified by the friction in the banking sector. The financial accelerator derives from falling capital prices which reduces banking sector net worth forcing banks to reduce their investments in corporate equity and in consumer loans, and induces a rise in interest rate spreads. The higher cost of capital finance leads firms to reduce their purchases of new capital which reinforces the decline in capital prices and sets the financial accelerator in motion. To see this, it is instructive to compare the impact of the capital quality shock in the baseline model with the responses in the model without the banking sector (shown in blue). Absent financial intermediation, output is much less sensitive to the capital quality shock, there are no fire sales of capital, and this economy witness a much smaller decline in investment and in hours worked.

On the other hand, the presence of incomplete markets matters comparatively less for the impact of capital quality shocks on aggregate outcomes. This can be seen by comparing the impulse responses of the benchmark model with the RANK model. The impact of the capital quality shock on output is somewhat higher in the short run than in the RANK economy which is due mainly to a stronger decline in hours worked. There is also a slightly stronger decline in investment while aggregate consumption behaves very similarly in the two alternative economies.

Figure 4 decomposes the aggregate consumption response to the capital quality shock into the separate impact of the different prices in the economy on consumption: interest rates, real wages, and corporate sector profits. This is informative about the underlying mechanisms that drives the consumption response. The decline in the level of consumption derives mainly from the fall in real wages that reduces household wealth and impacts directly on constrained households (i.e. households either at the borrowing limit or with no liquid wealth). In line with this, Panel B of the figure shows that the average marginal propensity to consume increases because the rise in the interest rate spread means a larger fraction of the population have zero or close to zero wealth.[7] The non-monotonic consumption dynamics instead are mostly due to the impact of the savings rate. The increase in the borrowing rate reduces aggregate consumption but the impact on aggregate consumption is quantitatively small because it impacts mainly on low-wealth households who also consume less. The profit channel is quantitatively irrelevant.

[7] We compute the MPC as the change in consumption in response to a marginal wealth change.



Notes: Panel A plots the decomposition of the response of aggregate consumption to a one percent negative capital quality shock into the effect of each price sequence by using household policy functions. Panel B plots the impulse response of the average MPC and the fraction of households at the kink (with close to zero wealth) to the capital quality shock.

Figure 4: Transmission to consumption: Capital quality shock

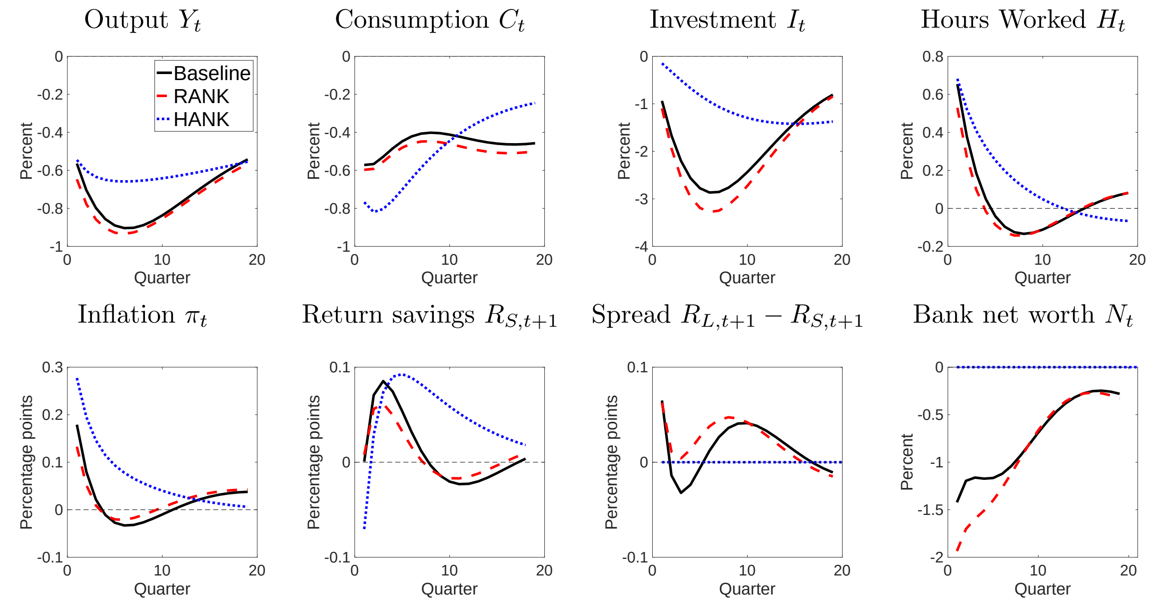
4.2.2 TFP Shocks

A negative TFP shock leads to a strong reduction in output, consumption and investment in the baseline model of a size that is very similar to the RANK model with banking, see Figure 5. The shock also reduces capital prices which impacts negatively on banking sector net worth and leads to a strong reduction in corporate sector investment. The reduction in banking sector net worth increases interest rate spreads but much less than the capital quality shock (a four basis point maximum rise after the TFP shock vs. 50 basis points for the capital quality shock) due to a smaller effect of TFP shocks on capital prices. Eliminating banks mutes the impact of the shock on output in the medium term and on investment in the short and medium term. The message coming out of this analysis is therefore essentially the same as for the capital quality shock: The introduction of banks into the HANK model introduces an amplification mechanism through a financial accelerator. Market incompleteness again adds less to the aggregate dynamics.

4.2.3 Monetary Policy Shocks

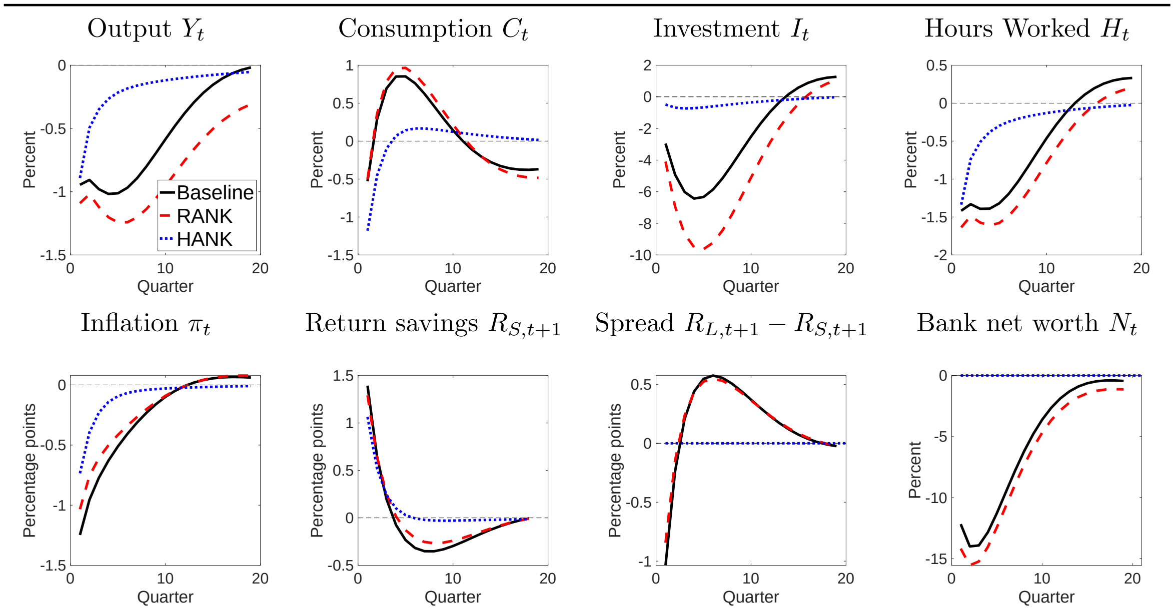
Finally, Figure 6 reports the impulse responses for an increase in the nominal interest rate due to a monetary policy shock. The increase in the nominal interest rate is contractionary as in standard New Keynesian models and the shock is amplified by the financial frictions.

The rise in nominal interest rates increases the cost of capital to banks through the deposit rate and, at the same time, lowers their net worth due to a reduction in capital prices. There is a short lived decline in the interest rate spread that derives from interest rate smoothing but thereafter it rises strongly and persistently peaking at 50 basis points with a six quarter delay after the monetary



Impulse responses to a one percent negative TFP shock. See Figure 3 for legend.

Figure 5: Aggregate effects of a TFP shock



Impulse responses to a one percentage point positive shock to the nominal interest rate. See Figure 3 for legend.

Figure 6: Aggregate effects of a monetary shock

policy shock. Lower banking sector net worth reduces asset investment by the banking sector which reinforces the decline in the price of capital and generates a strong decline in aggregate investment. For this reason, the monetary policy shock generate a persistent decline in output while aggregate consumption follows a non-monotonic pattern declining in the very short run and from around 3 years after the shock.

Removing the banking friction, the monetary policy shock has a much smaller and less persistent recessionary impact on aggregate output and consumption and approximately eliminates the reduction in aggregate investment. Thus, for the study of monetary policy shocks, financial frictions matter very significantly in HANK models. Relative to the RANK model, the HANK economy with banks produces a somewhat smaller output and investment response to monetary policy shocks because the rise in the spread leads to a decline in demand for consumer loans which allows banks to reduce corporate investment more moderately than in the RANK model.

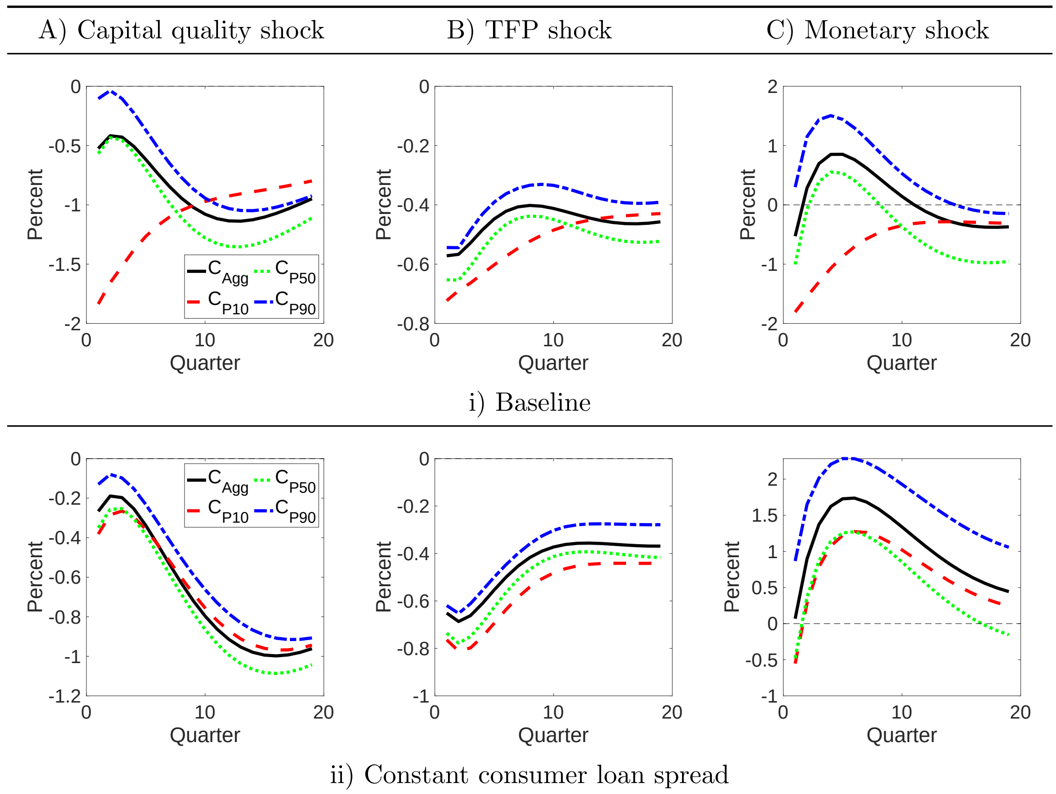
In summary, shocks to the economy are amplified at the aggregate level through a financial accelerator mechanism. Frictional financial intermediation therefore appears an important ingredient of HANK models. At the aggregate level, market incompleteness and heterogeneous agents appear comparatively less important for the transmission mechanism, a finding that resonates with the results in Berger, Bocola and Dovis (2020).

5 Aggregate Shocks and Inequality

The heterogeneous agents framework we have adopted in this paper allows us to examine not only the aggregate fluctuations in the economy but the impact of aggregate shocks on household inequality. Inequality is a concern for economic policy, see e.g. Feiveson et al (2020) which formed part of the Federal Reserve's recent monetary policy strategy, since it may have implications for the design of stabilization policy. As we will show, the introduction of frictional financial intermediation has important consequences for this issue due to the link between interest rate spreads and household opportunities for smoothing of income shocks. We will focus our discussion on the impact on consumption dispersion across the wealth distribution since there is a tight connection to welfare and because this inequality measure can be measured in the data in much more straightforward way than other dimensions of inequality.

5.1 Consumption Dispersion in Theory

Figure 7 illustrates the consumption paths in response to the three aggregate shocks for households in the 10th percentile (who are indebted), 50th percentile, and 90th percentile of the wealth distribution, together with aggregate per capita consumption. In the top row we show the consumption responses for the baseline economy and in the bottom row for the HANK model with banks but a constant spread on consumer loans. This helps to isolate the impact of the countercyclical consumer

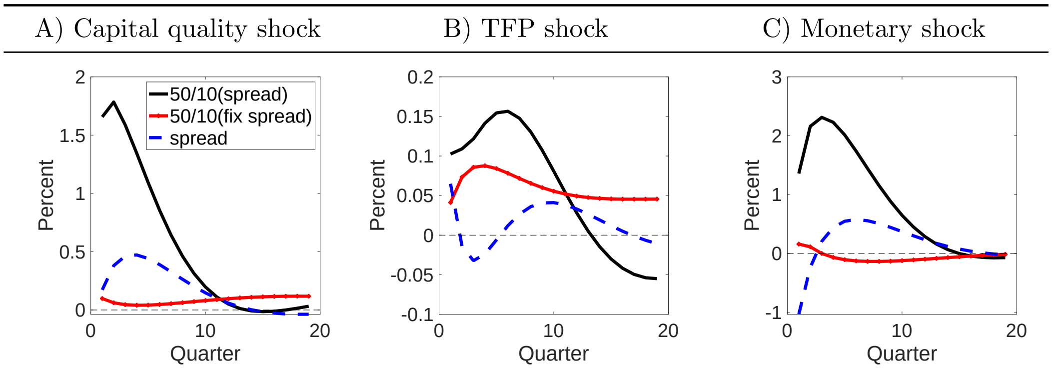


Impulse responses of consumption at the 10th, 50th, and 90th percentile of the wealth distribution. The shocks are a one percent decline in capital quality (column A), a one percent decline in TFP (column B), and a one perentage point increase in the nominal interest rate (column C). Top row: Baseline model. Bottom row: Baseline model with constant consumer loan spread.

Figure 7: Consumption impulse responses by wealth percentiles

loan spread on consumption dispersion. In Figure 8 we plot a slightly different measure of consumption dispersion computed from the consumption distribution (rather than the wealth distribution) concentrating on ratio of consumption of the 50th percentile to the 10th percentile, c_t^{5010}, together with the response of the interest rate spread to the shocks.

The first column of Figure 7 shows the impact of a one percent decline in capital quality on consumption choices across the wealth distribution. Consumption choices are determined by agents' net asset positions, their idiosyncratic productivity state, and by the impact of the aggregate shocks shock on real wages and on interest rates. Regardless of whether the consumer loan spread is constant or not, lower capital quality induces a reduction in real wages which depresses consumption across the wealth distribution. The behavior of interest rates instead depend crucially on whether the spread on consumer loans is constant or not. When the consumer loan spread is held constant, savings and borrowing rates decline in tandem after a negative capital quality shock. It follows from consumer optimization that the consumption growth rates of households that are either unconstrained savers or unconstrained borrowers therefore move in parallel. Thus, when inspecting the 10th, 50th and 90th



Impulse responses of the 50/10 ratio of the consumption distribution in the baseline model (black-solid line) and the baseline model with constant consumer loan spread (red-solid-diamonds line). The shocks are a one percent decline in capital quality (column A), a one percent decline in TFP (column B), and a one perentage point increase in the nominal interest rate (column C). Blue-dashed line: Impulse response of the spread in the baseline model.

Figure 8: Consumption impulse responses by consumption percentiles (50/10 ratio) (blue: baseline, red: constant spread)

deciles, we see no consumption dispersion in this economy, see Figure 8. The decline in borrowing rates effectively allows poor households to obtain considerable insurance through borrowing while lower savings rates give richer households little incentive to reduce consumption.

In contrast, in the face countercyclical consumer loan spreads, the capital quality shock is accompanied by *higher* borrowing rates while savings rates still fall. The spread exaggerates the kink in the budget constraint facing agents and therefore the share of liquidity constrained agents. In addition, changes in the spread induces differences in consumption growth rates for indebted households relative to savers. Higher borrowing rates produce a strong reduction in indebted households' consumption spending due to the higher cost of consumer debt and the additional higher interest rate costs of servicing outstanding debt. For this reason, faced with lower real wages and higher costs of borrowing, indebted households reduce their consumption strongly, see Figure 7. Households with positive net asset positions, while also being negatively affected by lower real wages, instead face lower savings rates and, due to intertemporal substitution, choose to reduce consumption only marginally. Thus, the financial frictions induce a strong increase in consumption dispersion both between the wealthiest households and the poorest decile and between the median household and the poorest decile. The latter is brought out very clearly by the path of c_t^{5010} in Figure 8 which increases by close to two percent at the peak relative to a peak increase in the consumer loan spread of approximately 50 basis points.

A reduction in TFP gives rise to lower real wages which exert downward pressure on consumption across the wealth distribution. In the face of a constant consumer loan spread, despite substantial differences in net asset positions across the wealth distribution, inequality as measured by c_t^{5010}

changes only little. When the consumer loan spread is endogenized, the decline in banking sector net worth leads to an increase in the spread. The higher consumer loan spread increases the share of households with near-zero liquidity and reinforces the incentive for indebted households to reduce their consumption. As a result, c_t^{5010} rises considerably more than in the economy with a constant spread, see Figure 8.

A standard intuition in the literature is that wealth inequality may be sufficient to induce substantial distributional impact of monetary policy shocks. In particular, higher policy rates reward savers through higher returns on their assets while at the same time increase borrowing costs and interest rate repayments of indebted households. Moreover, changes in interest rates have general equilibrium effects on labor income which may impact particularly strongly on liquidity constrained and indebted households. When the consumer loan spread is constant, this intuition *is* born out in the HANK model, but only for the richest decile of the wealth distribution relative to the median or 10th percent poorest households. The wealth of the median household is sufficiently moderate that substitution effects of interest rate changes dominate and consumption choices move in almost perfect tandem with those of indebted households. Thus, in this case c_t^{5010} remains as good as constant.

Introducing the endogenously determined consumer loan spread instead bears out the standard intuition about the impact of monetary policy shocks on inequality even when comparing the median household and the 10th lowest percentile due to the movements in the interest rate spread. In this economy, a contractionary monetary policy shock reduces real wages more strongly and gives rise to movements in the interest rate spread which, after a short lived decline (due to interest rate smoothing), increases persistently. The stronger decline in real wages and the persistent rise in borrowing costs induce a much stronger decline in indebted households' consumption level than in the absence of banks, see Figure 7, which opens up substantial consumption dispersion even between the median household and the poorest decile. As a result, in this economy we find a large increase in c_t^{5010} which accompanies the rise in the interest rate spread.

Thus, endogeneous movements in consumer loan spreads have substantial consequences for the distributional impact of aggregate shocks. When this feature is introduced, the countercyclical consumer loan spread induces rising consumption dispersion in response to contractionary aggregate shocks.

5.2 Consumption Dispersion: Empirics

Figure 1 presented earlier shows the time series of interest rate spreads and consumption dispersion in the U.S. data. We show two measures of the interest rate spread, the spread between the two year personal loan rate and the three months T-Bill rate (spr_t^{loan}), and the spread between the Commercial Bank interest on three months Credit Card plans and the three months T-Bill rate (spr_t^{credit}) both at annual rates obtained from the FRED.[8] The consumption dispersion measure is the logarithm of the ratio of median household to the 10th percentile (in the consumption distribution) consumption level ($c_t^{50/10}$) computed using data from the Bureau of Labor Statistics' Consumer Expenditure Survey (the CEX). Our consumption measure reflects spending on non-durable goods, durables, and housing for households with heads between the age of 20 and 60, see Appendix A.1 for more details. We detrend the interest rate spreads with a fourth order polynomial in time and consumption dispersion seasonal dummies and a fourth order polynomial in time.[9]. We also illustrate NBER recession periods by shading these episodes in grey.

As discussed earlier, interest rate spreads are countercyclical increasing suddenly during recessions and generally declining during expansions. It is also clear that the two measures of the spread are highly correlated despite maturity differences. Consumption dispersion is somewhat volatile when computed from the CEX but does also displays countercyclical behavior increasing in the aftermath of the 1981-82 recession, in the early 2000's recession, and after the Global Financial Crisis, albeit with a shorter duration than the rise in the interest rate spreads.

Coibion et al (2017) estimate the impact of monetary policy shocks on consumption dispersion in the U.S. They find that contractionary monetary policy shocks induce persistently higher consumption inequality measuring the latter by dispersion between the 90th and 10th percentile computed from the CEX. Mumtaz and Theophilopoulou (2017) similarly find that contractionary monetary policy shocks increase consumption dispersion in UK data as do Blomhoff Holm, Paul and Tischbirek (2021) in Norwegian data. These findings are consistent with the model that we have presented, and as argued above, intrinsically linked to the presence of frictional financial intermediation.

Here we provide new evidence on the relationship between consumption dispersion and interest rate spreads, and on the impact of TFP on consumption dispersion and interest rate spreads. We examine quarterly data for the U.S. for the sample period 1982:1-2012:4.[10] We use the two interest rate spread measures illustrated above. To start with, we estimate the relationship between consumption dispersion and interest rate spreads from the following local projection regressions:

$$c_{t+h}^{50/10} = \alpha_h + \beta_h spr_t^i + \gamma_h Z_{t-1} + \epsilon_{t+h} \tag{57}$$

where $h \geq 0$ is the forecast horizon, spr_t^i is the interest rate spread in question, and Z_{t-1} is a vector of control variables (which are potentially important given the relatively short sample periods). We control for lags of consumption dispersion, the interest rate spread, the CPI, real GDP, real investment, labor productivity (all in logarithms), and for the charge-off rate on credit card loans by commercial banks. The latter variable is important because it controls for the extent to which

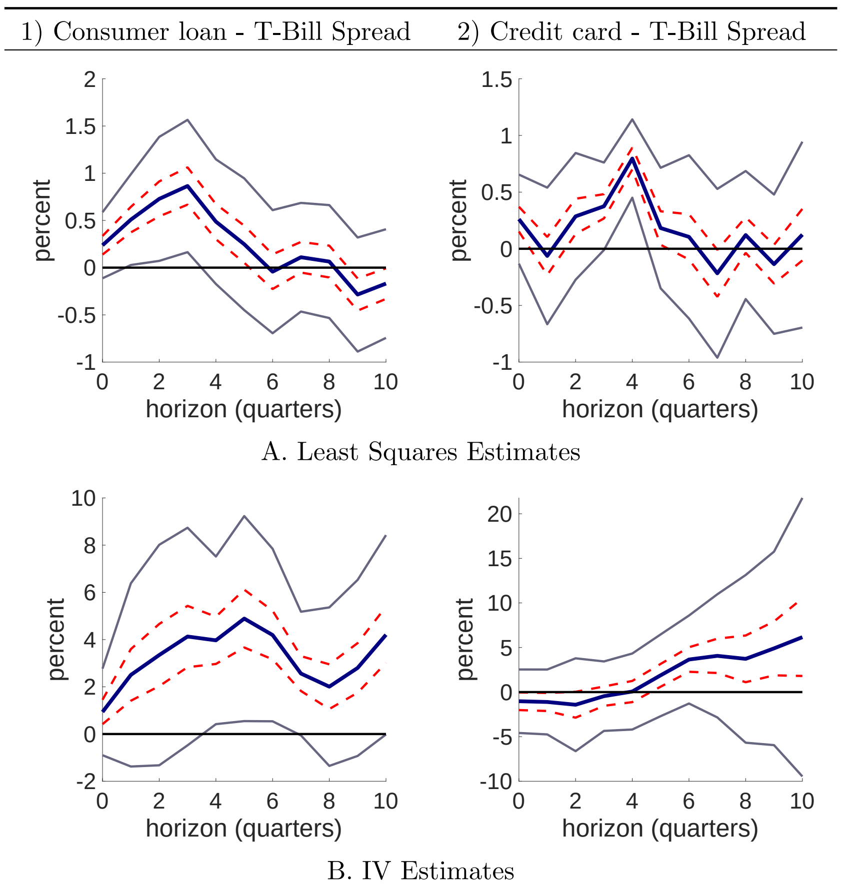
[8]We measure spreads as the log difference between gross returns.

[9]Following Coibion et al (2017), we smooth the consumption dispersion measure with a centred three quarter moving average

[10]The relatively short sample period is dictated by the availability of household consumption data. Results for the credit card interest rate spread relate to a sample period starting in 1995:1.

spreads are impacted by consumer default issues. All data are detrended with a quadratic trend (and with a seasonal dummy for consumption dispersion). We estimate equation (57) allowing for four lags of the controls and for forecast horizons $h = 0, 1.., 10$ quarters. Inference is conducted using Newey-West robust errors and we show 68 percent and 90 percent confidence bands.

Panel A of Figure 9 reports the impact of the two interest rate spreads on consumption dispersion estimated with least squares. We find that an increase in the spread is associated with higher consumption dispersion regardless of the interest rate spread measure that we use. The increase in consumption dispersion is significant at the 68 percent level for around a year and a half to two years for both measures and at the 90 percent level for the first 3 quarters for the consumer loan T-Bill rate spread but not for credit card spread. The latter may be due to the relatively short sample period for which both interest rate spread and the consumption dispersion measure are available.



The figure illustrates the impulse response functions of $c_{t+h}^{50/10}$ to the interest rate spreads estimated using local projection. Blue lines are point estimates, red lines are 68 percent bands, black lines are 90 percent bands.

Figure 9: Relationship between Interest Rate Spreads and Consumption Dispersion

The results in Panel A cannot be given any causal interpretation and simply illustrate the dynamic correlation structure between spreads and consumption dispersion partialling out the variables in the control vector. To make further progress, Panel B of Figure 9 illustrates instrumental variables results when we instrument the spread with the financial stress indicator constructed by Romer and Romer (2017). We think of this indicator as the most direct measure available of the capital quality shocks in the model which impact directly on financial sector net worth. We showed earlier that this source of shocks have no impact on consumption dispersion when the interest rate spread is constant and the Romer and Romer (2017) indicator therefore constitutes a valid instrument for spreads by satisfying the exclusion restriction.[11]

The results in Panel B indicate a much larger impact of the interest rate spread on consumption dispersion than those deriving from the OLS estimates. The results for the consumer loan - T-Bill rate spread indicate that a one percentage point increase in the spread is associated with a persistent rise in consumption dispersion of up to four percent which is significant at the 68 percent level for all forecast horizons that we consider at the 90 percent level for forecast horizons beyond one year. For the credit card - T-Bill spread, the instrument is less significant inducing weak instrument issues and large standard errors (probably because of the short sample period), but results are roughly consistent with those for the consumer loan rate.

Thus, in line with the model, there seems to be a positive relationship between interest rate spreads and consumption dispersion in the U.S. data. Given this, we also investigate how TFP shocks impact on interest rate spreads and consumption dispersion. We estimate the following impulse responses with local projection:

$$c_{t+h}^{50/10} = \alpha_h^c + \beta_h^c \Delta tfp_t + \gamma_h^c Z_{t-1} + \epsilon_{t+h}^c \tag{58}$$

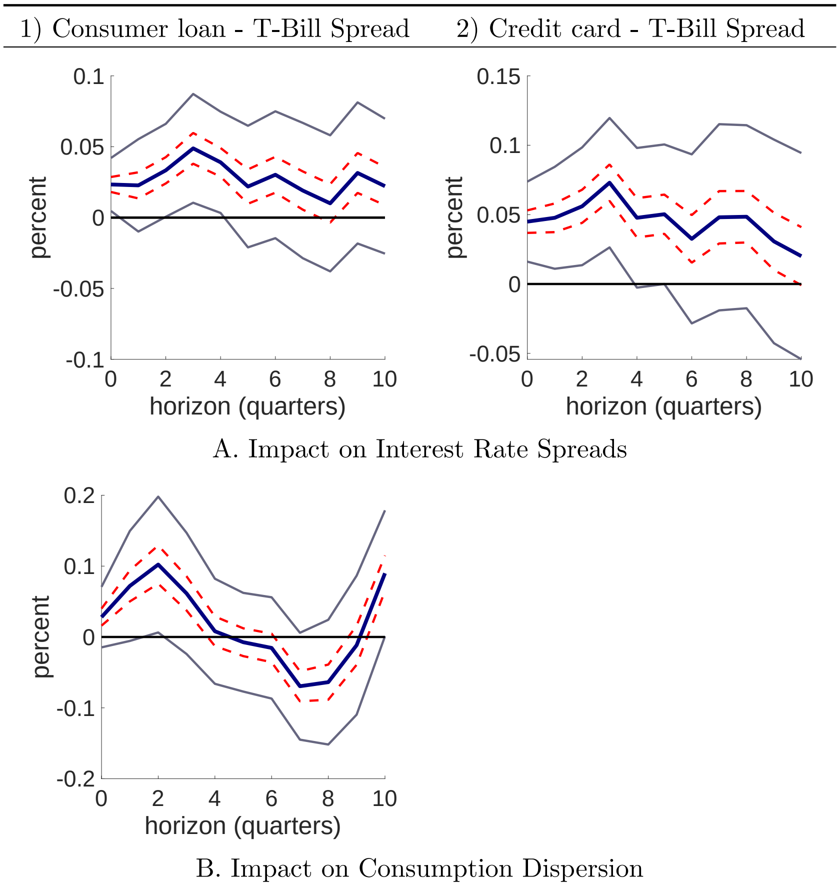
$$spr_{t+h} = \alpha_h^{spr} + \beta_h^{spr} \Delta tfp_t + \gamma_h^{spr} Z_{t-1} + \epsilon_{t+h}^{spr} \tag{59}$$

where Δtfp_t denotes (the latest vintage of) Fernald (2014) estimates of the innovation to U.S. total factor productivity. We estimate (58)-(59) with least squares. The vector of controls includes four lags of the dependent variable, Δtfp_t, real GDP, the CPI, real investment and labor productivity.

Panel A of Figure 10 illustrates the impact of a one percent negative TFP innovation on the two interest rate spreads. Consistent with our model, a decline in TFP induces a higher interest rate spread. The impact is larger and more persistent for the credit card - T-Bill spread which rises by 4-8 basis points and significantly so for all forecast horizons considered at the 68 percent level and for two years at the 90 percent level. The increase in the consumer loan - T-Bill spread is also very persistent but slightly smaller and significant for a shorter period.[12] Furthermore, we find that lower TFP gives rise to an increase in consumption dispersion which goes up by around 0.05-0.1 percent

[11] We linearly interpolate the semi-annual financial stress series produced by Romer and Romer (2017) to obtain a quarterly series and we add four lags of it to the vector of controls. Due to concerns about the degrees of freedom given the short sample, we eliminate aggregate investment and labor productivity from the vector of controls.

[12] Quantitatively, the impact on the interest rate spread is very similar to the one in the model.



The figure illustrates the impulse response functions of spr^{i}_{t+h} and $c^{50/10}_{t+h}$ to a one percent negative TFP innovation estimated using local projection. Blue lines are point estimates, red lines are 68 percent bands, black lines are 90 percent bands.

Figure 10: Impact of TFP on Consumption Dispersion and Interest Rate Spreads

after the decline in TFP, and with the increase being significant at the 68 perent level for the first year and half after the decline in productivity.

Thus, in combination with the earlier cited evidence on the relationship between consumption dispersion and monetary policy shocks, the evidence presented here is consistent with an important role of financial frictions for consumption dispersion.

6 Macro Prudential Regulation

We now examine the impact of introducing macro prudential policies. We concentrate on regulation that directly targets banks' leverage and investigate how such regulation affects long-run outcomes, macroeconomic aggregates over the business cycle, as well as the impact on individual households and welfare consequences.

Specifically, we study the consequences of introducing capital requirements that force banks to reduce their leverage (in the stationary equilibrium) by 25 percent thereby making them less sensitive to movements in asset prices.[13] The standard trade-off from introducing such regulation in a representative agent framework is that the induced decline in banking sector leverage, while stabilizing the economy through muting the financial accelerator, induces lower steady-state output (since banks become more restricted in their investment activities). We will now show that the trade-off is very different in the incomplete markets set-up: It involves a trade-off between *micro volatility* and *macro stability* while long run steady-state output costs may be close to zero. To bring this out, we first examine the consequences of the regulatory policy for long-run outcomes, then how it impacts the cyclical properties of macro aggregates, and then its distributional and welfare consequences.

6.1 Long Run Aggregate Effects and Cyclical Dampening

Table 5: Steady state: Baseline and low leverage

	Heterogeneity		**No Heterogeneity**	
	Baseline	Low Leverage	Baseline	Low Leverage
Leverage	3.35	2.49	3.36	2.51
	Interest rates			
Return on capital (R_K, %)	1.18	1.22	1.68	1.82
Return on savings (R_S, %)	0.77	0.49	1.50	1.50
Lending interest rate (R_L, %)	2.44	2.49	-	-
	Aggregates			
Output	3.022	3.042	2.519	2.475
Capital	30.129	29.888	21.660	20.500
Labor	0.957	0.970	0.859	0.8600
Consumption	1.984	1.974	1.782	1.760
	Household distribution			
At kink (%)	19.80	32.24	-	-
Borrowers (%)	23.52	30.03	-	-
Gini Wealth	0.845	0.927	-	-
Gini Consumption	0.242	0.259	-	-
Gini Income	0.332	0.357	-	-

Notes: We compare the baseline steady state to one with low leverage. The last two columns do so for the model with a representative household.

Table 5 reports the steady-state effects of introducing macro prudential regulation. We compare the HANK model with the RANK model in order to tease out the impact of introducing incomplete markets. Introducing capital requirements leads to an increase interest rate spreads since banks are

[13] Operationally, we impose on banks a λ^R (which replaces λ in the banking problem) such that steady-state leverage declines with 25 percent from 3.36 to 2.51 in the representative agent model.

more constrained in their investments in assets. In the representative agent setting, the deterministic steady-state savings return is determined entirely by households' intertemporal discount factor, $\overline{R}_S = 1/\beta - 1$. Hence, the increase in the spread is due entirely to an increase in the return on capital, $\overline{R}_K$. Higher return on equity, in turn, reduces the steady-state capital stock which induces lower steady-state output and consumption. Quantitatively, we find that the spread between the return on capital and the deposit rate increases from 75 basis points in the absence of regulation to 134 basis points in the regulated economy (both measured at the annual rate), that the aggregate capital stock declines by 5.4 percent, output drops by 1.75 percent, and aggregate consumption by 1.23 percent.

The interest rate spread also increases in the stationary equilibrium of the HANK model (the consumer loan spread goes up by 136 basis points annually). However, the rise in the spread occurs in a very different manner via the return on savings due to idiosyncratic risk and incomplete markets. In the HANK setting, a higher spread reduces households' ability to self-insure against idiosyncratic income risk and exaggerates the kink in the budget set at zero wealth. Households respond to this by increasing their precautionary savings and labor supply. Therefore, the economy witnesses an increase in the steady-state savings rate and the labor supply. Due to the increase in savings rate, the return on capital and the consumer loan rate increase only marginally (the latter rises from 10.1 percent annually to 10.3 percent).

Since the impact of the regulation on the return on capital is limited, the aggregate capital stock declines only marginally in the HANK model. This aspect combined with the increase in precautionary labor supply, leads to an *increase* in output in the stationary equilibrium in the HANK economy by 0.7 percent following the regulation of banks. Thus, in terms of aggregate output, the long run outcome in the HANK economy reverses the result obtained in the representative agent model. The regulation still imposes a decline in aggregate consumption, but it is much smaller than in the representative agent economy (0.50 percent and 1.23 percent, respectively). However, the smaller effects on output and consumption comes at the cost of less leisure since households increase their precautionary labor supply.

Appendix Figure A.2 illustrates the impact of capital quality shocks in the model with and without ex-ante macro prudential regulation demonstrating that the regulation succeeds in stabilizing the impact of this source shocks on macroeconomic aggregates as well as on interest rate spreads. More generally, Table 6 reports the standard deviation of macroeconomic aggregates in the baseline model with and without macro prudential regulation in response to all the three aggregate shocks.[14] Macro prudential regulation reduces the standard deviation of output by approximately 12 percent and investment volatility by no less than 23 percent, while consumption volatility increases slightly by 3.2 percent.[15] The stabilization of macroeconomic aggregates is marginally bigger than in the

[14] We report the standard deviations from model data obtained from simulating the model for a long period. The data have been filtered with the Hodrick-Prescott filtered.

[15] Without filtering the data, consumption volatility declines by 1.8 percent.

Table 6: Volatility of aggregate variables

	Baseline (A)	Low Leverage (B)	(B/A - 1)
Heterogeneity			
STD(Y) (%)	1.43	1.26	-11.9%
STD(C)	0.93	0.96	3.2%
STD(I)	5.56	4.28	-23.0%
No Heterogeneity			
STD(Y) (%)	1.45	1.31	-9.7%
STD(C)	0.96	1.03	7.3%
STD(I)	6.31	5.08	-19.5%

We report standard deviations of aggregate variables as $100 * \log(X/X^{SS})$ in response to TFP, monetary, and capital quality shocks (after HP(1600)-filtering).

RANK economy and comes about, as argued above, without any long run output losses and with a much smaller long run decline in consumption than in the representative agent model.

Thus, from the perspective of macroeconomic aggregates, the ex-ante macro prudential policy appears to be a potentially appealing instrument in the HANK model.[16]

6.2 Distributional Consequences and Welfare

The ensuing increase in the interest rate spreads produced by the capital requirements has distributional consequences in the incomplete markets setting. The bottom part of Table 5 reports various moments of the household distribution. The share of households with near zero wealth increases from 20 percent in the baseline model to 32.2 percent in the regulated economy because the kink in households' budget sets is amplified. We show this in panel A of Figure 11 which illustrates the stationary wealth distribution with and without macro prudential regulation.[17] The regulation also induces rising inequality in wealth, income, and consumption as measured by the Gini coefficients of the cross-sectional distributions.

Figure 11 panel B shows the impact of the regulation on distribution of the marginal propensity to consume (MPC) across wealth deciles. Due to the increase in the mass point of the wealth distribution with close to zero wealth, the economy witnesses a significant increase in the MPC for a large fraction of the population. The increase in the MPC is very large for many households. For the median wealth households, for example, the MPC rises from approximately 3 percent to close to 16 percent when banks are exposed to the regulation.

[16] Jensen, Hove Ravn, and Santoro (2017) find that tighter financial regulation may induce *higher* aggregate volatility in a model with occasionally binding collateral constraints.

[17] Perhaps counter-intuitively, the share of borrowers in the economy also increases from 23.5 percent to 30 percent. This is due to movements in and out of debt due to idiosyncratic income shocks and the fact that there are more households close to the kink in the budget set.

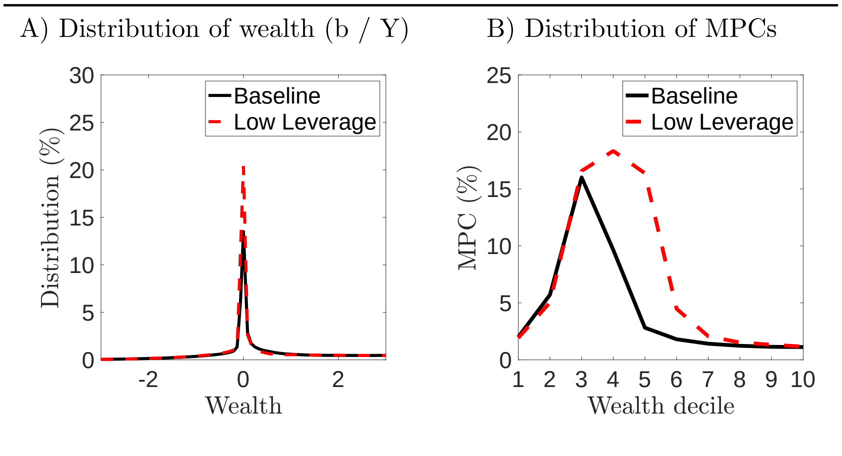
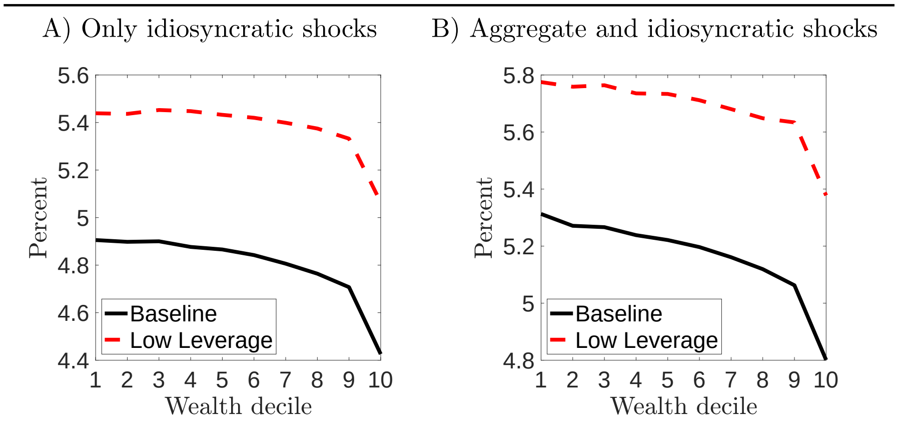


Figure 11: Distributions: Baseline and low leverage



Notes: Volatility refers to the standard deviation of quarterly growth rates of household consumption over five years (averaged over wealth deciles) computed by simulating 200.000 individuals and 1.000 periods.

Figure 12: Micro consumption volatility by wealth deciles

This increase in the MPC, in combination with the high variance of idiosyncratic income risk relative to aggregate risk, has significant consequences for household consumption smoothing. Figure 12 illustrates the volatility of *household* consumption spending across wealth deciles. We compute this measure as the standard deviation of consumption growth over a 5 years horizon conditional on initial wealth.[18] Panel A reports this measure when allowing for idiosyncratic income risk only while Panel B introduces aggregate shocks as well. Regardless of whether one allows for aggregate shocks or not, household consumption volatility increases across the entire wealth distribution in the face of the regulatory policy.[19] Quantitatively, the increase in consumption volatility is very large with

[18] The figure shows the average standard deviation of quarterly growth rates of household consumption over a five year horizon computed over 200.000 individuals and 1.000 periods and then averaged over wealth deciles.

[19] There is ample evidence that changes in the cost of credit affect household consumption, see for example Leth-

the median wealth household experiencing an increase in its consumption volatility of more than 10 percent in the face of the regulatory policy thus indicating significantly reduced opportunities for consumption smooting in the regulated economy.

Given these results, we now examine the welfare consequences of macroprudential regulation. We compute consumption equivalent welfare measures across deciles of the wealth distribution. To capture the effects of aggregate volatility on welfare we solve the model by a second order perturbation.[20] We report the results in Table 7. There are significant welfare losses for households across the entire wealth distribution associated with the regulatory policy, all households regardless of their wealth prefer the unregulated economy. In the absence of aggregate shocks, the average welfare loss is as large as 1.04 percent of life-time consumption and this measure *rises* to 1.35 percent when adding aggregate risk.

Comparing the two first columns of the table informs about the sources of the welfare losses. The changes in the interest rate schedule harms all households in the face of idiosyncratic risk only. Indebted households lose out because of the higher cost of consumer credit. Households with little or no wealth suffer from the higher consumption volatility induced by the exaggerated kink in the budget set. Richer households are impacted negatively by the lower return on savings. The impact on the latter group corresponds to no less than a five percent drop in life-time consumption but losses are large across the distribution. Adding aggregate risk induces an additional welfare cost for all but the top ten percent of the wealth distribution despite the decline in aggregate volatility when regulating the banks. The reason for this additional welfare loss for the bottom 90 percent of the wealth distribution is the decline in consumption smoothing options induced by the larger interest rate spread. For the poorest third of the households, this second welfare loss is as big as the welfare loss in the face of idiosyncratic risk only. Only the richest ten percent of households gain from the decline in aggregate volatility in isolation but their overall welfare loss is still very large (4.8 percent). Thus, in the heterogeneous agent setting, while the macro prudential policy stabilizes at the aggregate economy level, it is associated with detrimental effects on the welfare of individual households.

Interestingly, the aggregate welfare loss in the representative agent economy is very similar to the corresponding loss in the HANK economy. The sources of the welfare losses are very different though. While it is the decline in consumption smoothing opportunities and in the return on capital that induce welfare losses in the HANK model, it is the increase in the cost of capital that does so in the representative agent economy.[21]

Petersen (2010) who find sizable consumption responses to lower cost of credit.

[20] 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 capital stock discussed above. The consumption equivalent measures are computed assuming that consumption adjusts while leaving labor supply to adjust to the new allocation.

[21] Another main difference is that the stabilization of the economy as such is welfare enhancing in the representative agent but not when we allow for heterogeneous agents.

These results add significantly to the literature on macro prudential regulation. The key new results are induced by (i) the endogeneity of the savings rate which is determined by preferences in a representative agent framework but impacted by precautionary savings in the HANK setting we study, and (ii) the impact of interest rate spreads on consumption smoothing possibilities in the face of idiosyncratic and aggregate risk. It is worth, though, pointing out that we have not considered systemic risk issues arising from occasionally binding aggregate constraints that would still pose potentially considerable costs in the heterogeneous agent setting.

Table 7: Welfare costs of macroprudential regulation

	Low vs High Leverage		**Countercyclical Leverage**
Shocks	idiosyncratic	aggregate&idiosyncratic	aggregate&idiosyncratic
1. Wealth decile	-0.52%	-1.06%	0.054%
2. Wealth decile	-0.39%	-0.87%	0.051%
3. Wealth decile	-0.39%	-0.86%	0.049%
4. Wealth decile	-0.37%	-0.84%	0.043%
5. Wealth decile	-0.45%	-0.87%	0.040%
6. Wealth decile	-0.52%	-0.89%	0.035%
7. Wealth decile	-0.65%	-0.95%	0.026%
8. Wealth decile	-0.91%	-1.14%	0.019%
9. Wealth decile	-1.35%	-1.56%	0.008%
10. Wealth decile	-5.14%	-4.76%	-0.063%
Aggregate	-1.04%	-1.35%	0.030%
RANK	-1.17%	-1.14%	0.092%

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 in columns 2-3. Column 4 compares the baseline to an economy with countercylical leverage rule. Aggregate welfare is calculated as $\left[\frac{\int \tilde{v}_i d\Theta^*}{\int v_i^* d\Theta^*}\right]^{\frac{1}{1-\mu}}$ and welfare for each decile in the same way for each decile of the baseline wealth distribution.

Last, we ask whether a cyclical macro prudential policy might work better. To investigate this, we study the following rule:

$$\lambda_t = \overline{\lambda}\left(\frac{\mathbb{E}_t\left(R_{K,t+1} - R_{S,t+1}\right)}{\overline{R}_K - \overline{R}_S}\right)^{-\kappa_\lambda} \tag{60}$$

where $\overline{\lambda}$ is the fraction of assets that bankers can divert discussed earlier, and $\kappa_\lambda \geq 0$ is the semi-elasticity of the macro prudential policy to the interest rate spread. The idea of this policy is to relax capital requirements in recessions when spreads are high and vice versa in booms. Gertler et al (2020) examine a similar policy rule that allows for a non-linear component whereby only increases in capital requirements beyond those imposed by the "market" are imposed. We solve by a perturbation and therefore to do not introduce such non-linearities.

This policy also stabilizes the economy, see Figure A.2, through the countercyclical variations in capital requirements which lead to much smaller variations in interest rate spreads than in the baseline economy. Since this policy does not impact on the stationary equilibrium (in the absence of aggregate shocks), this may indicate potential welfare gains from cyclical variations in bank regulation. The last column of Table 7 reports the welfare consequences of introducing the cyclical macro prudential policy discussed earlier. We find small but positive potential welfare gains for all wealth deciles apart from the wealthiest 10 percent of households. The welfare gains are largest for the poorest households who would be willing to sacrifice 0.054 percent of their consumption to see the policy implemented while the richest decile suffer a loss corresponding to a 0.063 percent drop in their consumption.

Nonetheless, these numbers ignore any resource costs of implementing the policy which could potentially outweigh the small welfare gains. Moreover, the policy also suffers from potential time-inconsistency issues since the regulator would have an incentive to abandon the regulation in booms.[22] Perhaps most seriously, in anticipation of the relaxation of capital requirements in recessions prescribed by the rule, there my be moral hazard problems associated with banks, see e.g. Farhi and Tirole (2012). Thus, there are good reasons to doubt whether the policy would eventually be able to produce welfare gains.

7 Conclusions and Summary

In this paper we have introduced frictional financial intermediation into a heterogeneous agents New Keynesian model. We argue that this setting has rich implications for macroeconomic fluctuations, for the distributional consequences of aggregate shocks, and for the impact of macro prudential regulation.

Relative to representative agent models, our analysis adds an important role for financial intermediaries in addition to facilitating financial flows from the household sector to the corporate sector: Provision of consumer loans to households experiencing adverse income shocks. This new aspect generates a key role in the model for the spread between the cost of consumer loans and the savings rate that introduces a wedge between the intertemporal marginal rate of substitution of borrowers and savers, and induces a mass-point in the wealth distribution at zero liquid wealth. Relative to the HANK literature, the model demonstrates the importance of the endogenous movements in the interest rate spread induced by frictional financial intermediation both for aggregate fluctuations and for the distributional consequences of aggregate shocks.

We have shown that the model produces a number of novel results. First, the HANK model

[22] Whether macro prudential policies suffer from time-inconsistency depends on their design and on the externality that they are meant to address. Bianchi and Mendoza (2019) show that optimal macro prudential policy is time-consistent in a setting with collateral constraints.

extended with frictional financial intermediation can account for key business cycle facts including the cyclical properties of consumer debt and interest rate spreads in addition to standard moments such as the volatility and comovement of macroeconomic aggregates. Furthermore, frictions in financial intermediation induce a financial accelerator as in standard representative agents model yet with novel implications at the micro level. In particular, recessionary shocks induce dispersion in consumption at the household level through their impact on interest rate spreads. We provided empirical evidence that is supportive of these implications. Finally, we argued that ex-ante macro prudential policies may have unwarranted consequences due to reducing household insurance options through borrowing and saving in the face of idiosyncratic income risk.

We have ignored another key role of financial intermediaries, provision of secured lending for, most importantly, real estate. We have also ignored issues surrounding consumer default as well as systemic banking crises through the presence of occasionally binding constraints. These and other issues would be interesting avenues for future research.

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A Appendix

A.1 Data

Unless otherwise noted, all series are available at quarterly frequency from 1973Q1 to 2019Q4 from the St.Louis FED - FRED database (mnemonics in parentheses).

A.2 Data for Calibration

Capital. Private fixed assets (NIPA table 1.1) over quarterly GDP, averaged over 1973-2019.
Government debt. Gross federal debt (MVGFD027MNFRBDAL) over quarterly GDP, averaged over 1973-2019.
Household Credit. Consumer loans (CLSACBW027SBOG) over quarterly GDP, averaged over 1973-2019.
Average top 10 percent share of wealth. Source is the World Inequality Database (1973-2019).

A.2.1 Data for Local Projections

See Table A.1 for the definitions and sources of the data used in the local projections. Below we describe the micro data from the Consumer Expenditure Survey in more detail.

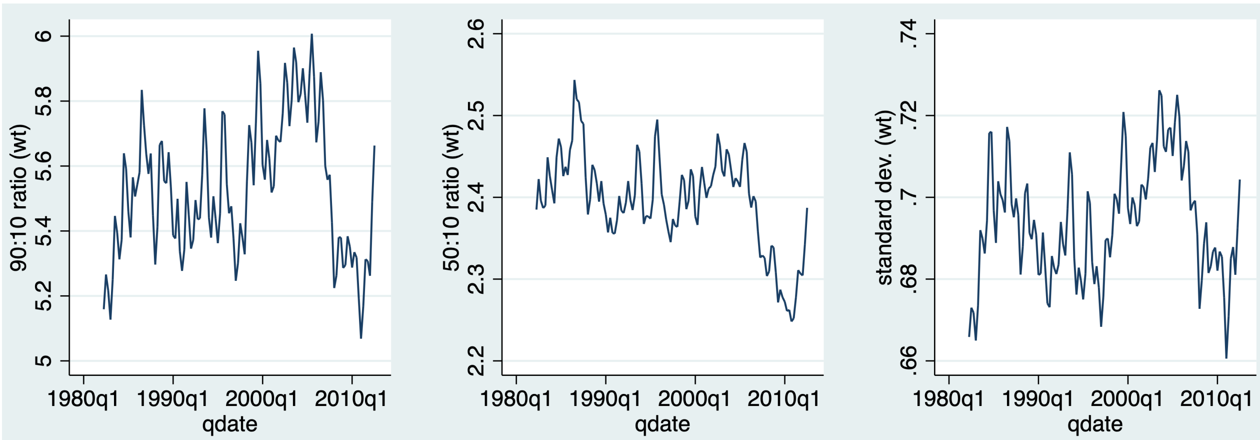
Consumer Expenditure Survey

We obtain the data on household consumption expenditures from the Consumer Expenditure Survey (CEX). The CEX has received a considerable amount of attention because it is the only U.S. data set with detailed information on consumption expenditure. While the Survey has been criticized for not aggregating up to the NIPA statistics, it has become clear that when concentrating upon comparable items and populations, changes in the CEX are mirrored in changes in the NIPA data. What is more, the CEX allows us to study the distribution of consumption expenditures quarter by quarter from the 1980s onward.

In our analysis we use repeated cross-sections and only apply limited sample selection to have a representative sample of U.S. households resembling the households in our model. Our definition of consumption is as wide as possible and includes non-durables, durables, and housing services. We restrict the sample to households age 20-60, working at least a quarter of full time, have a partner and less then 10 family members. Table A.1 shows the ratios of 90-10 and 50-10 percentiles of the consumption distribution and the standard deviation of log consumption for each quarter (all calculated using survey weights).

Table A.1: Data Definitions and Sources

Series	Definition	Source
Consumer loan rate (rpers)	Finance rate on 24 months personal loans at Commercial Bank	FRED, TERMCBPER24NS
Credit card rate (rcred)	Commercial Bank interest rate on credit card plans	FRED, TERMCBCCALLNS
T-Bill rate (tbill)	3 months Treasy Bill rate, secondary market	FRED, DTB3
CPI (cpi)	Consumer price index, all urban consumers	FRED, CPIAUCSL
Real GDP (gdp)	Real Gross Domestic Product, chained 2012 dollars	FRED, GDPC1
Real investment (inv)	Real gross private domestic investment, chained 2012 dollars	FRED, GPCIC1
Employment (emp)	All employees, total nonfarm	FRED, PAYEMS
Total Factor Productivity (TFP)	Log Change in TFP	Fernald (2014), https://www.johnfernald.net/TFP
Financial stress (finstress)	Romer-Romer indicator of financial stress	Romer and Romer (2017)
50th Decile Consumption (c^{50})	All consumption expenditures (non-durable, durable, housing)	Bureau of Labor Statistics, Consumer Expenditure Survey
10th Decile Consumption (c^{10})	All consumption expenditures (non-durable, durable, housing)	Bureau of Labor Statistics, Consumer Expenditure Survey
Charge-off rate	Charge-off rate on credit card loans all commercial banks	FRED, CORCCACBS
spr^{pers}	$\log(1 + rpers/100)/(1 + tbill/100)$	own calculation
spr^{cred}	$\log(1 + rcred/100)/(1 + tbill/100)$	own calculation
c^{5010}	$log(c^{50}/c^{10})$	own calculation
Labor productivity	gdp / emp	own calculation

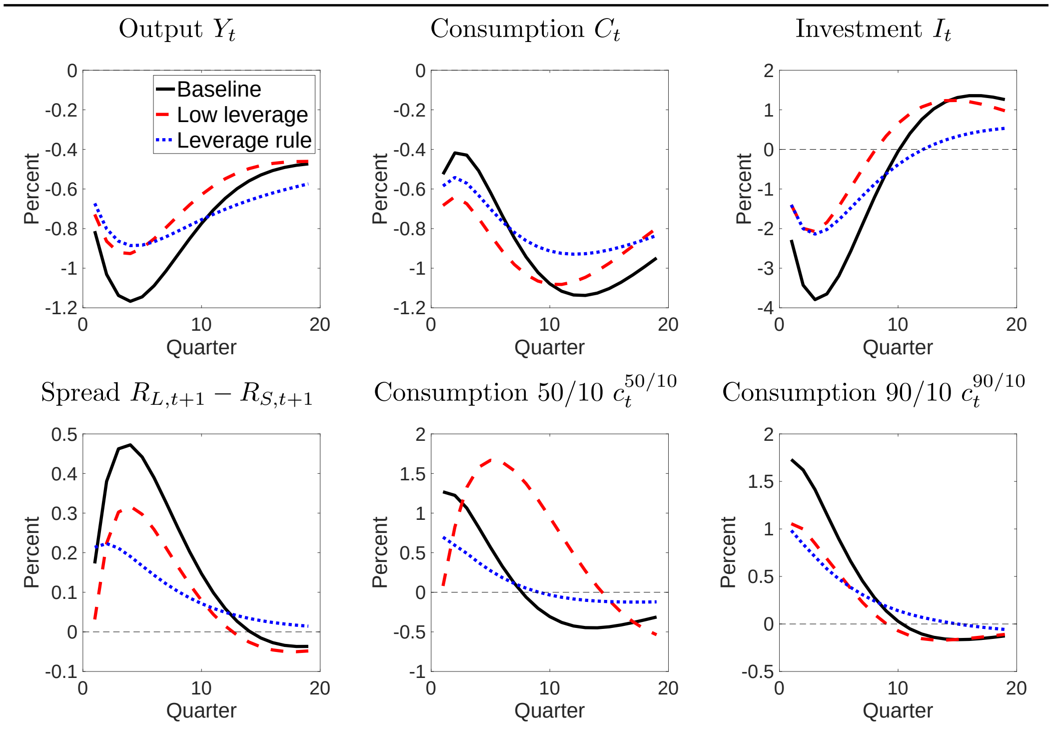


From left to right: ratio of 90-10 percentiles, ratio of 50-10 percentiles, standard deviation of log consumption.

Figure A.1: Consumption dispersion - CEX

A.3 Further Impulse Responses

Figure A.2 shows the impulse responses to a one percent capital quality shock in the baseline model, the model with less leverage in steady state, and the model with countercyclical leverage rule.



Impulse responses to a one percent capital quality shock in the baseline model (black-solid line), with stabilization via higher capital requirements in steady state (red-dashed line), and with stabilization via a rule for banking capital requirements (blue-dotted line).

Figure A.2: Aggregate and distributional effects of a capital quality shock under different macroprudential policies