DANMARKS NATIONALBANK

WORKING PAPER | Consumption
12 February 2024 | No. 200

Financial Frictions: Micro vs. Macro Volatility

Danish data show that elevated credit spreads reduce consumption of indebted households, inducing a countercyclical marginal propensity to consume. We develop a HANK model, incorporating bank financing for both firms and households. We find that banking regulation, while stabilizing at the aggregate level, may induce volatility at the household level.

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Keywords

Economic policy
Models
Macroprudential policy
Consumption

Financial Frictions: Micro vs Macro Volatility *

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February 1, 2024

Abstract

Consumer credit spreads significantly impact consumption and asset dynamics, affecting indebted households' spending behavior and the income sensitivity of consumption. Analyzing Danish data, we find that elevated credit spreads reduce consumption of indebted households. Our results suggest that the marginal propensity to consume (MPC) is countercyclical, with credit spreads playing a crucial role. We develop a HANK model, incorporating bank financing for both firms and households. Agency frictions generate a countercyclical credit spread, which induces heterogeneous incidence of aggregate shocks consistent with the data. Banking regulation, while stabilizing at the aggregate level, may induce volatility at the household level.

JEL Codes: C11, D12, D31, E32, E52, G51

Keywords: Household consumption, consumer credit spreads, business cycles, financial frictions, incomplete markets, macroprudential regulation, monetary policy.

*We are grateful to the editor and three referees for constructive comments. We also thank discussants and seminar participants at numerous seminars for comments. Luetticke gratefully acknowledges support through the Lamfalussy Research Fellowship funded by the European Central Bank. Ravn acknowledges financial support from ERC Project BUCCAC - DLV 8845598. The views expressed herein are those of the authors, and do not necessarily reflect the official views of the Bank of Korea, the ECB, or the National Bank of Denmark.

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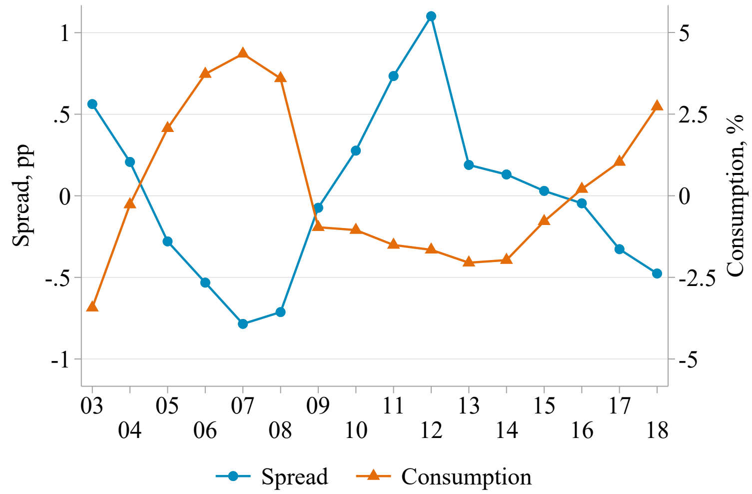
1 Introduction

In this paper, we examine how consumer credit spreads affect aggregate and household outcomes. We provide empirical evidence from Danish household data that the consumer credit spread matters for consumption and wealth dynamics. We then study a HANK model in which leveraged banks provide corporate loans to firms and consumer credit to households. Frictions in the financial sector induce a spread of borrowing rates over saving rates that moves countercyclically. Cyclical fluctuations in the consumer credit spread are an important source of heterogeneous effects of aggregate shocks across the wealth distribution. We argue that while tighter bank regulation may stabilize the aggregate economy by dampening the financial accelerator, it may destabilize at the microeconomic level.

We are not the first to highlight the importance of consumer credit spreads. Pissarides (1978) shows that spreads between borrowing and saving rates invalidate the decoupling of income and consumption dynamics of the permanent income hypothesis under perfect foresight. Davis, Kubler and Willen (2006) study how credit spreads affect household portfolio choices, while Kaplan and Violante (2014) focus on their impact on the marginal propensity to consume (MPC). Zeldes (1989) shows that differences in the price of credit across households matter for Euler equation-based tests of consumption dynamics under liquidity constraints. However, the lack of data on household-specific interest rates leads him to proxy the effect of liquidity constraints by the ratio of liquid assets to income. This practice has since been followed, including in influential work on estimating the MPC such as Johnson, Parker and Souleles (2016). An important exception to this practice is Kreiner, Lassen and Leth-Petersen (2019), who study the impact of cash transfers in Denmark in 2009 and argue that differences across households in "marginal interest rates" predict spending decisions.

We make three key contributions. First, we provide empirical evidence from Denmark on how household consumption choices are related to interest rate spreads. We study a dataset containing about 16 million observations for the period 2003-18 that combines administrative data on household characteristics, income, and asset positions with bank-level data to derive measures of household-specific credit spreads. Figure 1 shows the average consumer credit spread in these data plotted against detrended aggregate consumption in Denmark. It is evident that the interest rate spread is strongly countercyclical.[1] Using household data, we show that households with moderate assets that are exposed to higher consumer credit spreads are more likely to find themselves with close to zero net assets at the end of the year. Using quantile regressions we estimate how consumption, income and credit spreads are related across the net wealth distribution. Controlling for time- and household fixed effects, consumption and income are positively correlated, but mostly so for poorer households. Higher spreads are associated with lower consumption spending for indebted households, while the correlation is positive for wealthier households. When households are exposed to higher spreads, the income sensitivity of their consumption increases, especially for poorer households. Building on these

[1] The consumer credit spread is also countercyclical in the U.S., see Lee, Luetticke and Ravn (2020).



Notes: Evolution of the cyclical component of annual consumption and the credit spread in Denmark over time. Annual consumption is imputed from household balance sheets as described in Section 2, aggregated and then detrended using a 5th order polynomial. The spread is measured as the average cross-household bank-level spread between borrowing and deposit rates.

Figure 1: The Cyclicality of Interest Rate Spreads

results, we derive an aggregate measure of the consumption-income elasticity that varies over time as a function of how households move across wealth bins and as a function of changes in the consumer credit spread. We show that this measure is volatile and countercyclical due to changes in both net worth and the consumer credit spread. Holding spreads constant roughly halves its volatility and countercyclicality. We later show that this elasticity is highly correlated with the MPC in the model, suggesting that the MPC is countercyclical. To the best of our knowledge, the only other existing evidence on countercyclical MPCs is Gross, Notowidigdo, and Wang (2020), who use the removal of bankruptcy flags from credit reports to estimate MPCs in the U.S. and their time variation.

Second, we study a novel HANK model with banking in which spreads vary *endogenously* in response to aggregate shocks. Households supply labor, consume, and save in either bonds or bank deposits. Households cannot short these assets, but they can access consumer credit provided by banks. They are subject to idiosyncratic income risk and aggregate risk due to movements in the prices of labor, goods, and assets in response to aggregate shocks. Banks combine household deposits with net worth to invest in consumer and business loans. Following Gertler and Karadi (2011), banks are leverage constrained due to an agency problem that induces a spread between the expected return on their assets and the return they offer on deposits. On the supply side, we use a New Keynesian sticky price structure, with a central bank setting the short-term nominal interest rate and a fiscal authority responsible for debt, tax, and spending policies. We allow for aggregate shocks to monetary policy, total factor productivity, and capital quality, a shock that affects the net worth of banks.

Financial frictions affect both the household and the supply side. The spread between borrowing and saving rates induces differences in expected consumption growth rates between savers and borrowers in the household sector and introduces a kink in the household budget constraint at zero net worth. Because of this kink, the net wealth distribution has a mass point of households with no liquid assets. Spreads between corporate lending and deposit rates also raise the cost of capital for intermediate goods producers. The model can account for key business cycle statistics. These include a countercyclical consumer credit spread,[2] and volatile and procyclical consumer credit, moments that have received relatively little attention in the literature.[3] In response to monetary policy shocks and shocks to banking sector net worth, the HANK model generates a financial accelerator.

We confront the model not only with the aggregate data, but also with its implications for household data. As in the data, consumer credit spreads impact on asset dynamics for households with moderate net assets. Moreover, the relationship between consumption, income, and consumer credit spreads across the net wealth distribution is similar to that estimated in the data. We show that the MPC is countercyclical in the model, with the consumer credit spread being an important factor, because higher spreads in recessions discourage spending by debtors and increase the income sensitivity of households with near-zero net wealth. Importantly, the combination of financial frictions and idiosyncratic risk leads to heterogeneous effects of aggregate shocks across the wealth distribution. We show that, in the short run, a contractionary monetary policy shock stimulates consumption spending by wealthy households and sharply reduces consumption spending by indebted households, while in the medium run, the responses converge across the distribution.

Third, we examine the welfare consequences of tighter bank capital requirements. This policy dampens the financial accelerator at apparently no aggregate cost because, in contrast to complete market models, it stimulates saving (through a precautionary channel). However, there are significant welfare costs of such regulation across the wealth distribution, as such regulation increases the consumer credit spread and reduces the return on savings. Because of these effects, we find welfare costs across the distribution when we focus on the stationary equilibrium. These costs are mitigated in the face of aggregate shocks due to lower volatility of consumer credit spreads, but the costs outweigh the gains. Thus, the model indicates a trade-off between micro and macro volatility.

Our paper contributes to the literature on financial frictions, cf. Bernanke and Gertler (1989), Carlstrom and Fuerst (1997), Christiano, Motto and Rostagno (2014), Gertler and Karadi (2011) or Gertler and Kiyotaki (2010). We add incomplete markets and heterogeneous agents to this literature, and model banks as simultaneously intermediating between the corporate sector and households, and between different segments of the household sector. We also contribute to the literature on unsecured consumer credit, see for example Athreya (2002), Chatterjee et al (2007) or Nakajima and Rios-Rull (2019). This literature has mainly focused on the impact of consumer default risk, while ours focuses

[2]Consistent with empirical evidence, the model also implies a countercyclical corporate credit spread, see e.g. Gilchrist and Zakrajsek (2012)

[3]A notable exception is Nakajima and Rios-Rull (2019), who focus on defaultable consumer credit and introduce many realistic features of the U.S. legal system.

on agency problems in the financial sector as in Curdia and Woodford (2011). We argue that these factors, which Dempsey and Ionescu (2021) find empirically important for understanding variations in credit spreads, are important for consumption dynamics.

In contrast to the HANK literature, cf. Bayer et al (2019), Kaplan, Moll and Violante (2018), McKay and Reis (2016), Ravn and Sterk (2017), we introduce financial intermediation, thereby emphasizing another aspect of financial frictions in addition to the lack of insurance against idiosyncratic risk assumed in that literature. We show that this has important consequences for the distributional impact of aggregate shocks. Fernandez-Villaverde, Hurtado and Nuno (2023) also introduce frictional financial intermediation into a heterogeneous agent framework, but focus on the impact on aggregate risk in a setting that abstracts from goods market frictions and household debt. Wang (2018) studies a model of frictional financial intermediation and household heterogeneity, where the latter derives exclusively from life-cycle issues.

Finally, the paper adds new insights on the impact of financial regulation, see Bianchi and Mendoza (2010), Farhi and Werning (2016), Lorenzoni (2008) or Stein (2012). Our contribution is the introduction of heterogeneous agents and idiosyncratic risk, which we argue is important. Like us, Bigio and Sannikov (2023) consider the trade-off between macro and micro volatility in a setting with incomplete markets and banking frictions. These authors focus on frictions in interbank markets and study a model of incomplete markets with unemployment risk but without capital.

2 Spreads and Household Consumption: Empirical Evidence

We first provide empirical evidence on the relationship between consumption, income, assets, and credit spreads using Danish administrative data.

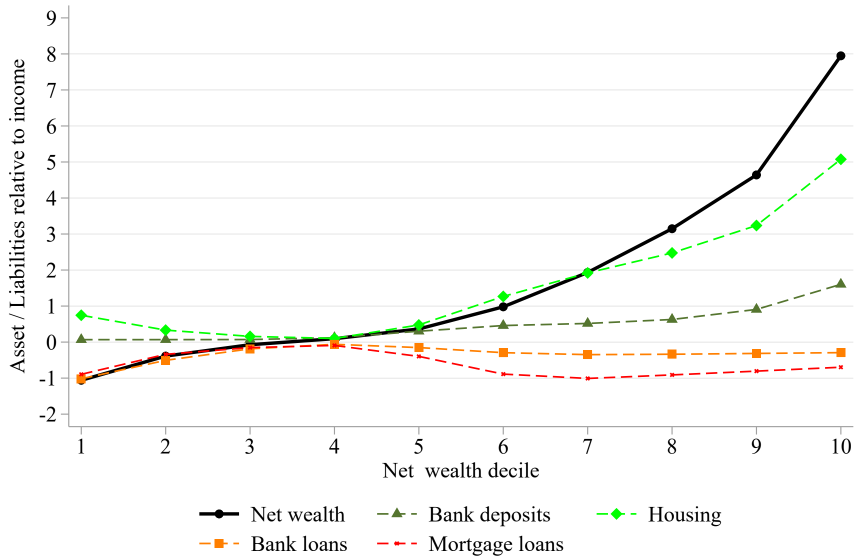
2.1 Data and Measurements

We examine annual Danish register data provided by Statistics Denmark for the sample period 2003-2018. The register data are collected by a third party. Basic information on age, sex, education, household composition, etc. and on income and wealth is compiled by Statistics Denmark by merging administrative data with income tax return data. In addition, we combine income tax return data with bank-level reporting of interest rates to Danmarks Nationalbank as part of its Monetary and Financial Institutions (MFI) data.[4]

We follow the imputation method described in Crawley and Kuchler (2023) to estimate consumption spending for household i in year t, $C_{i,t}$:

$$C_{i,t} = Y^L_{i,t} + Y^F_{i,t} - (A_{i,t+1} - A_{i,t}) \tag{1}$$

[4]The relevant bank data have been deposited and merged at Statistics Denmark.



Notes: The figure shows the average asset and liability to income ratios for deciles of the net wealth distribution. Average ratios are first constructed for each decile and year, then averaged over the period 2003-2018. Net wealth is the value of assets less liabilities.

Figure 2: Net Wealth and Asset Distribution in Denmark

where $Y_{i,t}^L$ is after-tax labor income net of transfers and $Y_{i,t}^F$ is after-tax financial income. $A_{i,t+1}$ is the value of the household's net worth at the end of the year t, which includes housing wealth, portfolio wealth, bank deposits, and bank and mortgage debt, all of which are reported in the household tax return data.[5] The wealth measure *does not* include pension wealth or business wealth. Following Crawley and Kuchler (2023), we make the following selection decisions. First, due to the lack of data on business assets, we exclude households with self-employed members or with substantial income from private businesses. Second, because housing values are estimated in non-adjustment years, we exclude households involved in a housing transaction in the current or previous year, as their wealth estimates may jump in this window when housing values are adjusted to transaction prices. Households with negative imputed consumption spending are also excluded. Finally, we exclude households in the bottom and top one percent of the wealth or income distribution and the first observation for each household. The nominal spending measures are deflated by the consumer price index to produce a real measure of household consumption spending, $c_{i,t}$. The total number of year $\times$ household observations is about 15.5 million, and summary statistics are reported in Appendix A. Aggregated across households, the imputed consumption measure is very close to the survey-based national accounts estimates of consumption for Denmark, see Abildgren et al (2018).

Figure 2 shows the distribution of household net wealth and its four most important components normalized by annual household income, $(Y_{i,t}^L + Y_{i,t}^F)$, across deciles of the net wealth distribution (averaged across the sample period). The net wealth-to-income ratio goes from close to eight for the

[5]Some large durable goods, such as cars, are also included.

wealthiest decile to about minus one for the poorest decile. 8.7 percent of households—located in the third and fourth deciles—hold no more than two weeks of median income in net assets, and typically have very few gross financial assets and liabilities as well. In contrast, those in the top decile tend to hold positive bank deposits and have little bank debt, while those in the bottom deciles hold no bank deposits, but have considerable bank debt. 25.2 percent of households have negative net wealth exceeding two weeks of median income, and 66.1 percent of households have positive net wealth.

We combine tax return data and bank-level reporting of interest rates to estimate household-level interest rate spreads. Danish households report the end-of-calendar year balances on all their bank accounts to the tax authorities. Using this information, we define each household's primary bank connection (for loans and for deposits separately) as the bank in which they have the largest balance at the end of the calendar year.[6] From this, we derive a household-specific interest rate spread, $R^S_{i,t}$, as the difference between the loan rate at household i's primary loan bank and the return on deposits at its primary deposit bank in year t. We use the averages of the interest rates the banks applied during year t to measure these spreads. If a household does not have loans, we use the loan rate of the primary deposit bank. Figure 1 shows the cross-sectional average interest rate spread and (detrended) aggregate consumption. The "aggregate" consumer credit spread is strongly countercyclical, a feature that is shared by the U.S., see Lee, Luetticke and Ravn (2020).

2.2 Results

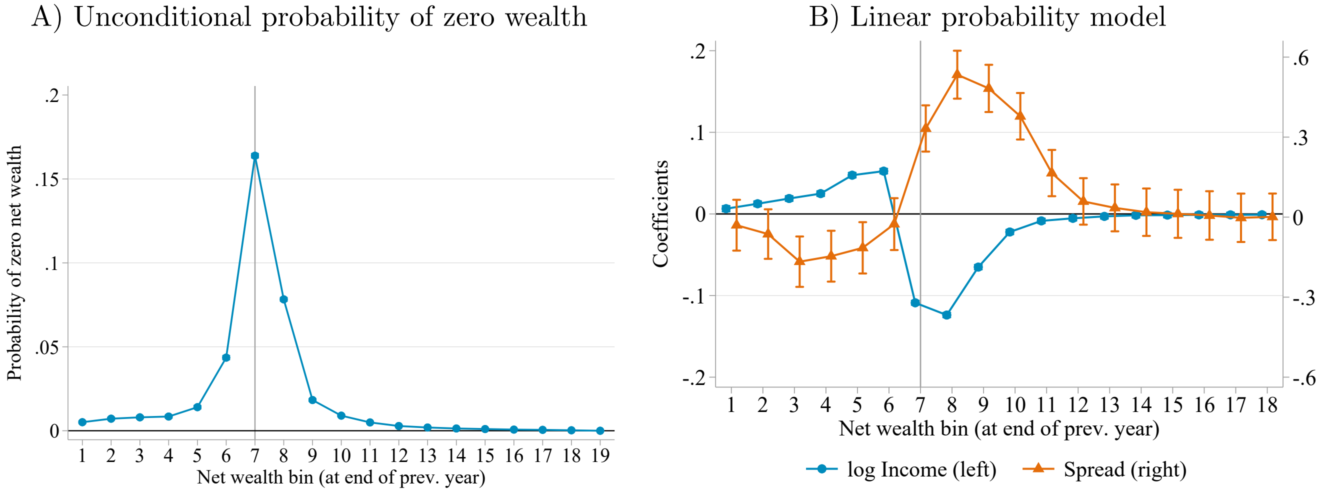
Using a threshold of two weeks of income, Figure 3 Panel A shows the fraction of households with zero net wealth at the end of the year across bins of the beginning of year net wealth distribution with the seventh bin corresponding to this state.[7] Approximately 16 percent of households that begin the year with zero net wealth find themselves in that situation by the end of the following year. There is considerable movement into this state by households in the immediately adjacent bins of the net wealth distribution, while there is essentially no risk of households in the upper bins having zero net wealth at the end of the year. To understand the determinants of such wealth dynamics, we estimate:

$$\mathbf{1}_{(|A_{i,t+1}| \leq Y_i^{Crit})} = \sum_j \mathbf{1}_{(A_{i,t} \in A_j^{Net})} \beta_j X_{i,t} + \gamma_t + \varepsilon_{it} \tag{2}$$

where $\mathbf{1}_{(|A_{i,t+1}| \leq Y_i^{Crit})}$ is a dummy equal to 1 for households with net wealth at the end of calendar year t below two weeks of median weekly income (in 2007), and γ_t is a time-fixed effect. $X_{i,t}$ consists of a wealth bin-specific constant, household-specific interest rate spreads and residualized household

[6] Deposits are mostly traditional bank accounts but also some slightly less liquid products. Loans includes all non-mortgage loans with banks: credit cards, overdraft accounts, bank loans, student loans, etc.

[7] Bins are constructed using fixed thresholds based on the 2007 distribution of net wealth. The "zero" bin includes households with plus/minus two weeks of 2007 median HH income. The remaining 18 bins are of approximately equal size in 2007. Each bin contains approximately 5% of households in that year.



Notes: The figure shows unconditional transition probabilities to the zero net wealth state by net wealth decile (Panel A) and the change in transition probabilities with cross-sectional changes in income and spread (Panel B), estimated from Equation (2). Sampling uncertainty is indicated by vertical bars (95 percent confidence bands). See notes to Figure 2 for definition of net wealth. Zero wealth is defined as net assets within a range of plus/minus two weeks of median household income.

Figure 3: Zero Net Wealth Dynamics

income, estimated as the residual after regressing log household income on household and time fixed effects and household characteristics (age of household head, household size, number and age of children, and education of household head).

Figure 3 Panel B shows the estimated coefficients across net wealth bins. Higher spreads increase the transition rate into the zero net wealth state for households with moderately positive net wealth at the beginning of the year and reduce the outflow rate for households already in this state. Households in the third to fifth net wealth bins that are indebted, on the other hand, appear to be less likely to go to zero net wealth at the end of the year. One interpretation of this is that higher credit spreads increase debt repayments for indebted households, making wealth accumulation more difficult. Recall from Panel A that the poorest households and those with more substantial positive net worth face essentially no risk of transitioning to the zero net wealth bin within a year; consistent with this, we also find that changes in spreads have no impact on the transition rates of these households. The effect of income shocks is intuitive: Positive income shocks reduce the probability of going to zero net wealth for households with low but positive net wealth, and increase this probability for moderately indebted households, while households with more substantial net wealth, whether negative or positive, are unaffected. Thus, credit spreads appear to be important for wealth dynamics.

Next, we investigate the link between consumption dynamics and changes in income and in consumer credit spreads. We estimate the following consumption regressions:

$$\log c_{i,t} = \sum_j \mathbf{1}_{(A_{i,t} \in A_j^{Net})} \left(\beta_{0,j} \log y_{i,t} + \beta_{1,j} R_{i,t}^S + \beta_{2,j} R_{i,t}^S \log y_{i,t} \right) + \alpha_i + \gamma_t + \varepsilon_{i,t} \tag{3}$$

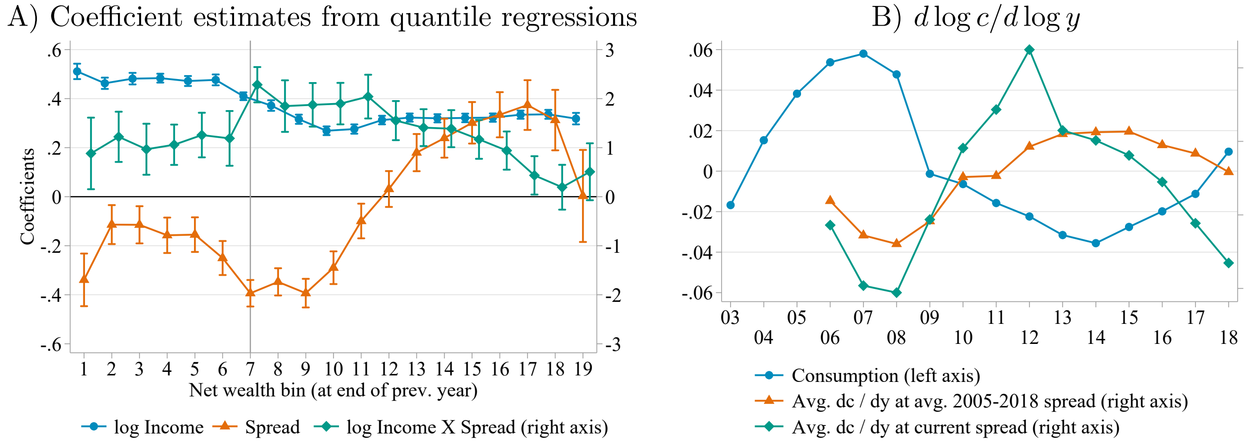
where $y_{i,t}$ is real household after-tax income. We include household fixed effects through α_i and time fixed effects through γ_t. We residualize consumption and income measures (using same controls as above) and allow coefficients to differ across bins of the net wealth distribution.

Table 1: Consumption Regressions

Dependent variable: log consumption	(1) Overall	(2) By net wealth	(3) Model	(4) Model
log income	0.372***		0.259	
	(0.00351)			
Low net wealth × log income		0.397***		0.352
		(0.00481)		
High net wealth × log income		0.335***		0.079
		(0.00425)		
Rate spread	-0.266***		-1.847	
	(0.0138)			
Low net wealth × spread		-0.362***		-2.818
		(0.0161)		
High net wealth × spread		-0.101***		-0.052
		(0.0196)		
log income × rate spread	1.366***		1.087	
	(0.0761)			
Low net wealth × log income × spread		1.640***		1.687
		(0.108)		
High net wealth × log income × spread		0.875***		0.024
		(0.0925)		
R^2	0.591	0.594		
RMSE	0.236	0.235		
Observations	15,610,327	15,610,327		
Fixed effects	HH, year	HH, year		

Notes: Columns (1) and (2) reports the coefficients estimated from Equation (3) on the Danish household data. Columns (3) and (4) reports the coefficients when estimating Equation (3) on artificial data from the baseline model. High net wealth denotes households above the median and low net wealth those below.

Table 1 reports the results when pooling households across the wealth distribution (column 1), and when distinguishing between above and below the median wealth households (column 2). In the pooled regression, we find a positive coefficient on income, a negative coefficient on the spread and a positive interaction effect. When allowing coefficients to depend on wealth, we find that the income-consumption link is strongest for below-median wealth households; that a higher spread is



Notes: Panel A illustrates the parameters estimated from Equation (3). The underlying wealth distribution is trimmed at the 3rd and 97th percentile. The error bars illustrate 95% confidence intervals. Standard errors clustered at the household level. Panel B illustrates detrended aggregate consumption together with the implied variations in $d \log c/d \log y$ coming from either movements in net wealth or in the interest rate spread using the cross-sectional average of the implied path using the parameter coefficients shown in Panel A.

Figure 4: Consumption, Wealth and the Spread

negatively associated with consumption for households below median wealth; and, that there is a strong positive interaction effect between income and spreads especially for below-median wealth households. Although the results should not be given a causal interpretation,[8] they would be consistent with poorer households' consumption being more income-sensitive, and with higher costs of credit reducing wealth-poor households' consumption relative to wealthier households. Appendix A shows that the results are robust to either excluding households when purchasing a car or capitalizing car expenditures, and to estimating Equation (3) using a difference specification. Another concern is that the relationship between credit spreads and consumption is confounded with mortgage rates because of the correlation between consumer credit spreads and mortgage rates at the household level. Institutional features specific to the Danish mortgage market minimize such concerns, as mortgage rates do not depend on the borrower's credit situation, provided that the borrower is approved for a mortgage.[9]

Panel A of Figure 4 shows the parameters when estimating (3) for five percent bins of the net wealth distribution. The coefficients on income are positive across the wealth distribution and decline with wealth, ranging from nearly 0.5 for the poorest households to about 0.35 for the wealthiest

[8]For one, income and consumption choices are likely to be jointly determined.

[9]Mortgages in Denmark are financed by covered bonds, i.e. obligations of mortgage lenders collateralized by pools of mortgages. These bonds are issued by mortgage banks that operate in a very competitive market and charge very similar mortgage rates and fees. Investors buy the mortgage bonds while borrowers take out mortgages from the banks. Once the banks have approved a loan, they have no further influence on mortgage rates, which are determined entirely by the market. For more details on the Danish mortgage market, see Andersen et al (2020).

households. Consumer credit rate spreads, on the other hand, have a non-monotonic relationship with consumption: Higher spreads are associated with lower consumption for households with negative, zero, and moderately positive wealth. Conversely, for households with significantly positive wealth, higher spreads are associated with higher consumption. The interaction effect between income and spreads is insignificant for the very richest households, but positive for all other households. Interestingly, this term is largest for households with net wealth close to zero.

We use the quantile parameter estimates reported in Figure 4 to derive a measure of the consumption-to-income elasticity across asset bins, $d\log c_{i,t}/d\log y_{i,t} = \beta_{0,j} + \beta_{2,j} R^S_{i,t}$ (j is the asset bin of household i's net wealth at time t). The cross-sectional average of this measure varies over time because of (a) time variation in the distribution of households across bins of the net wealth distribution and (b) changes in interest rate spreads. Panel B in Figure 4 shows detrended aggregate consumption in Denmark and the cross-sectional average of this elasticity measure when we consider, first, only the observed time variation in the allocation of households across wealth bins (line with diamonds) and, second, also the observed time variation in credit spreads (line with triangles). The results indicate some countercyclicality of $d\log c_t/d\log y_t$ in response to wealth fluctuations, but much stronger countercyclicality when also allowing for movements in interest rate spreads.[10] Below, we argue that while this elasticity is not a direct measure of the MPC, it strongly correlates with it.

3 Model

We study a HANK model where banks provide consumer credit and corporate loans. In the baseline model, all assets are liquid. In Section 8 we extend the model with illiquid assets.

3.1 Households

There is a continuum of measure one of ex-ante identical infinitely-lived households, indexed by $i \in [0,1]$, with rational expectations, maximizing the expected present discounted value of their utility streams, which depend on consumption, c_{it}, and hours worked, l_{it}. Households discount future utility at the rate $\beta \in (0,1)$, and the flow utility function is given by:

$$\mathrm{u}\left(c_{i,t}, l_{i,t}\right) = \frac{c_{i,t}^{1-\vartheta_c} - 1}{1-\vartheta_c} - \chi \frac{l_{i,t}^{1+1/\vartheta_l}}{1+1/\vartheta_l}, \tag{4}$$

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

[10] When only allowing for movements across wealth bins, the percentage standard deviation of the elasticity is 1.3 percent and its cross-correlation with HP-filtered output is -0.31. When also accounting for movements in spreads, its standard deviation is 2.4 percent and its cross-correlation with output is -0.53.

Households switch stochastically between being workers and rentiers. Workers take the real wage per efficiency unit, w_t, as given, and have idiosyncratic productivity $h_{i,t} \geq 0$. A worker household remains so in the next period with probability $1-\phi_w \in (0,1)$ and otherwise becomes a rentier, in which case its labor productivity goes to zero. Rentiers receive a non-tradable share $\mathcal{F}_t$ of the corporate and financial sector profits and remain in this state each period with probability $1-\phi_r \in (0,1)$ and otherwise switch to the worker state. In that case, its labor productivity starts at the unconditional mean of 1. Workers' idiosyncratic labor productivity follows the stochastic process:

$$h_{i,t} = \begin{cases} \exp\left(\rho_h \log h_{i,t-1} + \varepsilon^h_{i,t}\right) & \text{with probability } 1-\phi_w \quad \text{if } h_{i,t-1} \neq 0 \\ 1 & \text{with probability } \phi_r \quad \text{if } h_{i,t-1} = 0 \\ 0 & \text{otherwise} \end{cases} \tag{5}$$

where $\varepsilon^h_{i,t} \sim \mathcal{N}\left(0, \sigma_h^2\right)$.

Households can save in riskless nominal government bonds, $b^G_{i,t+1}$, and in nominal bank deposits, $b^D_{i,t+1}$, which are perfect substitutes. Let $R_{N,t}$ be the nominal interest rate on government bonds and $R_{S,t}$ be the gross real return on bank deposits. By arbitrage, it follows that $\mathbb{E}_t R_{S,t+1} = \mathbb{E}_t R_{N,t+1}/\pi_{t+1}$, where π_t is the gross inflation between $t-1$ and t, and $\mathbb{E}_t x_s$ is the expected value of x_s given all the information available at time $t \leq s$. They cannot short any of these assets, but they have access to consumer credit, $b^L_{i,t+1}$, supplied by banks. The banks charge a gross real interest rate $R_{L,t}$ and impose a borrowing limit, $\underline{\mathbf{b}}$ (stricter than the natural borrowing limit), on households' consumer debt:

$$\underline{\mathbf{b}} \geq b^L_{i,t+1} \geq 0, \tag{6}$$

$$b^G_{i,t+1}, b^D_{i,t+1} \geq 0, \tag{7}$$

The banking friction discussed later introduces a premium on consumer credit such that $\mathbb{E}_t(R_{L,t+1} - R_{S,t+1}) \geq 0$ and, as a result, households will only take out consumer loans if they have no assets. We present the households' dynamic problems in Appendix B.

The consumer credit spread drives a wedge between the intertemporal consumption prices faced by borrowers and savers, and induces a kink in household budget constraints at $(b^L_{i,t+1}, b^G_{i,t+1} + b^D_{i,t+1}) = (0,0)$. Consider the households' savings problems (ignoring type switches for simplicity). Four possible states may occur. First, some households (type I) are savers and on Euler equations with a slope given by the savings rate. Other households (type II) are borrowers not constrained by (6) and on Euler equations with a slope determined by the borrowing rate:

$$(c^{\mathrm{I}}_{i,t})^{-\vartheta_c} = \beta \mathbb{E}_t (c^{\mathrm{I}}_{i,t+1})^{-\vartheta_c} R_{S,t+1}$$

$$(c^{\mathrm{II}}_{i,t})^{-\vartheta_c} = \beta \mathbb{E}_t (c^{\mathrm{II}}_{i,t+1})^{-\vartheta_c} R_{L,t+1}$$

Consumer credit spreads thus induce a divergence in the consumption growth rates of savers and borrowers. There are also two groups of high MPC *constrained* households that are not in their Euler equations, either because they are up against the borrowing constraint (III) or because they are at the kink in the budget constraint (IV). Assuming for simplicity that households were in one of these two states at time $t-1$, their consumption levels are given by

$$\begin{aligned} c_{i,t}^{\text{III}} &= (1-\tau_{h,t})\, w_t h_{i,t} l_{i,t} - (R_{L,t}-1)\underline{\mathbf{b}} \\ c_{i,t}^{\text{IV}} &= (1-\tau_{h,t})\, w_t h_{i,t} l_{i,t} \end{aligned}$$

The measure of type III agents is small in most models of incomplete markets, unless agents are close to risk neutral. However, when spreads are significant, there may be a substantial fraction of type IV agents that increases as credit spreads rise.

3.2 Banks

A continuum of banks, indexed by $z \in [0, Z]$, owned by rentiers, is managed by risk-neutral bankers who discount future utility at the rate β and face mortality risk $1-\theta \in (0,1)$. When a banker dies, her wealth 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, as well as between savers and borrowers within households. Combining net worth with household bank deposits, they invest in corporate equity and in consumer credit.

At the beginning of the period, the mortality risk is realized and new bankers enter the economy. Banks then receive deposits $b_{D,t+1}^z$ from households. Next, banks invest the sum of deposits and net worth, n_t^z, 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

$$Q_t b_{F,t+1}^z + b_{L,t+1}^z = n_t^z + b_{D,t+1}^z \tag{8}$$

The nominal deposit rate must equal the government bond rate. We abstract from borrower default so that the expected real return to the *bank* of investing in consumer loans must equal the expected real return on corporate investment, $\mathbb{E}_t R_{K,t+1}$.[11] Instead, the cost to *households* of taking out a consumer loan exceeds the return on capital because banks face intermediation costs in checking borrowers' credit balances, which we assume are proportional to the size of the loan and are passed on to households. Denoted by ω_b, the interest rate on consumer loans is then

$$R_{L,t} = (1+\omega_B)\, R_{K,t} \tag{9}$$

[11] Consistent with the model, Dempsey and Ionescu (2021) document large spreads in consumer loan rates that are not accounted for by household default risk in administrative data.

The law of motion of bank z's net worth follows as

$$n^z_{t+1} = (R_{K,t+1} - R_{S,t+1}) \left(Q_t b^z_{F,t+1} + b^z_{L,t+1} \right) + R_{S,t+1} n^z_t \tag{10}$$

As in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011), bankers can divert a fraction $\lambda \in (0,1)$ of bank assets. If they do so, depositors declare the bank bankrupt, recover the remaining fraction $1-\lambda$ of assets, and terminate the bank. This agency problem constrains the supply of deposits to the banks. Let S_t denote the aggregate state and $\mathbf{V}^b(n^z_t, S_t)$ the value of bank z:

$$\mathbf{V}^b(n^z_t, S_t) = \max \mathbb{E}_t \beta \left((1-\theta) n^z_{t+1} + \theta V^b \left(n^z_{t+1} \right) \right) \tag{11}$$

subject to (10) and to:

$$\lambda a^z_t \leq \mathbf{V}^b(n^z_t, S_t) \tag{12}$$

where $a^z_t = \left(Q_t b^z_{F,t+1} + b^z_{D,t+1} \right)$ are the bank's assets. (12) imposes that assets cannot exceed $\mathbf{V}^b/\lambda$, otherwise bankers would choose to divert their assets. To solve this problem, following Bocola (2016), we make a guess about the value function of banks:

$$\mathbf{V}^b(n^z_t, S_t) = \varrho_t n^z_t \tag{13}$$

Subject to this guess, (12) can be expressed as a constraint on leverage, l^s_t:

$$l^z_t = \frac{a^z_t}{n^z_t} \leq \frac{\varrho_t}{\lambda}$$

Appendix B contains the details of how we solve this problem. A key aspect is that, when the incentive constraint binds, banks expect to earn excess returns on their investments relative to the cost of capital (the deposit rate), $\mathbb{E}_t(R_{K,t+1} - R_{S,t+1}) > 0$, otherwise they equalize. We impose that the constraint binds, and subject to this, we find that:

$$\varrho_t = \frac{\mathbb{E}_t \beta \left((1-\theta) + \theta \varrho_{t+1} \right) R_{S,t+1}}{1 - \mathbb{E}_t[\beta \left((1-\theta) + \theta \varrho_{t+1} \right) (R_{K,t+1} - R_{S,t+1}) / \lambda} \tag{14}$$

$$l_t = \frac{\varrho_t}{\lambda} = \frac{\mathbb{E}_t \beta \left((1-\theta) + \theta \varrho_{t+1} \right) R_{S,t+1}}{\lambda - \mathbb{E}_t[\beta \left((1-\theta) + \theta \varrho_{t+1} \right) (R_{K,t+1} - R_{S,t+1})} \tag{15}$$

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

$$N_{t+1} = \theta \left(l_t R_{K,t+1} + (1-l_t) R_{S,t+1} \right) N_t + \zeta \left(Q_{t+1} B_{F,t} + B_{L,t} \right) \tag{16}$$

where $B_{F,t} = \int b^z_{F,t} dz$, $B_{L,t} = \int b^z_{L,t} dz$.

3.3 The Corporate Sector

The corporate sector is composed of retailers, goods producers, intermediate goods producers, and capital producers. When firms face intertemporal problems, rentiers delegate management to a mass-zero set of risk neutral managers that discount future payoffs at the rate β. Managers are compensated by a share of the profits and do not participate in any asset markets.

3.3.1 Retailers

Competitive retailers purchase a continuum of differentiated goods, $y_{r,t}$, $r \in (0,1)$, at the nominal prices $P^F_{r,t}$ and produce a single homogeneous final good, Y_t, using a CES technology:

$$Y_t = \left(\int_0^1 y_{r,t}^{1-1/\eta} dj \right)^{1/(1-1/\eta)} \tag{17}$$

where $\eta > 1$ is the elasticity of substitution. Let $P_t = \left(\int_0^1 \left(P^F_{r,t}\right)^{1-\eta} dh \right)^{1/(1-\eta)}$ be the price index of the final good. The demand functions for the differentiated goods and the final goods resource constraint are then:

$$y_{r,t} = \left(\frac{P^F_{r,t}}{P_t} \right)^{-\eta} Y_t \tag{18}$$

$$Y^n_t = C_t + G_t + CI_t \tag{19}$$

where $C_t = \int_i c_{it} di$ is aggregate consumption, G_t government purchases, CI_t gross investment, and $Y^n_t = Y_t - Y^{ad}_t$ where Y^{ad}_t denotes various adjustment costs.

3.3.2 Good Producers

A continuum of mass one of monopolistically competitive goods producers indexed by $r \in (0,1)$ differentiate a homogeneous intermediate good purchased at price P^m_t. They set the price of their goods subject to a Rotemberg (1981) quadratic price adjustment cost. Their real flow profit (denominated in units of the consumption good) in period t is given as:

$$\upsilon^G_{r,t} = \left(\frac{P^F_{r,t}}{P_t} - \frac{P^m_t}{P_t} \right) y_{r,t} - \frac{\eta}{2\omega_Y} \left(\log \left(\frac{P^F_{r,t}}{P^F_{r,t-1}} \right) \right)^2 Y_t \tag{20}$$

The right hand side is net real revenues (sales, $(p^F_{r,t}/P_t)y_{r,t}$, less cost of acquiring the intermediate goods, $(P^m_t/P_t)y_{r,t}$) less price adjustment costs where $\omega_Y \geq 0$ parameterizes the extent of nominal rigidities with $\omega_Y \to \infty$ denoting flexible prices. Appendix B contains the details of the goods producers' optimization problems. In a symmetric equilibrium this implies the Phillips curve relationship:

$$\log\left(\pi_t\right) = \beta \mathbb{E}_t \log\left(\pi_{t+1}\right) \frac{Y_{t+1}}{Y_t} + \omega_Y \left(\frac{P_t^m}{P_t} - \frac{\eta - 1}{\eta} \right) \tag{21}$$

3.3.3 Intermediate Goods Producers

A continuum of mass one of identical competitive intermediate goods firms indexed by $j \in [0,1]$ produce a single homogeneous good, $m_{j,t}$ with a constant returns Cobb-Douglas technology in capital and labor perturbed by a random aggregate productivity shock, Z_t:

$$m_{j,t} = Z_t n_{j,t}^{\alpha} \left(k_{j,t}^e\right)^{1-\alpha} \tag{22}$$

where $n_{j,t} \equiv \int h_{i,t} l_{i,t}^j di$ ($l_{i,t}^j$ denotes household i's hours worked for producer j), $k_{j,t}^e$ is the input of effective capital and $\alpha \in (0,1]$ is the elasticity of output to labor. Labor is rented from households at the real wage w_t per efficiency unit. At $t-1$, the firm issues $b_{f,t}$ units of equity at the price Q_{t-1} and uses the revenue to purchase capital at the price Q_{t-1} per unit:

$$Q_{t-1} k_{j,t}^P = Q_{t-1} b_{f,t} \tag{23}$$

At the start of period t, firms are subject to common a capital quality shock, $\xi_t > 0$ which is log normally distributed with mean 0 and variance σ_{xi}^2. This shock impacts on the amount of effective capital that it operates with:

$$k_{j,t}^e = \xi_t k_{j,t}^P \tag{24}$$

Since banks own the equity, ξ_t can be interpreted as shocks to the value of banks.

The stochastic processes for total factor productivity is:

$$\exp(Z_t) = \exp(\rho_Z Z_{t-1} + \varepsilon_{Z,t}) \tag{25}$$

where $\varepsilon_{Z,t} \sim \mathcal{N}(0, \sigma_Z^2)$ and $\rho_Z \in (-1,1)$. Labor is rented on a competitive spot market and after production, firms pay its equity owners its profits and the market value of its capital stock net of maintenance costs. Thus, labor demand and the return on equity satisfy:

$$w_t = P_t^m \alpha Z_t n_{j,t}^{\alpha-1} \left(k_{j,t}^e\right)^{1-\alpha} \tag{26}$$

$$R_{K,t} = \frac{\left(r_{K,t} + Q_t - \delta\right) \xi_t}{Q_{t-1}} \tag{27}$$

where $r_{K,t} = (1-\alpha) P_t^m Z_t n_{j,t}^{\alpha} \left(k_{j,t}^e\right)^{-\alpha}$ is the marginal product of "effective" capital.

3.3.4 Capital Goods Producers

New capital goods are created by competitive capital goods producers. Depreciated capital is refurbished costlessly while new capital goods are produced subject to adjustment costs. Let Q_t denote the relative price of new capital goods (in units of the final good), gross new capital created by I_t, net investment by $I_{n,t}$, and CI_t total resources spent on capital production. A capital producer's net revenue in period t is given as:

$$\upsilon_t^I = (Q_t - 1) I_{n,t} - \frac{\omega_I}{2} \left(\log \left(\frac{I_{n,t} + \psi}{I_{n,t-1} + \psi} \right) \right)^2 (I_{n,t} + \psi) \tag{28}$$

where $\omega_I > 0$ parametrizes adjustment costs and $\psi \geq 0$ is a constant. Appendix B formulates capital producers' dynamic problems. The price of new capital is determined as:

$$\frac{Q_t - 1}{\omega_I} = \log \left(\frac{I_{n,t} + \psi}{I_{n,t-1} + \psi} \right) + \frac{1}{2} \left(\log \left(\frac{I_{n,t} + \psi}{I_{n,t-1} + \psi} \right) \right)^2 - \beta \mathbb{E}_t \left(\log \left(\frac{I_{n,t+1} + \psi}{I_{n,t} + \psi} \right) \right) \frac{I_{n,t+1} + \psi}{I_{n,t} + \psi} \tag{29}$$

Furthermore, it follows that:

$$K_{t+1} - \xi_t K_t = I_{n,t}, \tag{30}$$

$$I_t = I_{n,t} + \delta \xi_t K_t, \tag{31}$$

$$CI_t = I_t + \frac{\omega_I}{2} \left(\log \left(\frac{I_{n,t} + \psi}{I_{n,t-1} + \psi} \right) \right)^2 (I_{n,t} + \psi). \tag{32}$$

3.4 Government

A fiscal authority collects taxes, purchases final goods, and has a long target for debt, $\overline{B}^G$. The law of motion of real government debt, B_{t+1}^G issued in period t is:

$$B_{t+1}^G = R_{S,t} B_t^G + G_t - T_t \tag{33}$$

where T_t are real tax revenues in period t:

$$T_t = \tau_{h,t} (w_t H_t + \mathcal{F}_t) \tag{34}$$

We assume that spending responds to government debt so as to ensure government solvency:

$$\frac{G_t}{\overline{G}} = \left(\frac{B_t^G}{\overline{B}^G} \right)^{-\kappa_G} \tag{35}$$

A monetary authority sets the short-term interest rate using simple rule:

$$\left(\frac{R^N_{S,t}}{\overline{R}^N}\right) = \left(\frac{R^N_{S,t-1}}{\overline{R}^N}\right)^{\kappa_R} \left(\frac{\pi_t}{\overline{\pi}}\right)^{\kappa_\pi(1-\kappa_R)} \exp\left(\varepsilon^m_t\right) \tag{36}$$

$\overline{R}^N$ is the long-run level of the short-term nominal interest rate, $\kappa_R \in (0,1)$ allows for interest rate smoothing, $\overline{\pi}$ is the inflation target, and $\kappa_\pi > 1$ determines interest rate responses to deviations of inflation from its target. $\varepsilon^m_t \sim \mathcal{N}\left(0, \sigma^2_m\right)$ is a monetary policy shock.

3.5 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:

$$\int_h \int_b l^*(b,h)\, h\Theta_t(b,h)\, dbdh = \left(\frac{w_t}{P^m_t Z_t \alpha}\right)^{1/(\alpha-1)} K^e_t \tag{37}$$

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

$$\int_h \int_{b*>0} b^*(b,h)\, \Theta_t(b,h)\, dbdh = B_{t+1} = B_{D,t+1} + B_{G,t+1} \tag{38}$$

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

$$N_t + B_{D,t+1} = Q_t K_{t+1} + \int_h \int_{b^*<0} b^*(b,h)\, \Theta_t(b,h)\, dbdh \tag{39}$$

The capital market clearing condition is:

$$\frac{\Delta K_{t+1}}{K_t} = \Gamma\left(Q_t - 1, \mathbb{E}_t I_{n,t+1}\right) - \delta K_t \tag{40}$$

where Γ is implicitly defined in (29)-(30). Finally, goods market clearing implies that:

$$\left(1 - \frac{\eta}{2\omega_Y}\log\left(\pi_t\right)^2\right) Y_t = C_t + CI_t + G_t + \left(\omega_b - 1\right) B_{L,t+1} \tag{41}$$

where the term in parentheses on the left hand side corrects for price adjustment costs and the last term on the right hand side is the intermediation cost of lending to consumers. Added to these is the government budget constraint which holds by Walras' law.

4 Calibration

We solve the model by first-order perturbation using the method of Bayer and Luetticke (2020). A period is a quarter. Given the use of Danish micro data in Section 2, we calibrate the model to Denmark. A subset of the parameters are chosen using conventional values from the literature. A second subset is fitted directly to the data. A third set of parameters is matched to a set of targets listed in Table 3, which come from Danish micro data and Danish National Accounts. The sample period is 2003-2018 unless otherwise stated. The values of the parameters are given in Table 2.

We set the intertemporal elasticity of substitution, $1/\vartheta_c = 2/3$, consistent with empirical estimates from household consumption studies such as Attanasio and Weber (1995) or aggregate data such as Eichenbaum, Hansen and Singleton (1988). Based on estimates in the micro literature (e.g., Chetty et al (2011)), we set the Frisch labor supply elasticity $\vartheta_l = 0.75$. The preference weight χ is calibrated so that steady-state hours worked (averaged across households) is one third. We adopt Guvenen, Ozkan and Song (2014)'s estimates of the probability of households leaving the top one percent of the income distribution and set $1 - \phi_r = 6.25$ percent.[12] β, $\underline{\mathbf{b}}$, and ϕ_w are calibrated below.

On the supply side, we assume that the output elasticity to labor, $\alpha = 0.67$, and the depreciation rate, $\delta = 0.02$, are standard values in the literature. The value of the investment adjustment cost parameter, ω_I=0.96, is calibrated to the ratio of the standard deviation of aggregate consumption to the standard deviation of aggregate output (0.94 in the Danish data, see Table 5). The elasticity of substitution between goods in the final goods sector, $\eta = 21$, is calibrated to imply a five percent steady-state markup in the final goods sector. We exploit the equivalence of the Calvo and Rotemberg models in terms of implied price Phillips curves to calibrate the price adjustment cost ω_Y. Assuming that prices adjust on average every four quarters, this implies $\omega_Y = 0.10$.

We follow Gertler and Karadi (2011) and assume that bankers can divert 38.1 percent of bank assets, $\lambda = 0.381$, and the survival rate of bankers is $\theta = 0.972$ per quarter (so their planning horizon is about 9 years). To calibrate the transfer to new banks, we target a leverage ratio of 2.93 for Danish banks (see Table 3), which gives us $\zeta = 0.4$ percent of bank assets.

We calibrate $(\beta, \underline{\mathbf{b}}, \phi_w, \omega_B) = (0.9875, 8\bar{Y}, 0.0022, 0.0075)$ to the moments of the Danish wealth distribution in Table 3. Specifically, we target an annual aggregate capital-output ratio of 252 percent, a fraction of households with debt exceeding two weeks of income of 25 percent, a consumer credit spread of four percent annually, and a wealth share of the top ten percent of 55 percent.

Denmark pegs its exchange rate to the Euro and its trade is closely integrated with the European Union. Rather than introducing open economy features, we simply adopt standard values for the monetary policy part of the model. We assume that the inflation coefficient in the Taylor rule is 1.5, and set the degree of interest rate smoothing equal to 0.7 close to the estimates of Gerali et al

[12] Guvenen, Ozkan and Song (2014) estimates this probability at 25 percent annually. So we set $\phi_r = 0.25/4$, which is an approximation that works well because ϕ_w is very close to zero in our calibration.

Table 2: Baseline Model Parameterization

	Description	Value		Description	Value
Households			**Monetary and fiscal policy**		
β	Discount factor	0.9875	$\overline{\pi}$	Inflation target	1.00
χ	Disutility weight of labor	0.20	κ_π	Response to inflation	1.50
$1/\vartheta_c$	Intertemp. elasticity	2/3	κ_R	Int.rate smoothing	0.70
ϑ_l	Frisch elasticity	0.75	$\overline{G}/\overline{Y}$	Gov. spending share	0.26
ϕ_w	Transition prob. to rentier	0.0022	$\overline{B}^G/\overline{Y}$	Gov. debt ratio	0.39
ϕ_r	Transition prob. to worker	0.0625	τ_h	tax rate	0.37
$\underline{\mathbf{b}}$	Borrowing constraint	$8\ \overline{Y}$	κ_G	Response of G to debt	0.10
Supply side			**Stochastic shocks**		
α	Output elasticity to labor	0.67	ρ_h	Persistence of HH income shocks	0.948
δ	Depreciation rate	0.02	ρ_z	Persistence of TFP shocks	0.967
ω_I	Adjustment costs	0.96	σ_h^2	Variance of HH income shocks	0.097^2
η	Elasticity of substitution	21	σ_z^2	Variance of TFP shocks	0.022^2
ω_Y	Price stickiness	0.10	σ_ξ^2	Variance of cap.q. shocks	0.022^2
			σ_R^2	Variance of mon.pol. shocks	0.001^2
Banking					
λ	Divertible fract. of assets	0.38	θ	Bank survival rate	0.972
ζ	Funds new managers	0.004	ω_B	Consumer loan cost	0.0075

(2010) for the Euro area. We also assume that the central bank pursues price stability and set $\overline{\pi} = 1$. Steady-state government spending, $\overline{G}$, is calibrated to target a ratio of government spending to GDP of 26 percent, see Table 3. We set the level of long-run government debt, $\overline{B}^G$, to target an average Danish government debt-to-GDP ratio of 39 percent, see Table 3. Given these values, the income tax rate, τ_h, is 37 percent. Finally, to ensure government solvency in the long run, government spending declines in response to higher government debt, $\kappa_G = 0.1$.

The parameters of the idiosyncratic income process are calibrated by assuming that residualized log household income, $y_{i,t}$, is given as the sum of a persistent and a transitory component:

$$
\begin{aligned}
y_{i,t} &= \delta_t + \delta_z Z_{i,t} + \tilde{y}_{i,t} \\
\tilde{y}_{i,t} &= x_{i,t} + \varepsilon_{i,t} \\
x_{i,t} &= \rho_x x_{i,t-1} + e_{i,t}
\end{aligned}
$$

where δ_t is a time fixed effect, $Z_{i,t}$ is a vector of household characteristics, $\tilde{y}_{i,t}$ is residualized household

Table 3: Calibration Targets

Targets	Data	Model	Source	Parameter
Capital to annual output	252%	252%	NA	Discount factor
Government debt to output	39%	39%	NA	Share in household net wealth
Fraction of borrowers	25%	22%	Micro data	Borrowing limit
Borrowing spread	4%	4%	Micro data	Borrowing penality
Top 10% wealth share	55%	55%	Micro data	Fraction of entrepreneurs
Banking leverage	293%	293%	DN	Banking friction
Consumption volatility relative to output	94%	94%	NA	Investment adjustment costs
Government spending to output	26%	26%	NA	Tax rate

Notes: 'Micro data' refers to register data administered by Statistics Denmark, 'NA' refers to National Account data, https://www.statbank.dk/, 'DN' to the financial statistics dataset administered by Danmarks Nationalbank, https://nationalbanken.statistikbank.dk. Banking leverage is computed as assets/(assets - deposits) using the banking balance sheet data for the Monetary and Financial Institutions (DNBALA).

income, $x_{i,t}$ is the persistent component of household income with the innovation $e_{i,t} \sim \mathcal{N}(0, \sigma_e^2)$, and $\varepsilon_{i,t} \sim \mathcal{N}(0, \sigma_\varepsilon^2)$ is a transitory shock which may be interpreted as classical measurement error. We estimate $(\rho_x, \sigma_e, \sigma_\varepsilon)$ with GMM using moment conditions for the auto-covariance of $\tilde{y}_{i,t}$ of order 0-2, see Appendix C. To estimate residual income we control for age and education of the household head, and for the number and age of children. We find that $(\widehat{\rho}_x, \widehat{\sigma}_e, \widehat{\sigma}_\varepsilon) = (0.807, 0.180, 0.041)$. Translating this to the quarterly frequency implies a persistence of idiosyncratic income shocks of 0.948 per quarter, and a variance of the idiosyncratic income shocks of 0.097^2.[13]

We set $\sigma_R = 0.1$ percent in line with Gerali et al (2010). We calibrate the persistence of TFP shocks, $_Z = 0.967$, by estimating a first-order regressive process for detrended log total factor productivity data for Denmark.[14] We then set the variance of the TFP and capital quality shocks, $\sigma_Z = \sigma_\xi = 2.2$, constraining them to be identical, to imply a standard deviation of (HP-filtered) aggregate real GDP of 1.83 percent per quarter as in the Danish data. Table 4 reports net wealth shares across deciles of the Danish household data and for the stationary distribution of the model. The top 10 percent wealth share is matched by construction, but the model closely matches the net wealth share distribution, apart from the very poorest decile, whose net indebtedness we underestimate. With this calibration, the real return on saving is 3.8 percent per annum, the annual real return on capital is 4.7 percent, while the borrowing rate is 7.9 percent.

[13]Let z_t be an AR(1) process at the quarterly frequency, $z_t = \rho z_{t-1} + e_t$ which implies that at the annual frequency $z_t = \rho^4 z_{t-4} + e_{a,t}$ where $e_{a,t} = e_t + \rho e_{t-1} + \rho^2 e_{t-2} + \rho^3 e_{t-3}$. Hence, $\sigma^2 = \sigma_a^2/(1 + \rho^2 + \rho^4 + \rho^6)$.

[14]We fit an AR(1) process to the log of annual TFP estimates produced by Statistics Denmark, linearly de-

Table 4: Wealth Shares by Decile

	1	2	3	4	5	6	7	8	9	10
Data	-8.1	-1.7	-0.3	0.3	1.3	4.3	9.1	15.4	24.8	54.9
Model	-4.2	-0.9	0.3	1.6	3.3	5.3	7.8	11.6	20.4	54.8

Notes: Wealth shares are calculated from Danish register data and refer to averages between 2003 and 2018. Wealth is measured as in Section 2. The model moments correspond to the stationary distribution.

5 Aggregate Fluctuations

5.1 Business Cycle Moments

An important check on the properties of the model is the extent to which it generates aggregate fluctuations with properties that resemble those in the data. Table 5 reports business cycle statistics for Danish data and for stochastic simulations of the model. We filter both the actual data and model data with a Hodrick-Prescott filter (with a smoothing parameter of 1,600).[15] By construction, the model matches the volatility of aggregate output and aggregate consumption over the business cycle. However, it also captures very well the relative volatility of investment and the significant procyclicality of both aggregate consumption and investment.

Of particular interest for our exercise are the moments of consumer credit and interest rate spreads. In the Danish data, aggregate consumer credit is more than twice as volatile as output and procyclical, with a cross-correlation with output of 0.56.[16] The model accounts for both the volatility of consumer credit and its procyclicality. The moments of consumer debt are closely related to movements in the consumer credit spread. In the data, the standard deviation of the credit spread is about 17 percent (annually) of output, and it is countercyclical, with a cross-correlation with output of -0.44.[17] The model also generates a countercyclical spread with a cross-correlation of output of -0.31. In our model, as we discuss below, banking frictions generate the countercyclical spreads, which in turn induce procyclical consumer credit. In a sophisticated model with a strategic default motive and aggregate shocks, Nakajima and Rios-Rull (2019) show that default probabilities fall in expansions, which also generates procyclical credit. However, such models typically imply very smooth consumer

trended. The estimate of the annual persistence parameter is 0.883, which we convert to the quarterly rate.

[15]Following Ravn and Uhlig (2002), we use a smoothing parameter of 6.25 for the annual data. We do not HP-filter the consumption-to-income elasticity because the data series is very short and the HP-filter is well-known to have issues with the end-points of the data. Model moments are computed by filtering the simulated data, with a very long sample and removing the early periods.

[16]U.S. consumer credit is even more volatile but somewhat less procyclical, see Lee, Luetticke and Ravn (2020).

[17]The moments in the data refer HP-filtered data. However, the time-series for the credit spread is short, which could be an issue when filtering. Filtering only real GDP, the volatility of the log of the gross credit spread has a standard deviation of 40 percent of that of output, and its correlation with output is -0.62.

Table 5: Business Cycle Moments

Moments	Data	Model	Moments	Data	Model
σ_Y (target)	1.83	1.83	$corr(Y)$	1.00	1.00
σ_C/σ_Y (target)	0.94	0.94	$corr(C,Y)$	0.75	0.67
σ_I/σ_Y	3.62	3.95	$corr(I,Y)$	0.84	0.68
σ_{B_L}/σ_Y	2.11	1.51	$corr(B_L,Y)$	0.56	0.67
$\sigma_{R_L-R_S}/\sigma_Y$ *	0.17	0.31	$corr(R_L-R_S,Y)$ *	-0.44	-0.31
σ_{DCDY}/σ_Y **	1.66	3.09	$corr(DCDY,Y)$ **	-0.53	-0.38
σ_{MPC}/σ_Y **		1.52	$corr(MPC,Y)$ **		-0.32

Notes: B_L is aggregate consumer credit, $R_L - R_S$ is the consumer credit spread, $DCDY$ is the consumption-income elasticity computed as in Figure 4. σ_x is the percentage standard deviation of x, $corr(x,y)$ is the correlation of x and y. Both data and model moments are computed for HP-filtered quarterly data. Model moments are in response to TFP, monetary and capital quality shocks. (*) The spread is based on annual data and HP filtered. (**) $DCDY$ and MPC are based on annual data. Both are logged but not HP-filtered.

credit. Nevertheless, it would be interesting to combine the mechanism stressed in their analysis with the banking frictions we focus on, but this is beyond the scope of this paper.

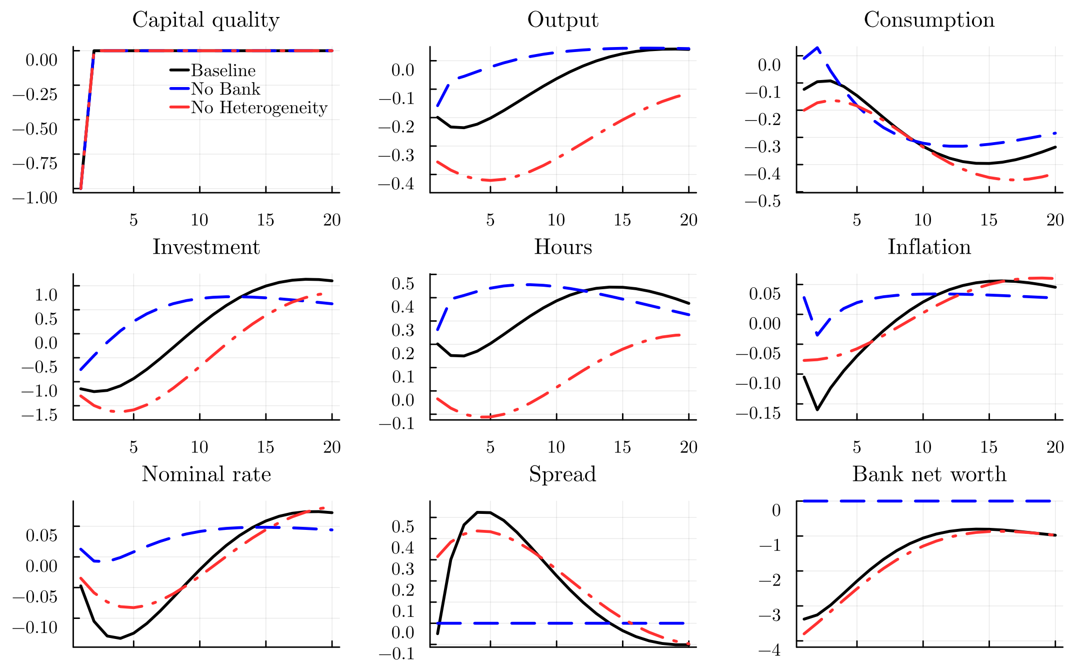
5.2 The Impact of Aggregate Shocks

We now examine the impact of the three aggregate shocks on aggregate outcomes. We compare the baseline model to two alternative economies. First, we close the heterogeneous agent aspects of the model but retain the banking friction in a RANK economy where banks only intermediate between households and firms. Second, we drop the banking friction and examine a HANK economy with no banks and a constant spread fixed at its stationary value in the baseline model.

5.2.1 Capital Quality Shocks

We first look at the capital quality shock, which Gertler and Karadi (2011) argue was an important factor in the global financial crisis.[18] Figure 5 illustrates the impact of a one percent decrease in ξ_t. We show the impact of the shock in the baseline model in black, the RANK economy in red and the HANK model without banks in blue. A negative capital quality shock destroys a fraction of the capital stock, is recessionary, and reduces the value of equity in the corporate sector. Since banks own corporate equity, the shock reduces the net worth of the banking sector. The shock is deflationary,

[18] Note that we assume no persistence in the capital quality shocks, while Gertler and Karadi (2011) allow for substantial persistence.



Notes: Impulse responses to a one percent negative capital quality shock. 'Baseline' refers to the baseline model, 'No Bank' to a HANK model without frictional financial intermediation. 'No Heterogeneity' refers to the representative household model with frictional financial intermediation.

Figure 5: Aggregate Effects of a Capital Quality Shock

causing the central bank to lower nominal interest rates. Nevertheless, the decline in banks' net worth forces them to reduce their supply of consumer credit and their purchases of corporate sector equity, which is accompanied by an increase in spreads. This leads to a significant decline in aggregate investment of about 1 percent in the baseline model. After the initial decline, investment gradually recovers, but remains below its steady-state level for about 2.5 years. The destruction of the capital stock also reduces household income. The combination of higher spreads and lower incomes leads to a significant and very persistent reduction in aggregate consumption.

Compared to a representative agent model, the incomplete markets model implies very similar consumption dynamics, while aggregate investment declines slightly less. This is due to an increase in labor supply in the incomplete markets model, which helps households insure their consumption in the face of higher credit spreads. Compared to the model with incomplete markets and a constant spread, there is a significant amplification of capital quality shocks, as rising spreads discourage investment. Thus, the model retains a financial accelerator in the face of capital quality shocks, although it is reduced relative to a RANK setting.

In Figure 11 in Appendix D, we illustrate a partial equilibrium decomposition of the aggregate consumption response to the capital quality shock into the separate effects on consumption of the various price and income determinants in the economy. The decomposition shows that the main determinant of the fall in aggregate consumption is a fall in wages, while the dynamic adjustment is dictated by the saving rate. Below, however, we show that consumption dynamics differ across the wealth distribution due to variations in the spread.

5.2.2 TFP and Monetary Policy Shocks

Next, in Figure 6, we examine the dynamics in response to shocks traditionally studied in the business cycle literature, a one percentage point positive monetary policy shock (left panel) and a one percent negative TFP shock (right panel).[19] An increase in the policy rate is recessionary and causes the inflation rate to fall, leading to a reversal of the policy rate after 4 quarters. The monetary shock leads to a sharp decline in aggregate investment and a large and persistent decline in output. The monetary shock is accompanied by a decline in equity returns, which leads to a decline in the banking sector's net worth and, with a lag, to a rise in interest rate spreads. Due to the rise in spreads, the monetary policy shock is amplified by banking frictions, while the heterogeneous agent aspects lead to some stabilization due to a smaller fall in hours worked in the incomplete markets model.

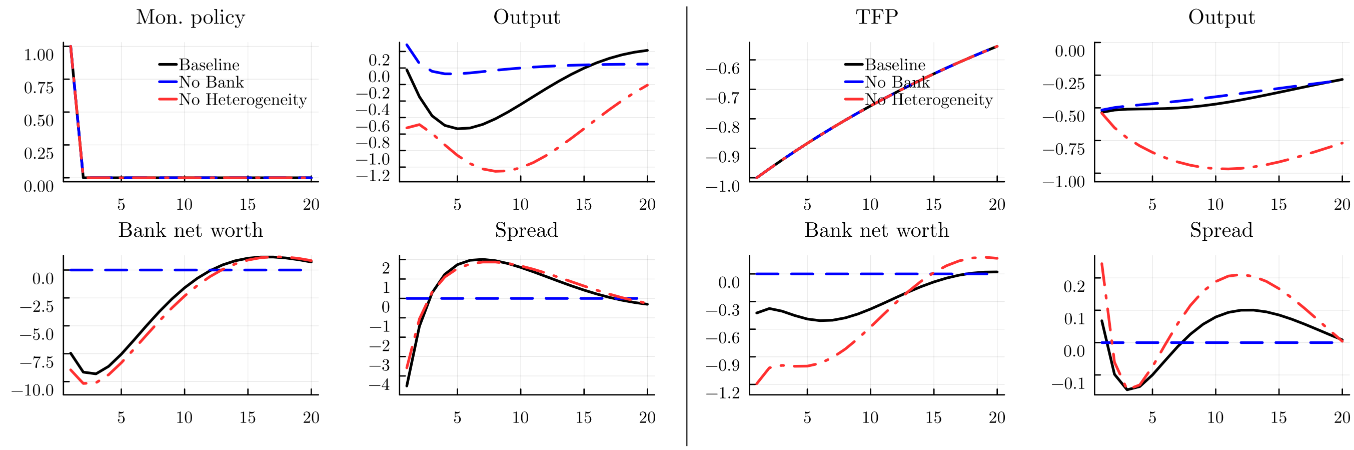
A reduction in aggregate TFP is recessionary and marked by persistent drops in aggregate output, investment and consumption. As productivity declines driving up marginal costs, inflation rises and the short terms interest goes up temporarily due to the monetary policy response. The shock is also associated with a drop in banking sector net worth, but, relative to the capital quality shock and the monetary policy shock, the impact on banks is quite minor. One factor behind this is that households raise their labor supply due to a wealth effect on their labor supply. For that reason, changes in spreads appear to play a minor role in response to TFP shocks. It follows that we find little amplification of TFP shocks when comparing the impact to the HANK model with a constant spread. Note that in the RANK model, TFP shocks *are* amplified since the labor supply rise is muted in this economy in our calibration.

In summary, capital quality shocks and monetary policy shocks are amplified at the aggregate level through a financial accelerator mechanism that works through interest rate spreads induced by the impact of these shocks on banking sector net worth. This effect is less evident for TFP shocks. Thus, at the aggregate level, the heterogeneous agents aspect appears to be less important, a finding consistent with the results in Berger, Bocola and Dovis (2020).

6 MPCs and Inequality

Inequality has been raised as a concern for economic policy, see for example Feiveson et al (2020), which was part of the Federal Reserve's recent review of monetary policy strategy. The heterogeneous agent framework allows us to examine not only aggregate fluctuations in the economy, but also distributional issues and variations in the MPC.

[19] To save space, we show a selection of the aggregate variables. A plot of the full set of variables shown for the capital quality shock is shown in Appendix D.



Notes: Impulse responses to a one percentage point positive shock to the nominal interest rate (left panel) and a one percent negative shock to TFP (right panel). See Figure 5 for legend.

Figure 6: Aggregate Effects of TFP and Monetary Shocks

6.1 Asset Distribution, Consumption Dynamics and the MPC

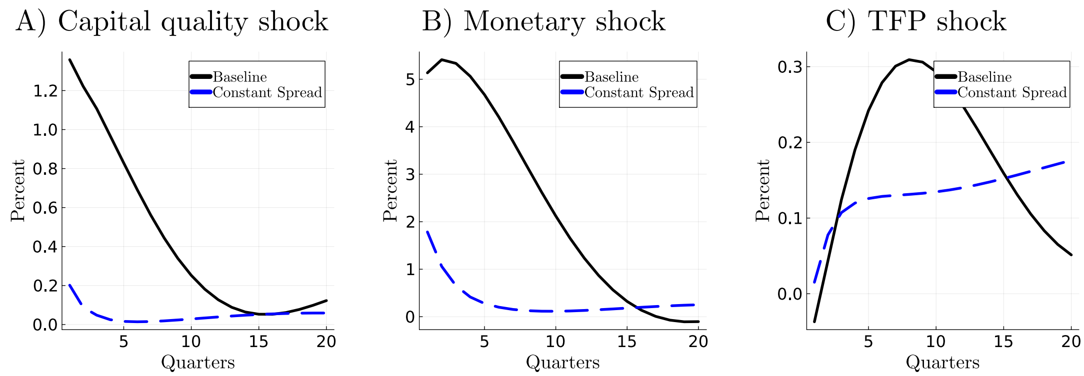
In Section 2, we showed how spreads matter for movements into and out of the zero net wealth state. In Figure 14 in Appendix D, we report the results of estimating Equation (2) using data from simulations of the model.[20] The patterns of the dynamics into the zero net-wealth state are very similar to the data: Consumer credit spreads have a large positive effect on the transition rate into the zero net wealth state for households close to this state. Moreover, as in the data, positive income shocks reduce the flow into the zero net wealth state for households with low but positive net wealth, while increasing this inflow for households with negative net wealth. Thus, the asset dynamics in the model shares important aspects with the household data.

In the empirical analysis, we also found interest rate spreads to be correlated with consumption dynamics. In particular, higher spreads correlate with lower consumption, especially for low wealth households, and higher credit spreads increase the consumption-income elasticity, see Table 1. Estimating Equation (3) on artificial model data produces exactly the same pattern of consumption dynamics (see columns (3) and (4) of Table 1) demonstrating the importance of consumer credit spreads for consumption dynamics. In addition, Figure 15 in Appendix D shows the parameter estimates from the quantile regressions. As in the data, the elasticity of consumption to income is positive and declining with wealth, higher spreads reduce consumption for households with debt or moderate wealth, and the interaction effect is largest for households close to zero net wealth.[21]

We can go further and examine the implications of the mechanisms in the model for the MPC.

[20] The estimates in Section 2 correspond to household-specific spreads because we control for a time-fixed effect. We compute the model statistics by simulating households subject to idiosyncratic spreads to mimic this. We calibrate the persistence and volatility of the idiosyncratic spread shock to match that in the Danish micro-data.

[21] We show below that the model extended with illiquid assets provides an even better fit to the data.



Notes: The figure shows the responses of the average MPC to the three aggregate shocks. The MPC is calculated as the integral over the slope of the consumption function. The black line shows the baseline model, the blue line is the baseline model with a constant consumer credit spread.

Figure 7: Impulse Responses of the MPC

In the model, the MPC (the response of consumption to a very small transitory income shock) is countercyclical in response to each of the three aggregate shocks, see Figure 7. An important reason for this is that there is a mass point in the wealth distribution at zero net wealth, which increases as the consumer credit spread rises. Households at or near this kink in the budget constraint have high MPCs. If we assume a constant spread, the MPC is close to constant (but countercyclical). Therefore, the model implies that the MPC is unconditionally countercyclical with a cross-correlation of output of -0.60, see Table 5.[22]

There is relatively little empirical evidence on the cyclical fluctuations of the MPC. Exceptions include Holm, Paul and Tiscbirek (2021), who find that the MPC in Norway rises in response to contractionary monetary policy shocks. This is consistent with our model. Gross, Notowidigdo, and Wang (2020) measure the MPC by estimating how the removal of bankruptcy flags from the credit reports of 160,000 bankruptcy filers affects credit card limits and balances. They find that the MPC was higher for households that had their bankruptcy flags removed during the Great Recession than for those that received the same treatment before or after the downturn.

We do not have a direct empirical estimate of the MPC. Recall, however, that we estimated the consumption-income elasticity in Section 2. This measure is countercyclical in the data, with a cross-correlation with output of -0.53 at the annual rate. We can determine the average consumption-income elasticity in the model data based on quantile regression estimates of the coefficients in (3). Doing so and backing out the elasticity measure implies a cross-correlation with output of -0.38 at the annual rate. Moreover, while the consumption-income elasticity is more volatile than the MPC in the model, the two measures are highly correlated with a cross-correlation of 90 percent at the annual

[22]The MPC is countercyclical but close to constant when a constant spread is assumed. Eliminating the spread altogether implies an acyclical MPC, see Table 12 in Appendix D.

rate.[23] Thus, we conclude that the empirical results strongly suggest that the MPC is countercyclical and that a central reason for this is the countercyclical movements in credit spreads.

6.2 Consumption Dispersion and Aggregate Shocks

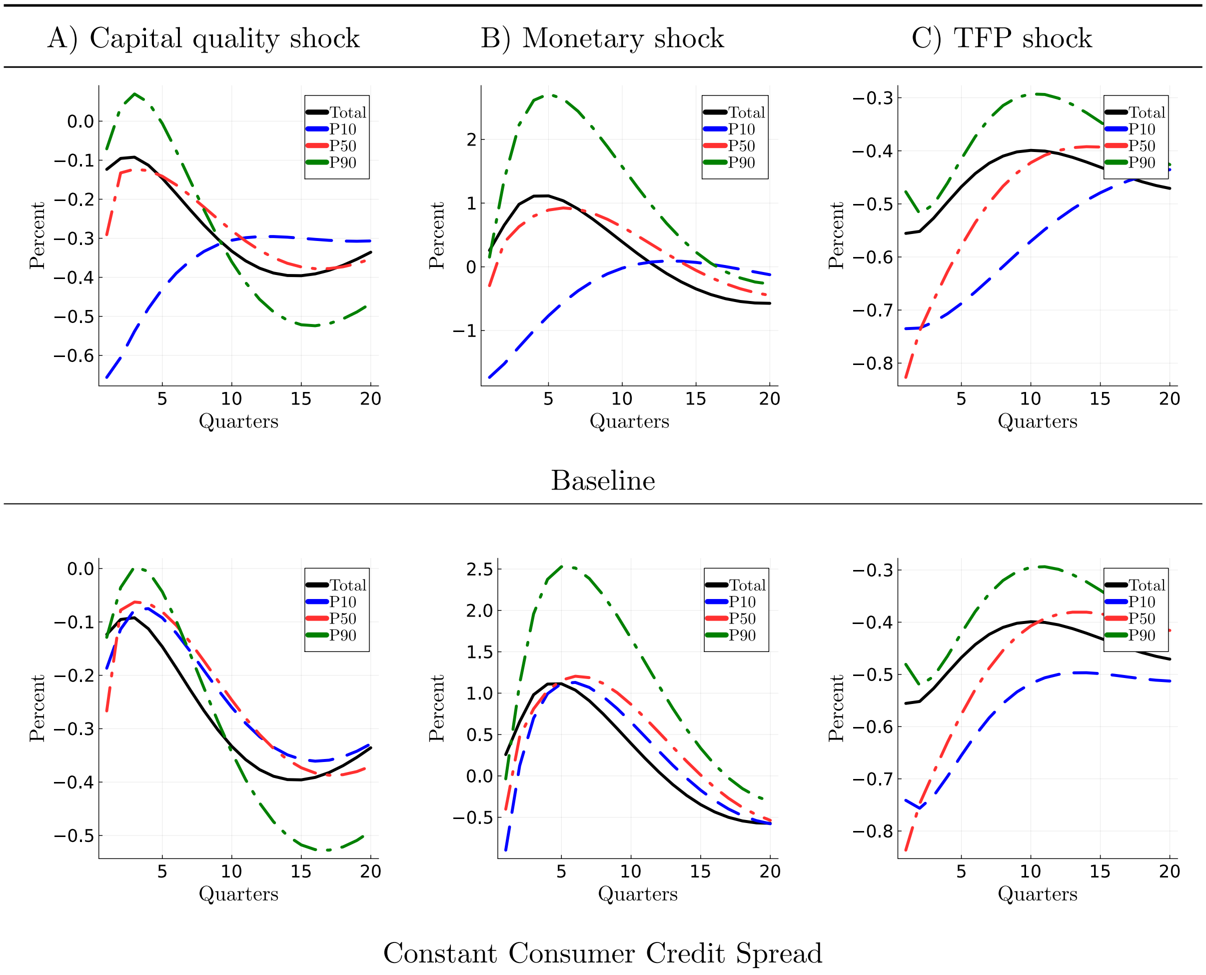
We now examine the extent to which the aggregate shocks have heterogeneous effects across the wealth distribution. Figure 8 shows the consumption paths in response to the three aggregate shocks for households at the 10th percentile of the consumption distribution (who are indebted), the 50th percentile and the 90th percentile, along with aggregate per capita consumption. The top row shows the consumption responses for the baseline economy, and the bottom row shows the HANK model with banks but a constant consumer credit spread so that we can isolate the effect of the countercyclical consumer credit spread on consumption dispersion.

The first column of Figure 8 shows the impact of a one percent decline in capital quality on consumption across the wealth distribution. Consumption choices are determined by agents' net wealth positions, their idiosyncratic productivity state, and the effects of inflation, wages and profits, and interest rates. Lower capital quality induces a reduction in real wages, which depresses consumption across the wealth distribution. When the spread is constant, saving and borrowing rates fall in tandem, and the consumption growth rates of households that are either unconstrained savers or unconstrained borrowers therefore move in parallel. Thus, we see little consumption dispersion in this economy. In the baseline economy, the capital quality shock is instead accompanied by *higher* borrowing rates while savings rates are still falling. The spread exaggerates the kink in the budget constraint faced by agents, and higher borrowing rates lead to a large reduction in consumption spending by indebted households. Thus, banking crises have distributional effects in this economy because of the response of interest rate spreads.

There is empirical evidence that monetary policy shocks induce consumption inequality, see for example Coibion et al (2017) or Holm, Paul and Tiscbirek (2021). The latter authors show how contractionary monetary policy shocks stimulate consumption by rich households in the short run, but lead to a sharp contraction in spending by poor households, while the longer run responses are similar across the distribution. A standard intuition is that wealth inequality accounts for this, as higher policy rates reward savers but raise borrowing costs for indebted households.

The baseline model produces exactly this result, as the contractionary monetary policy shock not only reduces the labor income of poor households in the short run, but also leads to a substantial increase in their borrowing costs. Wealthy households instead enjoy higher real returns on their savings and their consumption rises in the short run. Over time, the economy recovers and the consumption responses of households with different wealth levels converge as spreads return to their normal levels. Assuming instead that spreads are constant implies that consumption paths move in

[23] Appendix D shows the close relationship between these measures by means of a scatterplot.



Notes: Impulse responses of aggregate consumption and the 10th, 50th and 90th percentiles of the consumption distribution. The top panel is the baseline model, while the bottom panel assumes a constant consumer credit spread. The shocks are a one percent decline in capital quality (column A), a one percentage point increase in the nominal interest rate (column B), and a one percent decline in TFP (column C).

Figure 8: Consumption Impulse Responses by Consumption Percentiles

parallel across the distribution, with only small differences between the 90th and 10th percentiles at the time of the shock.

Thus, endogenous movements in consumer credit spreads have significant implications for the distributional impact of banking and monetary policy shocks. For TFP shocks, the impact is smaller because, as discussed earlier, spreads do not move much in response to this shock. A fall in TFP reduces real wages, which puts downward pressure on consumption across the wealth distribution. Wealthier households are better insured against these shocks, so their consumption falls less than that of poor households. Thus, TFP shocks do affect consumption inequality, but the role of movements in spreads is less important.

7 Macro Prudential Regulation

We now examine the effects of macroprudential policy. Specifically, we study the consequences of introducing capital requirements that force banks to reduce their leverage in the stationary equilibrium by 10 percent, thereby making them less sensitive to movements in asset prices.

7.1 Long Run Aggregate Effects and Cyclical Dampening

Table 6: Moments: Baseline and Restricted Leverage

	Baseline		**No Heterogeneity**	
	Baseline	Low leverage	Baseline	Low leverage
Leverage	2.93	2.64	2.93	2.64
	Interest rates			
Return on capital (R_K, %)	4.69	4.82	5.58	5.83
Return on savings (R_S, %)	3.81	3.54	5.16	5.16
Lending interest rate (R_L, %)	7.87	8.00	-	-
	Aggregates			
Output	4.89	4.91	4.39	4.37
Capital	49.26	48.93	41.42	40.44
Labor supply	1.44	1.45	1.43	1.43
Consumption	2.64	2.70	2.45	2.43
	Household distribution			
At kink (%)	4.03	4.82	-	-
Borrowers (%)	21.95	24.47	-	-
Gini wealth	77.50	82.02	-	-
Gini consumption	15.67	16.46	-	-
Gini income	28.53	30.11	-	-

Notes: We compare the baseline steady state to one with 10% less leverage (diversion parameter λ going from 0.381 to 0.445). The last two columns do so for the model with a representative household.

Table 6 reports the steady state effects of introducing macroprudential regulation. We compare the HANK model with the RANK model to tease out the effects of introducing incomplete markets. In both cases, higher capital requirements lead to higher interest rate spreads because banks are more constrained in their asset investments. In the representative agent setting, the deterministic steady-state rate of return on saving is determined entirely by households' intertemporal discount rate. Thus, the entire increase in the spread comes from an increase in the return to capital, which is produced by a reduction in the steady-state capital stock. Less capital, in turn, reduces steady-state

Table 7: Standard Deviations of Aggregate Variables

	Baseline	Low leverage	% Decline in volatility
Variable		**Baseline**	
Output	1.83	1.73	5.5%
Consumption	1.71	1.76	-2.9%
Investment	7.22	6.49	10.1%
Credit spread	0.54	0.49	9.3%
Variable		**No Heterogeneity**	
Output	2.62	2.51	4.2%
Consumption	2.36	2.41	-2.1%
Investment	11.43	10.79	5.6%
Credit spread	0.54	0.49	9.3%

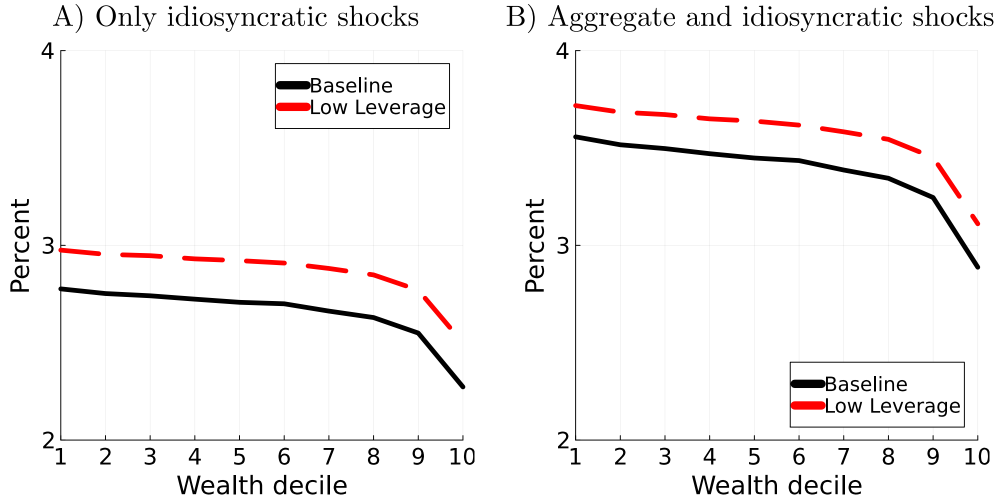
Notes: We report percentage standard deviations of quarterly aggregate variables in response to TFP, monetary, and capital quality shocks after HP(1600)-filtering.

output and consumption. Quantitatively, we find that the annual spread between the return on capital and the deposit rate increases by 25 basis points, the aggregate capital stock declines by 2.4 percent, output declines by 0.5 percent, and aggregate consumption declines by 0.8 percent.

In the HANK model, the tightening of bank regulation increases credit spreads by 40 basis points at an annual rate. Due to incomplete markets, much of the change in the spread is due to a reduction in the return on deposits rather than a reduction in the return on bank assets. As spreads rise, households are effectively offered less insurance against income shocks and respond by increasing their precautionary savings and labor supply. Thus, the return on savings declines (from 3.8 percent annually to 3.5 percent), limiting the increase in the consumer credit rate to 10 basis points annually. Moreover, while the return on equity rises and the capital stock declines slightly, the higher labor supply induces an increase in aggregate consumption and output in the stationary equilibrium.

The regulation succeeds in stabilizing the impact of aggregate shocks on the economy, see Table 7. We find a reduction in the standard deviation of output by 5.5 percent and in investment volatility by no less than 10 percent. The stabilization of macroeconomic aggregates is even greater than in the RANK economy and, as argued above, occurs without any long-run consumption or output losses. Thus, from the perspective of macroeconomic aggregates, ex ante macroprudential policy appears to be a potentially attractive instrument in the HANK model.[24]

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



Notes: Volatility refers to the standard deviation of quarterly growth rates of household consumption over 5 years (averaged over wealth deciles) calculated by simulating 100.000 households over 1.000 periods.

Figure 9: Micro Consumption Volatility by Wealth Deciles

7.2 Distributional Consequences and Welfare

The regulatory policy has distributional consequences and increases various measures of inequality, see the bottom part of Table 6. Panel A of Figure 17 in Appendix D illustrates the steady-state distribution of wealth with and without macroprudential regulation, and shows how higher capital requirements increase the share of households with near-zero net wealth. Perhaps counterintuitively, the share of borrowers in the economy also increases, as there are more households close to the kink in the budget set. Accompanying the changes in the wealth distribution, Panel B in this figure shows that a large fraction of the population experiences a significant increase in the MPC.

This increase in the MPC suggests that the regulation may have a significant impact on the ability of households to smooth consumption. Figure 9 shows the standard deviation of household consumption growth over a five-year horizon conditional on initial wealth, either allowing only idiosyncratic shocks (Panel A) or also including aggregate shocks (Panel B).[25] Focusing first on the stationary equilibrium, Panel A shows that consumption volatility increases across the distribution.[26] The increase in the volatility of household consumption, as measured by the standard deviation over the five-year horizon, is substantial, rising from about 8 percent for the poorest households to 10 percent for the 90th decile. For poorer households, it is the increase in the cost of credit and the spread that reduces their ability to smooth consumption. Wealthy households are instead mainly

[25]The figure shows the average standard deviation of quarterly household consumption growth rates over a five-year horizon computed over 100,000 households and 1,000 periods and then averaged across wealth deciles.

[26]There is ample evidence that changes in the cost of credit affect household consumption, see for example Leth-Petersen (2010), who finds substantial consumption responses to lower credit costs.

Table 8: Welfare Costs of Macroprudential Regulation

	Baseline Model		**3-Asset Model**	
Shocks	idiosyncratic	+ aggregate	idiosyncratic	+aggregate
1. Wealth decile	-0.28%	-0.04%	-0.19%	0.00%
2. Wealth decile	-0.24%	-0.05%	-0.22%	-0.03%
3. Wealth decile	-0.24%	-0.03%	-0.27%	-0.14%
4. Wealth decile	-0.26%	-0.03%	-0.26%	-0.07%
5. Wealth decile	-0.30%	-0.06%	-0.27%	-0.03%
6. Wealth decile	-0.36%	-0.12%	-0.29%	-0.02%
7. Wealth decile	-0.43%	-0.20%	-0.35%	-0.05%
8. Wealth decile	-0.55%	-0.31%	-0.43%	-0.12%
9. Wealth decile	-0.95%	-0.73%	-0.61%	-0.31%
10. Wealth decile	-4.28%	-4.23%	-6.90%	-6.76%
Average	-0.79%	-0.58%	-0.98%	-0.75%

Notes: We report the fraction of lifetime consumption that households are willing to give up to stay in the baseline economy relative to a counterfactual economy with 10% less leverage. Columns 2-3 report results for the 2 asset baseline model; columns 4-5 report results for the 3-asset model. Aggregate welfare is calculated as $\omega_i = \left[\frac{v(s_{i,t},S_t)+\frac{1}{1-\beta}\frac{1}{1-\vartheta_c}+\hat{v}_l(s_{i,t},S_t)}{\hat{v}_c(s_{i,t},S_t)}\right]^{1/(1-\vartheta_c)} - 1$ and welfare for each decile in the same way as for each decile of the initial wealth distribution.

affected by the reduction in the return on their savings, which induces a more rapid drift down the wealth distribution once they experience a negative idiosyncratic income shock. When we add aggregate shocks, consumption volatility remains higher across the distribution. However, relative to Panel A, the increase in consumption volatility is smaller when comparing the baseline calibration with the regulated economy. This is because the regulatory intervention reduces the sensitivity of the credit spread to aggregate shocks, as we report in Table 7. Quantitatively, we find an increase in consumption volatility from 5 percent for the poorest deciles to 6 percent for the wealthiest households when aggregate shocks are included. This suggests that, relative to the stationary equilibrium with idiosyncratic shocks, there is some stabilization in the face of aggregate shocks due to the lower cyclical volatility of interest rate spreads.

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 both idiosyncratic and aggregate volatility on welfare, we solve the model with a second-order perturbation.[27] We report the results in terms of consumption equivalents in Table 8, with negative numbers

[27] As is standard practice, the welfare measures are computed assuming that consumption is compensated while hours worked remain at their equilibrium level.

indicating welfare losses in the regulated economy. In the face of idiosyncratic risk only, we find welfare losses across the distribution. Quantitatively, the welfare losses are fairly similar across the first seven deciles of the wealth distribution, ranging from 0.24 to 0.43 percent of consumption. For the wealthiest households, the losses are even larger due to the lower return they receive on their savings. At the aggregate level, we find a welfare loss equivalent to 0.8 percent of consumption.

When we add aggregate shocks, the welfare effects remain negative across the distribution, but they are substantially reduced for the poorest 80 percent of the population. This suggests, as highlighted above, that the reduced sensitivity of spreads to aggregate shocks brings some benefits, although the overall welfare effects for these households remain negative. For the richest households, on the other hand, the large welfare losses in the face of idiosyncratic shocks are preserved when aggregate shocks are taken into account, because the largest source of welfare losses for these households is the reduction in the return on their savings. This also implies that the aggregate welfare loss remains as high as 0.58 percent of consumption.

These results make a significant contribution to the literature on macroprudential regulation. The key new results are induced by (i) the endogeneity of the saving rate, which is determined by preferences in a representative agent framework but is affected by precautionary savings in the HANK setting we study, and (ii) the impact of interest rate spreads on consumption smoothing capabilities in the face of idiosyncratic and aggregate risk. It is worth noting, however, that we have not considered systemic risk issues arising from occasionally binding aggregate constraints, which would still have potentially significant costs in the heterogeneous agent setting.

8 Illiquid Assets

The baseline model assumes that all assets are liquid. Parts of the HANK literature have highlighted the importance of households' illiquid assets, see e.g. Kaplan, Moll and Violante (2018) or Bayer et al (2019), for household insurance and for the impact of aggregate shocks. To investigate whether this abstraction from illiquid assets has first-order implications for our results, we now assume that households can hold capital, $k_{i,t+1}$, which they purchase at the price Q_t (denominated in units of consumption) and rent out to firms at the real capital rental rate, $r_{k,t}$. They can maintain their capital stock each period (which corresponds to depreciation), but face the trade-off that while capital earns a positive expected excess return over bonds and deposits, it can only be *actively* adjusted in any given period with some probability, $\phi_k \in (0, 1)$. We assume that the expected return on illiquid assets is less than the expected cost of consumer credit.

In this economy, households may hold liquid and illiquid assets simultaneously for insurance purposes, but they will never choose to borrow consumer credit if they have liquid assets. When a household is given the opportunity to adjust its holdings of illiquid assets, it will either choose to hold none (if it is sufficiently poor) or to adjust to a "long-run" Euler equation:

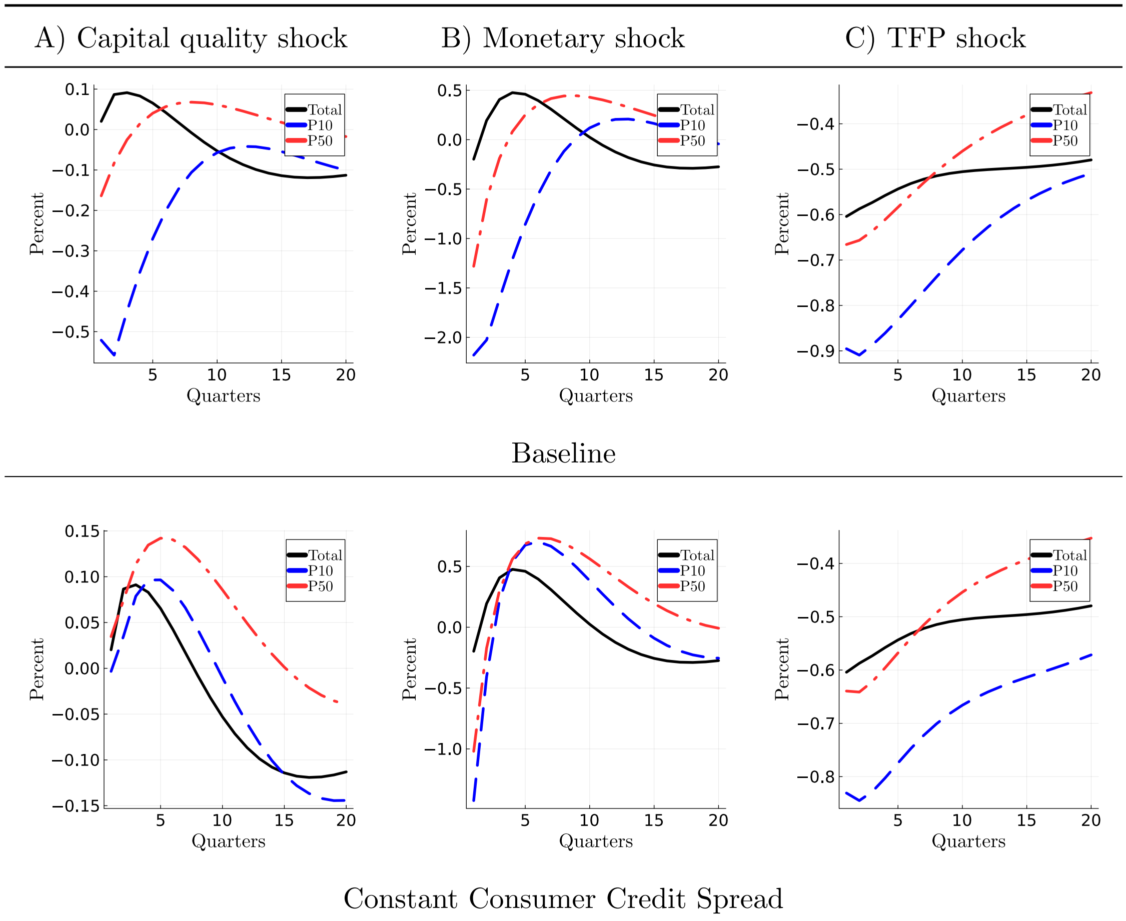
$$
\begin{aligned}
Q_t(c^a_{i,t})^{-\vartheta_c} &= \beta \sum_{s=1}^{\infty} (\beta(1-\phi_k))^{s-1} \\
&\quad \mathbb{E}_t \left[\phi_k (Q_{t+s} + r_{K,t+s} - \delta)(c^a_{i,t+s})^{-\vartheta_c} + (1-\phi_k)(r_{K,t+s} - \delta)(c^n_{i,t+s})^{-\vartheta_c} \right]
\end{aligned}
$$

where we use the index 'a' to denote the state in which the illiquid asset can be adjusted and 'n' to denote the complement state. Households discount future payoffs by β due to impatience and by $1-\omega_I$ due to illiquidity. The term in square brackets is a weighted average of the return on the asset in period $t+s$ when the household can adjust its illiquid position and the return when the household cannot adjust its illiquid position (which excludes capital gains and losses).

In this economy, a household may be liquidity constrained even if it has positive net worth, because it may only have illiquid assets that cannot be adjusted. Therefore, it is the liquid asset position that matters for whether households are constrained or not, and there can be both rich and poor hand-to-mouth households, cf. Kaplan and Violante (2014). However, if the household finds itself at the kink in the budget constraint with zero liquid assets, it will choose to liquidate its illiquid assets (or parts of them) whenever it has the chance to do so. The likelihood of a household being at the kink in the budget constraint depends on the composition of its asset portfolio, which is affected by both the consumer credit spread and by the spread of illiquid assets over liquid assets, both of which respond to aggregate shocks. For this reason, it is conceivable that the heterogeneous effects of aggregate shocks that we have discussed can arise even when the consumer credit spread is constant.

We close the model by assuming that intermediate goods producers rent a part of the capital stock from households and finance the remaining part, as in the baseline economy, through corporate equity issues to banks. We assume that the equity held by banks is liquid and that capital quality shocks affect only the fraction of capital that is financed by equity. The details of the new elements of the model are presented in Appendix E. We calibrate the new parameter in this economy, ω_I, by introducing an additional target, the ratio of bank deposits to output in the stationary equilibrium. This ratio is 34 percent in the Danish economy. Together with other parameters, this implies that $\phi_k = 0.0025$ per quarter. Assuming instead that illiquid assets consist of housing and targeting the ratio of the value of illiquid household assets to total assets (excluding business assets and pensions), which is 79 percent in the Danish economy, yields almost the same calibration. Table 13 in Appendix E summarizes the parameter values of the three asset model calibration.

Figure 10 illustrates how consumption for the median and the 10th and 90th percentiles is affected by the three aggregate shocks in this economy, assuming either a constant consumer credit spread or allowing this spread to adjust due to banking friction. The results are very similar to those reported for the simpler two-asset model: The movement in the consumer credit spread induces heterogeneous consumption dynamics across the distribution in response to the capital quality shock



Notes: Impulse responses of the consumption distribution in the 3-asset model (black solid line) and the 3-asset model with constant consumer credit spread.

Figure 10: Consumption Impulse Responses by Consumption Percentiles

and the monetary policy shock. A key reason for this, is the role of consumer credit as a principal means of insurance against adverse income shocks. It is the the increase in credit costs in recessions that affects these households. Thus, as in the baseline model, when we hold the spread constant, consumption moves in parallel across the distribution in response to aggregate shocks.

Because of the richer asset structure, it is interesting to examine whether the welfare effects of the regulatory intervention discussed in Section 7 differ significantly from the baseline model. Table 14 (in Appendix E) reports the impact of the regulatory policy on the stationary equilibrium. As in the baseline model, the regulatory policy increases the consumer credit spread, but in the three-asset model this is achieved mainly by reducing the return on liquid assets due to an increase in precautionary savings, while the consumer credit rate and the return on capital are approximately unchanged in the stationary equilibrium. The last two columns of Table 8 report the consumption-equivalent welfare measures for this economy. The results are very similar to those in the baseline model: There are welfare losses across the distribution in the stationary equilibrium, which are reduced when aggregate shocks are added. For the very poorest households, the lower volatility of spreads over the business cycle actually implies that the policy is welfare neutral. Moreover, the welfare losses are concentrated in the richest decile of households. This is because, as in the data, these households hold more liquid assets and are therefore more sensitive to the decline in the return on these assets. Nevertheless, despite some differences, the welfare effects discussed in Section 7 are robust to the introduction of illiquid assets.

This does not mean that illiquid assets are unimportant. In fact, the extended model with illiquid assets has many attractive features and provides a better fit with the micro data in some aspects. For example, in Figure 18 in Appendix E, we show how the model generates a relationship between consumption, income, and consumer credit spreads across the wealth distribution at the household level that is very similar to what we find in the data. However, for the question we have focused on, the banking friction and the endogenous consumer credit spread is more important.

9 Summary and Conclusions

We examine the role of consumer credit spreads for aggregate and household outcomes. We provide empirical evidence from high-quality household data that consumer credit spreads affect household wealth dynamics and consumption decisions. Our analysis suggests that households with low net wealth that are exposed to higher consumer credit spreads are more likely to remain in such a low net wealth state. Moreover, higher consumer credit spreads are correlated with lower consumption spending by low wealth households, while stimulating consumption by wealthy households. Using quantile regressions, we derive a time-varying measure of the consumption-income elasticity that is countercyclical, with the consumer credit spread being an important source of its cyclical variation.

We then introduce frictional financial intermediation into a HANK model. In this model, banks provide funds for corporate investment and consumer credit at a spread over the return they offer depositors on their savings. This spread moves countercyclically due to agency friction. The consumer credit spread creates a kink in households' budget sets, inducing a mass point of low net wealth households with a high MPC. Moreover, the spread drives a wedge between the intertemporal prices faced by borrowers and savers. We show that the model generates a financial accelerator relative to a model with a constant spread in the face of shocks to banking sector net worth and monetary policy shocks. However, the amplification is somewhat more moderate than in a RANK setting due to labor supply responses to recessionary shocks.

At the household level, credit frictions have important consequences. First, because of the countercyclical spread, aggregate shocks have heterogeneous effects across the wealth distribution. A recessionary monetary policy shock exposes indebted households to a combination of lower real wages and higher borrowing costs, inducing a sharp decline in their consumption, while rewarding wealthy households with a higher return on their savings. Such a dynamic is consistent with empirical estimates and is absent in models that assume frictionless consumer credit or constant spreads. Second, the model implies countercyclical and volatile MPCs, which we show to be highly correlated with the measure of consumption-income elasticity that we estimate in the household data. Finally, we examine the consequences of imposing leverage constraints on banks in order to stabilize the financial amplification of aggregate shocks. We show that such regulation is effective in stabilizing the aggregate economy, with apparently low long-run costs. Nevertheless, the regulation is detrimental to welfare because it reduces the ability of households to insure their consumption streams against income shocks. Thus, we show that there is a trade-off between macro and micro volatility.

Our paper leaves open a number of avenues for future research. First, it would be interesting to examine the impact of consumer credit spreads on consumption dynamics in more detail. We did not attempt to estimate theory-consistent consumption dynamics using the unique data on household-specific interest rates, but this would be of obvious interest for a better understanding of household behavior. Second, we have based our modeling of banks on a setting with agency frictions but perfect competition among banks. It would be interesting to consider market power in the banking sector instead, as this would allow one to account for the imperfect pass-through from policy rates to deposit rates observed in the data. We leave these and other extensions to future research.

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10 Appendices

10.1 Appendix A: Additional Information for Section 2

Table 9 reports some characteristics of the household dataset examined in Section 2. The average age of the household head and the average household size are both stable over the sample. The Danish economy entered a cyclical downturn at the onset of the financial crisis, and has been recovering since 2014. The cyclical dynamics are reflected in average consumption expenditure and in fluctuations in asset values. The average ratio of net household wealth to disposable income shows considerable fluctuations over time, while the ratio of net liquid assets to disposable income excluding housing and mortgages is stable and close to one on average.

Table 9: Descriptive statistics

Year	2007	2012	2017
Net wealth	769,036.4	468,216.3	564,887.1
Assets	1,184,267	944,945.7	1,004,894
Debt	415,230.5	476,729.4	440,007
Liquid wealth	270,414.9	244,389.6	230,429.9
Share zero net wealth	0.076	0.092	0.101
Disposable income	246,472.7	257,716.1	266,936
Labor income	242,644	237,017.3	242,873.1
Consumption	246,018.3	231,832.7	242,305
Age of HH head	53.5	53.2	53.0
HH size	1.87	1.87	1.84
Households	1,761,950	1,936,132	1,974,170

Notes: Net wealth is defined as the sum of housing wealth, portfolio wealth, bank deposits, and bank and mortgage debt, as well as some major durable goods such as cars. Assets are gross assets, liabilities are gross liabilities. Liquid assets are defined as net wealth less housing and mortgages. Unless otherwise stated, all numbers are averages and deflated to 2003 Danish Kroner.

Table 10: Robustness: Different Treatment of Car Purchases

Dependent variable: log consumption	(1)	(2)	(3)	(4)
	Capitalize car purchases		Exclude HH w. car purchase	
	Overall	By net wealth	Overall	By net wealth
Log income	0.375***		0.357***	
	(0.00353)		(0.00373)	
Low net wealth × log income		0.397***		0.381***
		(0.00477)		(0.00513)
High net wealth × log income		0.341***		0.320***
		(0.00437)		(0.00451)
Rate spread	-0.254***		-0.220***	
	(0.0153)		(0.0146)	
Low net wealth × rate spread		-0.330***		-0.258***
		(0.0142)		(0.0154)
High net wealth × rate spread		-0.110***		-0.117***
		(0.0214)		(0.0208)
Log income× rate spread	1.217***		1.198***	
	(0.0767)		(0.0817)	
Low net wealth × log income× rate spread		1.479***		1.482***
		(0.107)		(0.117)
High net wealth × log income× rate spread		0.779***		0.714***
		(0.0955)		(0.0987)
R2	0.594	0.596	0.631	0.633
RMSE	0.232	0.232	0.220	0.220
N	15,575,244	15,575,244	13,240,379	13,240,379
Fixed effects	HH, year	HH, year	HH, year	HH, year

Notes: The table illustrates the relationship of consumption with income, consumer credit spreads and their interaction, estimated from Equation (3). High net wealth denotes households above the median and low net wealth those below. Standard errors clustered at the household level. In columns (1) and (2) we capitalize cars using their official tax value. In (3) and (4) we exclude households that have purchased a car in the current or previous year from the sample.

Table 10 reports the results of estimating Equation (3) when either capitalizing car expenditures or excluding households that purchase a car from the data in the year of the purchase. As is evident, the coefficient estimates are robust to the treatment of car spending and similar to those reported in Table 1.

Table 11: Robustness: Results for First-Difference Specification

Dependent variable: Δ log consumption	(1)	(2)	(3)	(4)
	Without HH trend		With HH trend	
	Overall	By net wealth	Overall	By net wealth
Δ log income	0.285***		0.297***	
	(0.00532)		(0.00621)	
Low net wealth $\times$ Δ log income		0.309***		0.330***
		(0.00695)		(0.00851)
High net wealth $\times$ Δ log income		0.241***		0.254***
		(0.00765)		(0.00840)
Rate spread	-0.145***		-0.320***	
	(0.00519)		(0.0138)	
Low net wealth $\times$ rate spread		-0.166***		-0.438***
		(0.00740)		(0.0179)
High net wealth $\times$ rate spread		0.0803***		-0.157***
		(0.00830)		(0.0191)
Δ log income $\times$ rate spread	2.582***		2.436***	
	(0.129)		(0.149)	
Low net wealth $\times$ Δ log income $\times$ rate spread		2.728***		2.568***
		(0.168)		(0.203)
High net wealth $\times$ Δ log income $\times$ rate spread		2.159***		2.057***
		(0.186)		(0.203)
R2	0.0621	0.0638	0.114	0.121
RMSE	0.323	0.323	0.341	0.339
Observations	16,158,006	16,158,006	15,567,030	15,567,030
Fixed effects	year	year	HH, year	HH, year

Notes: The table illustrates the relationship of consumption with income, consumer credit spreads and their interaction, estimated from Equation (3). High net wealth denotes households above the median and low net wealth those below. Standard errors clustered at the household level.

Table 11 reports the results from estimating:

$$\Delta \log c_{i,t} = \sum_j \mathbf{1}_{(A_{i,t} \in A_j^{Net})} \left(\beta_{0,j} \Delta \log y_{i,t} + \beta_{1,j} R_{i,t}^S + \beta_{2,j} R_{i,t}^S \Delta \log y_{i,t}\right) + \eta X_{i,t} + \alpha_i + \gamma_t + \varepsilon_{i,t} \quad (42)$$

We also experiment with including or excluding a household fixed effect. The results are similar to those reported in Table 1 except for the effect of the spread on above-median wealth households when we first differenced consumption and omitted the household fixed effect.

10.2 Appendix B: Choice Problems

10.2.1 Households

The dynamic programs faced by households can be formulated as follows. First, to simplify notation, remove time-subscripts and let $\mathbf{b}_i = (b_i^G, b_i^D, b_i^L)$ denote household i's beginning of period asset portfolio, and $\mathbf{S}$ the vector of relevant aggregate state variables. Let $\mathcal{V}_i^s$ denote the value functions for a worker household ($s = w$) and for a rentier ($s = r$). A worker's Bellman equation is given as:

$$\mathcal{V}_i^w(\mathbf{b}_i, h_i, \mathbf{S}) = \max\left[\mathrm{u}(c_i, l_i) + \beta\mathbb{E}((1-\phi_w)\mathcal{V}i^w(\mathbf{b}_i', h_i', \mathbf{S}') + \phi_w\mathcal{V}_i^r(\mathbf{b}_i', \mathbf{S}'))\right],$$

subject to (6)-(7) and to the flow budget constraint:

$$c_i + (b_i^G)' + (b_i^D)' - (b_i^L)' \leq (1-\tau_h)\, w h_i l_i + R_S\left(b_i^G + b_i^D\right) - R_L b_i^L,$$

where τ_h is a proportional income tax rate and a prime denotes next period. For rentiers instead:

$$\mathcal{V}_i^r(\mathbf{b}_i, 0, \mathbf{S}) = \max\left[u(c_i, l_i) + \beta\mathbb{E}(\phi_r\mathcal{V}_i^w(\mathbf{b}_i', 1, \mathbf{S}') + (1-\phi_r)\mathcal{V}_i^r(\mathbf{b}_i', 0, \mathbf{S}'))\right],$$

subject to (6)-(7) and to the flow budget constraint:

$$c_i + (b_i^G)' + (b_i^D)' - (b_i^L)' \leq (1-\tau_h)\,\mathcal{F} + R_S\left(b_i^G + b_i^D\right) - R_L b_i^L.$$

10.2.2 Banks

Banks face the following optimization problem:

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

subject to (10) and to:

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

where $a_t^z = \left(Q_t b_{F,t+1}^z + b_{D,t+1}^z\right)$ are the bank's assets. (12) imposes that assets cannot exceed $\mathbf{V}^b/\lambda$ since bankers otherwise would choose to divert their assets.

To solve this, guess that:

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

Subject to this guess, (12) can be expressed as a constraint on leverage, l_t^s:

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

Substituting (10) into (13), we can then express the bank's value as:

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

The first-order necessary conditions and the envelope condition are:

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

where $\mu_t^z \geq 0$ is the Kuhn-Tucker multiplier on (12). When the incentive constraint binds, banks expect to earn excess returns on their investments relative to the cost of capital (the deposit rate), $\mathbb{E}_t(R_{K,t+1}-R_{S,t+1})>0$, otherwise they equalize. We now impose that the incentive constraint binds so that leverage is equalized across banks. Given this, the Kuhn-Tucker multiplier is identical across banks and given as:

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

where $N_t=\int n_t^z dz$, $A_t=\int a_t^z dz$. This confirms the guess on the value function and implies:

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

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

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

The aggregate banking sector net worth now follows from noting that l_t is independent of net worth.

10.2.3 Goods Producers

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 then solve the problem:

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

subject to (18).

The first order condition for $P_{r,t}^F$ and the envelope condition are given as:

$$\begin{aligned}\left(1-\eta\left(1-\frac{P_t^m}{P_{r,t}^F}\right)\right)\frac{1}{P_t}y_{r,t} &= \frac{\eta}{\omega_Y}\frac{1}{P_{r,t}^F}\log\left(\frac{P_{r,t}^F}{P_{r,t-1}^F}\right)Y_t-\beta\mathbb{E}_t\frac{\partial\mathbf{V}_f^F\left(P_{r,t}^F,S_{t+1}\right)}{\partial P_{r,t}^F}\\ \frac{\partial\mathbf{V}_r^F\left(P_{r,t-1}^F,S_t\right)}{\partial P_{r,t-1}^F} &= \frac{\eta}{\omega_Y}\frac{1}{P_{r,t-1}^F}\log\left(\frac{P_{r,t}^F}{P_{r,t-1}^F}\right)Y_t\end{aligned}$$

which implies that:

$$\log\left(\pi_{h,t}\right)=\beta\mathbb{E}_t\log\left(\pi_{h,t+1}\right)\frac{Y_{t+1}}{Y_t}+\kappa_Y\frac{p_{h,t}}{P_t}\left(\frac{P_{m,t}}{p_{h,t}}-\frac{\eta-1}{\eta}\right)\frac{y_{h,t}}{Y_t}$$

Combining these and focusing on a symmetric equilibrium gives us Equation (21).

10.2.4 Capital Producers

Capital producers solve the following dynamic problem:

$$V^K\left(I_{n,t-1},S_t\right)=\max_{I_{n,t}}\left(v_t^I+\beta\mathbb{E}_tV^K\left(I_{n,t},S_{t+1}\right)\right)$$

The first-order necessary condition for $I_{n,t}$ and the envelope condition are given as:

$$\left(Q_t-1\right)+\beta\mathbb{E}_t\frac{\partial V^K\left(I_{n,t},S_{t+1}\right)}{\partial I_{n,t}}=\omega_I\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)+\frac{\omega_I}{2}\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)^2 \tag{43}$$

$$\frac{\partial V^K\left(I_{n,t-1},S_t\right)}{\partial I_{n,t-1}}=\omega_I\left(\log\left(\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi}\right)\right)\frac{I_{n,t}+\psi}{I_{n,t-1}+\psi} \tag{44}$$

Combining these gives us Equation (29).

10.3 Appendix C: Estimation of the Household Income Process

Assume that log household income is determined as:

$$
\begin{aligned}
y_{i,t} &= \delta_t + \delta_Z Z_{i,t} + \tilde{y}_{i,t} \\
\tilde{y}_{i,t} &= x_{i,t} + \varepsilon_{i,t} \\
x_{i,t} &= \rho x_{i,t-1} + e_{i,t} \\
\varepsilon_{i,t} &\sim N(0, \sigma_\varepsilon^2) \\
e_{i,t} &\sim N(0, \sigma_e^2)
\end{aligned}
$$

where δ_t is a time fixed effect, $Z_{i,t}$ is a vector of household characteristics, $x_{i,t}$ is a persistent idiosyncratic income component, and $\varepsilon_{i,t}$ is a transitory income shock. The autocovariances of residualized household income of order 0-2 are given as:

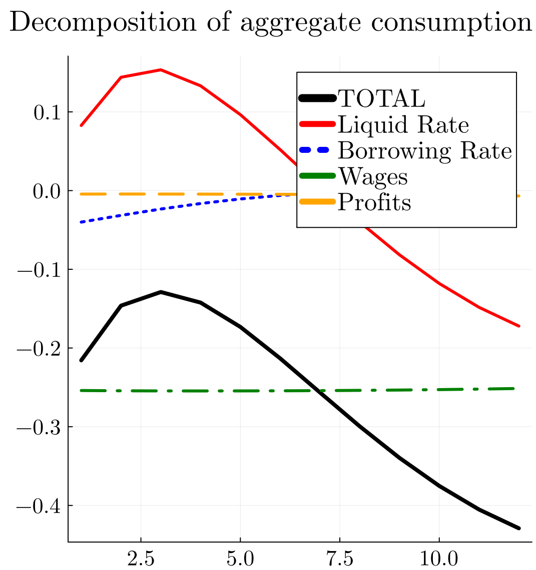
$$m_{1,t} = \mathbb{E}(\tilde{y}_{i,t} \cdot \tilde{y}_{i,t}) = \frac{1}{1-\rho^2}\sigma_e^2 + \sigma_\varepsilon^2 \tag{45}$$

$$m_{2,t} = \mathbb{E}(\tilde{y}_{i,t} \cdot \tilde{y}_{i,t-1}) = \frac{\rho}{1-\rho^2}\sigma_e^2 \tag{46}$$

$$m_{3,t} = \mathbb{E}(\tilde{y}_{i,t} \cdot \tilde{y}_{i,t-2}) = \frac{\rho^2}{1-\rho^2}\sigma_e^2 \tag{47}$$

These three moments identify jointly $\Gamma = (\rho, \sigma_e, \sigma_\varepsilon)$. We estimate Γ with GMM using an identity weighting matrix.

10.4 Appendix D: Further Results for the Baseline Model



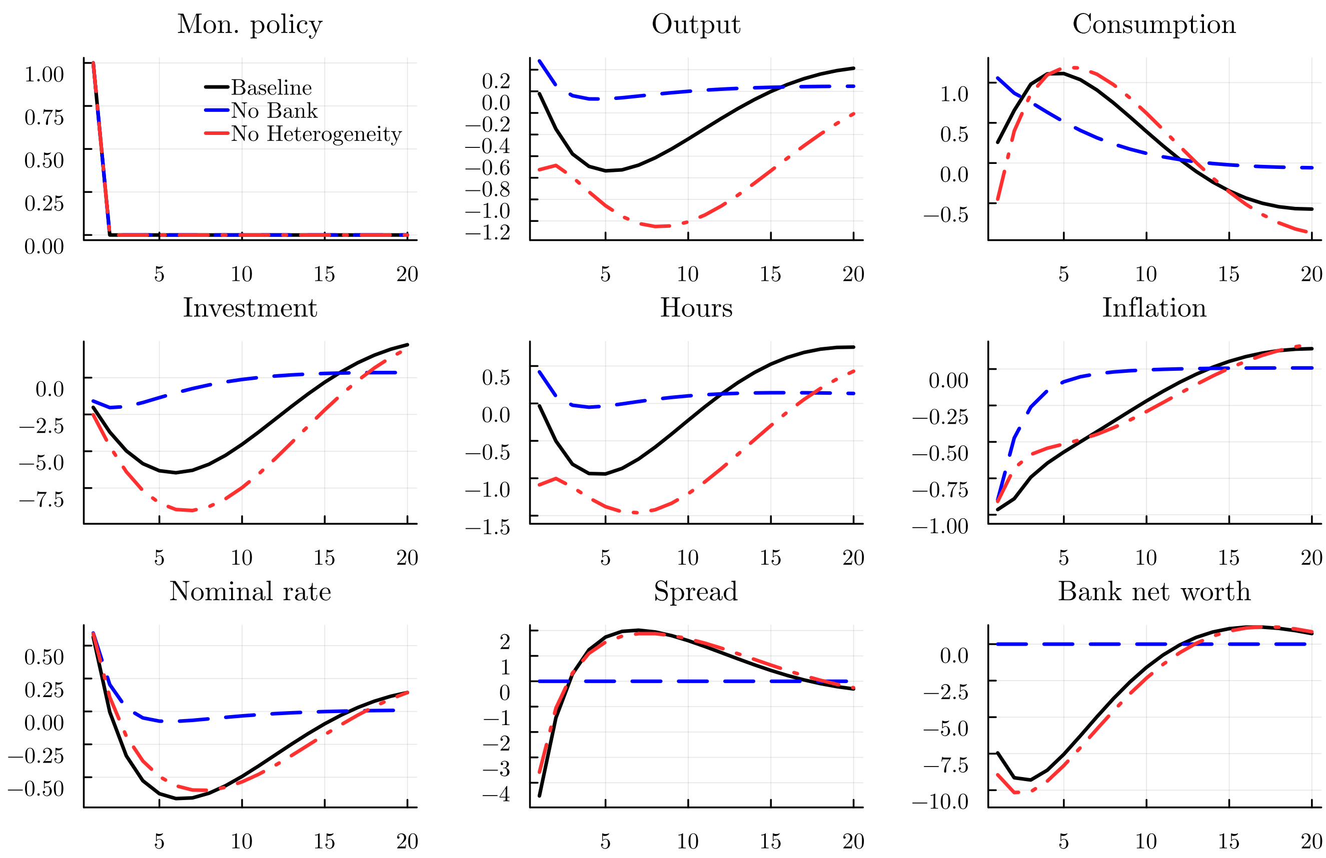
Notes: The figure plots the decomposition of the response of aggregate consumption to a one percent negative capital quality shock into the effect of each price sequence by using household policy functions.

Figure 11: Transmission to Consumption: Capital quality shock

Table 12: Business Cycle Moments: MPC Comparison

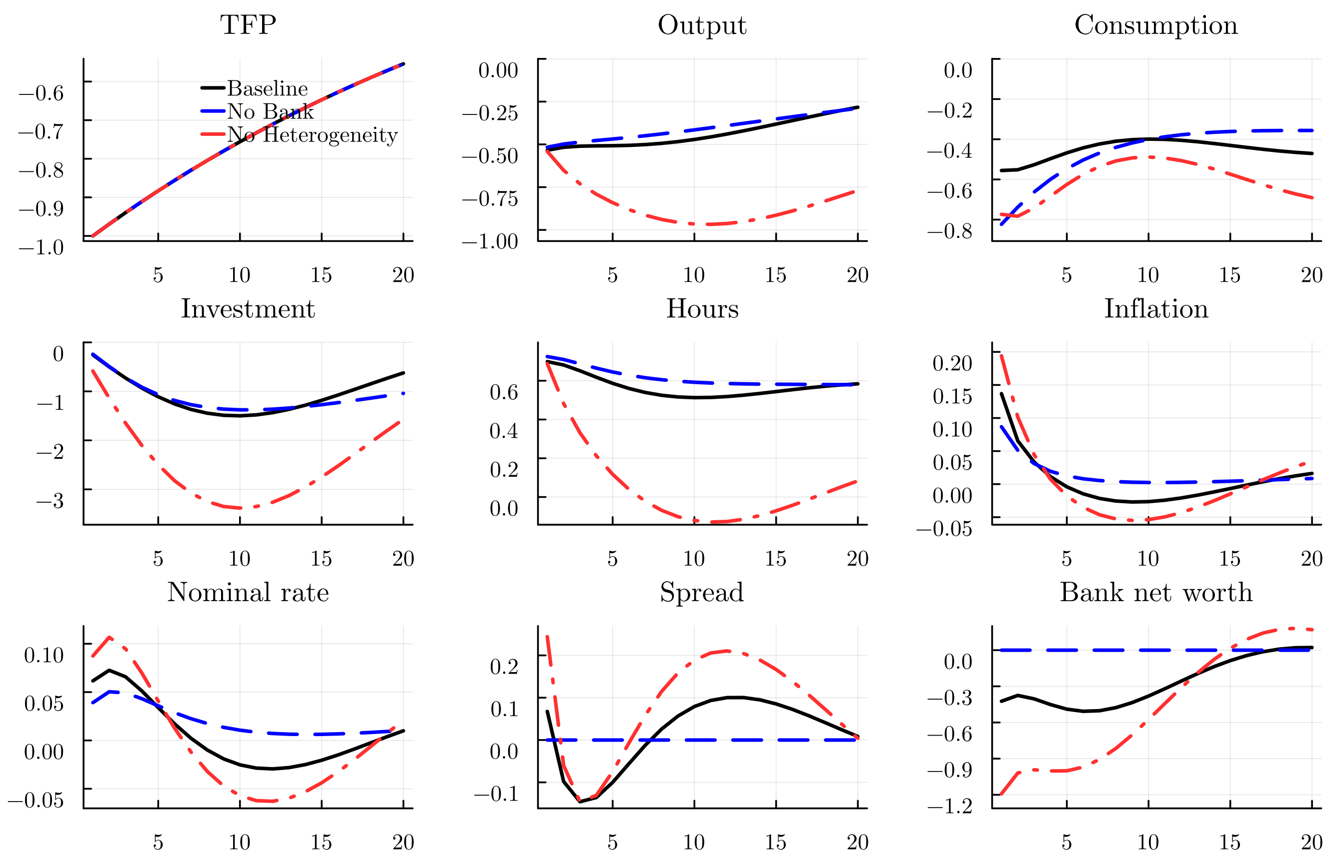
Moments	Baseline	Constant Spread	No bank
σ_{MPC}/σ_Y	0.60	0.06	0.17
$corr(MPC, Y)$	-0.60	-0.56	0.03

Notes: σ_x denotes the percentage standard deviation of x, $corr(x, y)$ is the correlation of x and y. Model moments computed for HP-filtered data. Model moments are in response to TFP, monetary, and capital quality shocks. Standard deviations and correlations for the MPC are based on annual data.



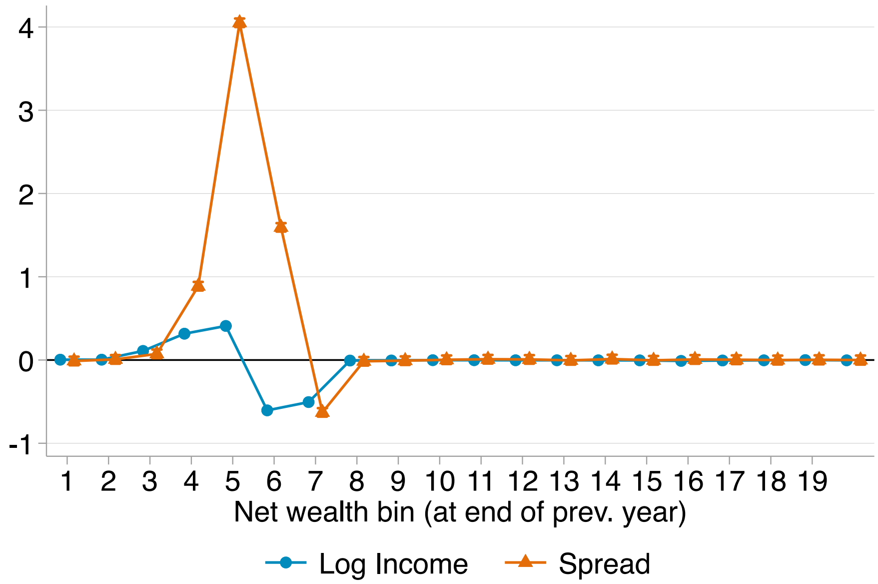
Notes: Impulse responses to a one percentage point positive nominal interest rate shock. See Figure 5 for legend.

Figure 12: Aggregate Effects of a Monetary shock



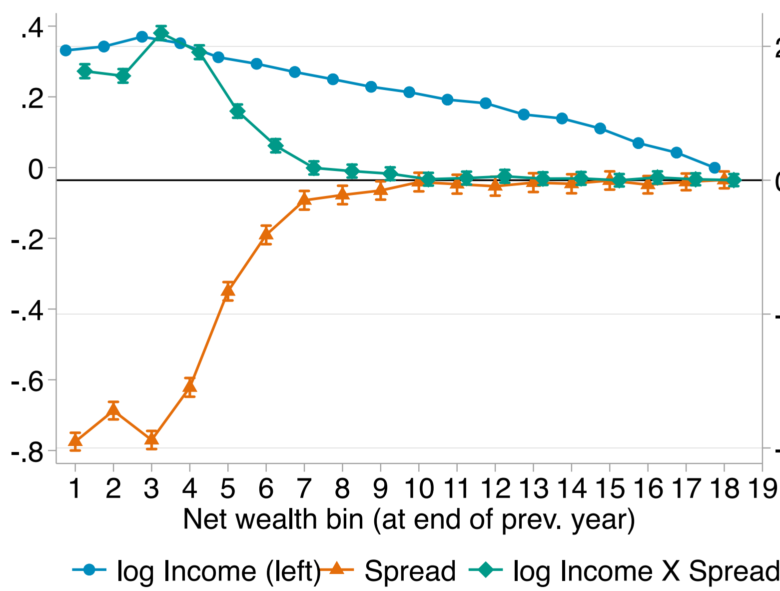
Notes: Impulse responses to a one percent negative TFP shock. See Figure 5 for legend.

Figure 13: Aggregate Effects of a TFP shock



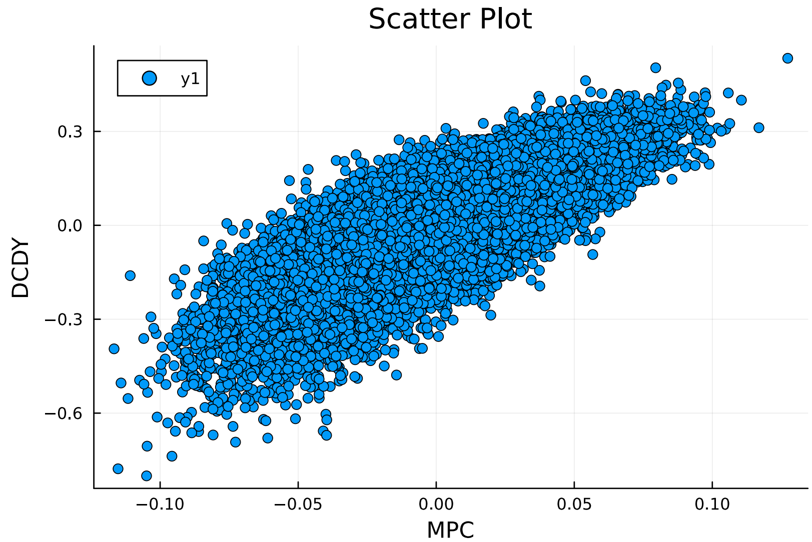
Notes: The figure shows the change in transition probabilities into the zero net wealth state with cross-sectional changes in income and the consumer credit spread (estimated from Equation (2)). Zero net wealth is defined as net assets within a range of plus/minus two weeks of median household income.

Figure 14: Zero Net Wealth Dynamics



Notes: The figure illustrates the parameters estimated from Equation (3) on model simulated data in response to idiosyncratic income and spread shocks. The underlying wealth distribution is trimmed at the 3rd and 97th percentile. The error bars illustrate 95% confidence intervals. Standard errors clustered at the household level.

Figure 15: Consumption and the Spread in the Model



Notes: Simulation of model implied average MPC and DCDY (HP-filtered) in response to TFP, monetary, and capital quality shocks. DCDY is calculated using the model regression coefficients from Table 1. The correlation between the two series is 90 percent.

Figure 16: Scatter Plot: DCDY and MPC

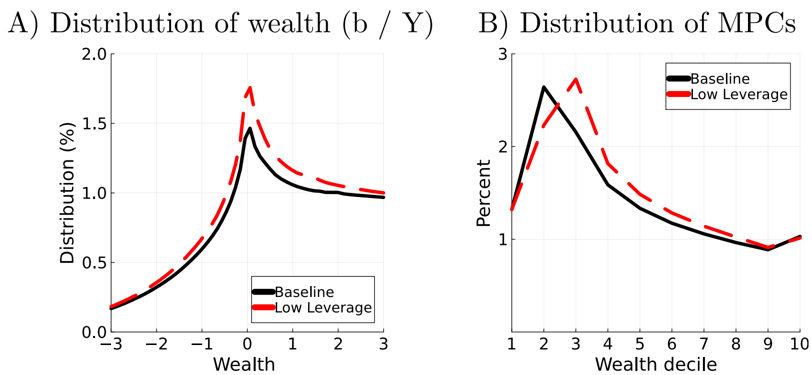


Figure 17: Distributions: Baseline and Restricted Leverage

10.5 Appendix E: The Three Asset Model

Here we discuss the relevant parts of the three-asset model studied in Section 8. We focus on the elements that differ from the baseline two asset model presented in Section 3.

Households: In the three asset model, households can hold capital, $k_{i,t}$ which they rent directly to firms at the real capital rental rate $r_{k,t}$. Households cannot go short on the illiquid asset $k_{i,t+1} \geq 0$. They can carry out maintenance every period which corresponds to depreciation at the constant proportional rate $\delta \in (0,1)$. However, in a given period, they can adjust capital holdings *actively* only with the probability $\phi_k \in (0,1)$ which is constant across time and households. Households that actively change their capital stock, purchase new capital at the price Q_t (relative to the price of consumption). Thus, the one-period expected return on the illiquid asset is $\mathbb{E}_t R_{I,t+1} = \mathbb{E}_t(r_{K,t+1} + Q_{t+1} - \delta)/Q_t$.[28] As long as $\phi_k < 1$, households will only hold capital if $\mathbb{E}_t(R_{I,t+1} - R_{S,t+1}) > 0$.

Let $\mathbf{b}_{i,t} = (b^G_{i,t}, b^D_{i,t}, k_{i,t}, b^L_{i,t})$ denote household i's beginning of period asset portfolio, $\mathbf{S}_t$ the vector of relevant aggregate state variables, and $\mathcal{V}^{w,a}_i$ the value function for a household that can adjust its illiquid bond holding. The Bellman equation for such a household is given as:

$$\begin{aligned}\mathcal{V}^{w,a}_i(\mathbf{b}_{i,t}, h_{i,t}, \mathbf{S}_t) &= \max[\mathrm{u}(c_{i,t}, l_{i,t}) \\ &+ \beta\mathbb{E}_t((1-\phi_w)(\phi_k \mathcal{V}^{w,a}_i(\mathbf{b}_{i,t+1}, h_{i,t+1}, \mathbf{S}_{t+1}) + (1-\phi_k)\mathcal{V}^{w,n}_i(\mathbf{b}_{i,t+1}, h_{i,t+1}, \mathbf{S}_{t+1})) \\ &+ \phi_w(\phi_k \mathcal{V}^{r,a}_i(\mathbf{b}_{i,t+1}, \mathbf{S}_{t+1}) + (1-\phi_k)\mathcal{V}^{r,n}_i(\mathbf{b}_{i,t+1}, \mathbf{S}_{t+1})))] \end{aligned} \tag{48}$$

subject to (6)-(7) and to the flow budget constraint:

$$\begin{aligned} c_{i,t} + b^G_{i,t+1} + b^D_{i,t+1} + Q_t(k_{i,t+1} - k_{i,t}) - b^L_{i,t+1} \leq \\ (1-\tau_{h,t})\, w_t h_{i,t} l_{i,t} + R_{S,t}\left(b^G_{i,t} + b^D_{i,t}\right) + (r_{K,t} - \delta)k_{i,t} - R_{L,t} b^L_{i,t} \end{aligned} \tag{49}$$

$\mathcal{V}^{w,n}_i$ is the value function of a household that cannot adjust illiquid assets this period, while $\mathcal{V}^{r,s}_i$ denotes the rentiers' value functions. $\mathcal{V}^{w,n}_i$ is given as:

$$\begin{aligned}\mathcal{V}^{w,n}_i(\mathbf{b}_{i,t}, h_{i,t}, \mathbf{S}_t) &= \max[\mathrm{u}(c_{i,t}, l_{i,t}) \\ &+ \beta\mathbb{E}_t((1-\phi_w)(\phi_k \mathcal{V}^{w,a}_i(\mathbf{b}_{i,t+1}, h_{i,t+1}, \mathbf{S}_{t+1}) + (1-\phi_k)\mathcal{V}^{w,n}_i(\mathbf{b}_{i,t+1}, h_{i,t+1}, \mathbf{S}_{t+1})) \\ &+ \phi_w(\phi_k \mathcal{V}^{r,a}_i(\mathbf{b}_{i,t+1}, \mathbf{S}_{t+1}) + (1-\phi_k)\mathcal{V}^{r,n}_i(\mathbf{b}_{i,t+1}, \mathbf{S}_{t+1})))] \end{aligned} \tag{50}$$

subject to (6)-(7) and to the flow budget constraint:

$$\begin{aligned} c_{i,t} + b^G_{i,t+1} + b^D_{i,t+1} - b^L_{i,t+1} \leq \\ (1-\tau_{h,t})\, w_t h_{i,t} l_{i,t} + R_{S,t}\left(b^G_{i,t} + b^D_{i,t}\right) + (r_{K,t} - \delta)k_{i,t} - R_{L,t} b^L_{i,t} \end{aligned} \tag{51}$$

The rentiers' value function is the solution to:

$$\begin{aligned}\mathcal{V}^{r,a}_i(\mathbf{b}_{i,t}, h_{i,t}, \mathbf{S}_t) &= \max[\mathrm{u}(c_{i,t}, l_{i,t}) \\ &+ \beta\mathbb{E}_t((1-\phi_r)(\phi_k \mathcal{V}^{w,a}_i(b_{i,t+1}, h_{i,t+1}, S_{t+1}) + (1-\phi_k)\mathcal{V}^{w,n}_i(b_{i,t+1}, h_{i,t+1}, S_{t+1})) \\ &+ \phi_r(\phi_k \mathcal{V}^{r,a}_i(b_{i,t+1}, S_{t+1}) + (1-\phi_k)\mathcal{V}^{r,n}_i(b_{i,t+1}, S_{t+1})))] \end{aligned} \tag{52}$$

[28]Note that $R_{I,t}$ includes a capital gain. For a household that cannot adjust its capital stock, the net-of-capital-gains return is $R_{I,t} - Q_t/Q_{t-1}$.

subject to (6)-(7) and to the flow budget constraint:

$$c_{i,t}+b^{G}_{i,t+1}+b^{D}_{i,t+1}+b^{I}_{i,t+1}-b^{L}_{i,t+1}\leq(1-\tau_{h,t})\,\mathcal{F}_t+R_{S,t}\left(b^{G}_{i,t}+b^{D}_{i,t}\right)+R_{I,t}b^{I}_{i,t}-R_{L,t}b^{L}_{i,t} \tag{53}$$

Finally, the dynamic programme of a rentier who cannot adjust their illiquid bonds is given as:

$$\begin{aligned}\mathcal{V}^{r,n}_{i}\left(\mathbf{b}_{i,t},h_{i,t},\mathbf{S}_t\right) &= \max[\mathrm{u}\left(c_{i,t},l_{i,t}\right)\\ &+ \beta\mathbb{E}_t((1-\phi_r)\left(\phi_k\mathcal{V}^{w,a}_{i}\left(\mathbf{b}_{i,t+1},h_{i,t+1},\mathbf{S}_{t+1}\right)+(1-\phi_k)\mathcal{V}^{w,n}_{i}\left(\mathbf{b}_{i,t+1},h_{i,t+1},\mathbf{S}_{t+1}\right)\right)\\ &+ \phi_r\left(\phi_k\mathcal{V}^{r,a}_{i}\left(\mathbf{b}_{i,t+1},\mathbf{S}_{t+1}\right)+(1-\phi_k)\mathcal{V}^{r,n}_{i}\left(\mathbf{b}_{i,t+1},\mathbf{S}_{t+1}\right)\right))]\end{aligned} \tag{54}$$

subject to (6)-(7) and to the flow budget constraint:

$$c_{i,t}+b^{G}_{i,t+1}+b^{D}_{i,t+1}-b^{L}_{i,t+1}\leq(1-\tau_{h,t})\,\mathcal{F}_t+R_{S,t}\left(b^{G}_{i,t}+b^{D}_{i,t}\right)+(R_{I,t}-1)b^{I}_{i,t}-R_{L,t}b^{L}_{i,t} \tag{55}$$

In this economy, households may again be constrained or not, but it is their liquid wealth that matters. First, the household may be a saver and on a "short run" Euler equation with a slope determined by the return on liquid assets. Alternatively, the household may be a borrower and not constrained by (6) and on an Euler equation with slope determined by the borrowing rate:

$$\begin{aligned}(c^{\mathrm{I}}_{i,t})^{-\vartheta_c} &= \beta\mathbb{E}_t(c^{\mathrm{I}}_{i,t+1})^{-\vartheta_c}R_{S,t+1}\\ (c^{\mathrm{II}}_{i,t})^{-\vartheta_c} &= \beta\mathbb{E}_t(c^{\mathrm{II}}_{i,t+1})^{-\vartheta_c}R_{L,t+1}\end{aligned}$$

using the same notation as in Section 3. There are also two groups of *constrained* households with high marginal propensities to consume. Households may be indebted and up against the borrowing constraint, or they may hold no liquid wealth and neither want to save nor borrow. Assuming for simplicity that households were in either of these states at date $t-1$, their consumption levels are given as:

$$\begin{aligned}c^{\mathrm{III}}_{i,t} &= (1-\tau_{h,t})\,w_t h_{i,t}l_{i,t}+(r_{K,t}-\delta)k_{i,t}-(R_{L,t}-1)\underline{\mathbf{b}}\\ c^{\mathrm{IV}}_{i,t} &= (1-\tau_{h,t})\,w_t h_{i,t}l_{i,t}+(r_{K,t}-\delta)k_{i,t}\end{aligned}$$

Here there may be a substantial amount of type IV agents and such households may be wealthy due to illiquid asset holdings. When credit spreads rise, the kink exaggerates and a larger measure of agents will find themselves with no liquid assets and high MPCs.

Intermediate Goods Producers: Intermediate goods producers rent part of their capital input from households. The effective capital input is given as:

$$k^{e}_{j,t}=\xi_t k^{P}_{j,t}+k^{R}_{j,t} \tag{56}$$

where $k^R_{j,t}$ denotes capital rented from households. We assume that the capital quality shock, $\xi_t > 0$ impacts only equity financed capital. The demand for labor and rented capital input solve:

$$\upsilon^m_{j,t} = \max_{n_{j,t}, k^R_{j,t}} \left(P^m_t m_{j,t} - w_t n_{j,t} - r_{K,t} k^R_{j,t} \right)$$

which implies that:

$$\begin{aligned} w_t &= P^m_t \alpha Z_t n^{\alpha-1}_{j,t} \left(k^e_{j,t}\right)^{1-\alpha} && (57) \\ r_{K,t} &= P^m_t \left(1-\alpha\right) Z_t n^{\alpha}_{j,t} \left(k^e_{j,t}\right)^{-\alpha} && (58) \end{aligned}$$

Having paid households for the cost of rental of labor and capital, the firm pays its equity holders its profits and the market value of its capital stock net of maintenance costs:

$$\varsigma^m_{j,t} = \upsilon^m_{jt} + Q_t \xi_t k^p_{jt} - \delta \xi_t k^p_{jt}$$

where $\upsilon^m_{jt} = (1-\alpha) P^m_t Z_t n^{\alpha}_{j,t} \left(k^e_{j,t}\right)^{1-\alpha} (1 - k^R_t / k^e_t)$. Thus, the return on equity offered is:

$$R_{K,t} = \frac{\left(r_{K,t} + Q_t - \delta\right) \xi_t}{Q_{t-1}} \qquad (59)$$

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. To get Equation (59), define the return $R_{K,t} = \varsigma_{j,t} / (Q_{t-1} k^P_{j,t})$ and note that $\upsilon^m_{j,t} = r_{K,t}(k^e_{j,t} - k^R_{j,t}) = r_{K,t} \xi_t k^P_{j,t}$.

Capital Goods Producers: The law of motion of aggregate capital is:

$$K_{t+1} - \left(K^r_t + \xi_t K^p_t\right) = I_{n,t}. \qquad (60)$$

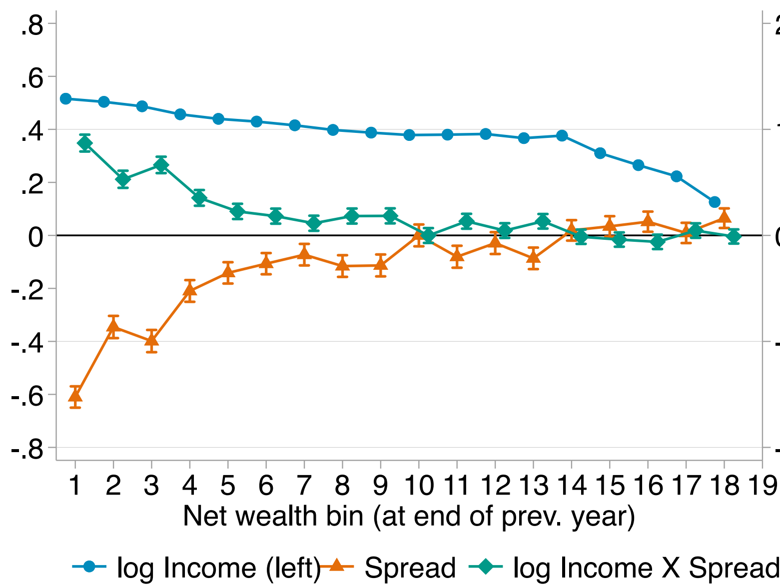
and I_t and CI_t then follow as:

$$\begin{aligned} I_t &= I_{n,t} + \delta \left(K^r_t + \xi_t K^p_t\right), && (61) \\ CI_t &= I_t + \frac{\omega_I}{2} \left(\log \left(\frac{I_{n,t} + \psi}{I_{n,t-1} + \psi} \right) \right)^2 \left(I_{n,t} + \psi\right). && (62) \end{aligned}$$

where K^r_t is the aggregate amount of capital held directly by households and rented to firms, and K^p_t is the aggregate amount of capital that intermediate firms finance through equity issues.

Table 13: Three Asset Model Parameterization

	Description	Value		Description	Value
Households			**Monetary and fiscal policy**		
β	Discount factor	0.9855	$\overline{\pi}$	Inflation target	1.00
χ	Disutility weight of labor	0.20	κ_π	Response to inflation	1.50
$1/\vartheta_c$	Intertemp. elasticity	2/3	κ_R	Int.rate smoothing	0.70
ϑ_l	Frisch elasticity	0.75	$\overline{G}/\overline{Y}$	Gov. spending share	0.26
ϕ_w	Transition prob. to rentier	0.001	$\overline{B}^G/\overline{Y}$	Gov. debt ratio	0.39
ϕ_r	Transition prob. to worker	0.0625	τ_h	tax rate	0.38
$\underline{\mathbf{b}}$	Borrowing constraint	$1\ \overline{Y}$	κ_G	Response of G to debt	0.10
ϕ_k	Illiquidity of capital	0.0025			
Supply side			**Stochastic shocks**		
α	Output elasticity to labor	0.67	ρ_h	Persistence of HH income shocks	0.948
δ	Depreciation rate	0.02	ρ_z	Persistence of TFP shocks	0.967
ω_I	Adjustment costs	2.00	σ_h^2	Variance of HH income shocks	0.097^2
η	Elasticity of substitution	21	σ_z^2	Variance of TFP shocks	0.022^2
ω_Y	Price stickiness	0.10	σ_ξ^2	Variance of cap.q. shocks	0.022^2
			σ_R^2	Variance of mon.pol. shocks	0.001^2
Banking					
λ	Divertible fract. of assets	0.38	θ	Bank survival rate	0.972
ζ	Funds new managers	0.0037	ω_b	Consumer loan cost	0.0075



Notes: This figure illustrates the relationship in the 3-asset model between consumption and income, borrowing spreads and their interaction, estimated from Equation (3) based on model-simulated data in response to idiosyncratic income and spread shocks.

Figure 18: Coefficient Estimates from Quantile Regressions on Model Simulations

Table 14: Moments: Baseline and Restricted Leverage

	Baseline		**3-asset model**	
	Baseline	Low leverage	Baseline	Low leverage
Leverage	2.93	2.64	2.93	2.63
	Interest rates			
Return on capital (R_K, %)	4.69	4.82	4.65	4.62
Return on bonds and deposits (R_S, %)	3.81	3.54	3.30	2.70
Lending interest rate (R_L, %)	7.87	8.00	7.83	7.80
	Aggregates			
Output	4.89	4.91	4.88	4.90
Capital	49.26	48.93	49.31	49.63
Labor supply	1.44	1.45	1.45	1.46
Consumption	2.64	2.70	2.68	2.66
	Household distribution			
At kink (%)	4.03	4.82	8.94	10.21
Borrowers (%)	21.95	24.47	27.91	31.86
Gini wealth	77.50	82.02	76.33	77.07
Gini consumption	15.67	16.46	17.84	17.85
Gini income	28.53	30.11	25.34	25.24

Notes: We compare the baseline steady state to one with 10% less leverage (diversion parameter λ going from 0.381 to 0.445). The last two columns do so for the model with household portfolios consisting of 3 assets.

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