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Davide Melcangi
Vincent Sterk

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Abstract

What role does stock investment play in the transmission of monetary policy to the real economy? We study this question using a New Keynesian model with heterogeneous households. Following a monetary tightening, stock market participants rebalance their investments away from stocks, in line with empirical evidence on mutual fund flows. This response depresses aggregate investment and hence aggregate output and income, which feeds back into an even larger decline in stock investment. The strength of this channel is, however, highly sensitive to household heterogeneity. Therefore, we design the model to account endogenously for the observed population share of stockholders, their income characteristics, and their saving behavior. We find that, quantitatively, the stock investment channel of monetary policy dominates the consumption channels often emphasized in the literature, and also that it has become more powerful since the 1980s, as stock market participation increased.

Key words: monetary policy, stock investment, heterogeneity

Melcangi: Federal Reserve Bank of New York (email: davide.melcangi@ny.frb.org). Sterk: University College London (email: v.sterk@ucl.ac.uk). The authors thank René Chalom and Brendan Moore for excellent research assistance. For helpful comments, they also thank Simon Gilchrist, David Lucca, and Andrea Tambalotti, as well as various seminar and conference participants. The views expressed in this paper are those of the authors and do not necessarily represent the position of the Federal Reserve Bank of New York or the Federal Reserve System.

1 Introduction

Monetary policy is widely believed to have a profound impact on the stock market, as suggested by the vast number of stock market analyst reports written on decisions of the Federal Open Market Committee. But what is the role of stock investors in the transmission of monetary policy to the *real* economy? Textbook models of monetary policy and the macro economy do not assign a central role to households' stock investments, but rather focus on how changes in interest rates affect their consumption decisions.

However, a long-standing narrative, put forward by Mundell (1963) and Tobin (1965), does suggest that at least some of the real effects of monetary policy operate via the stock market. These authors argued that an increase in interest rates raises the opportunity cost of investments into non-interest-bearing assets. According to this logic, a higher interest rate would induce households to rebalance their wealth away from the stock market and towards for instance saving accounts, thereby squeezing the equity funds available for capital investment. Indeed, this rebalancing channel is present in virtually any model with interest-bearing assets and capital investment, be it with or without household heterogeneity. Its quantitative importance, however, remains elusive.

In this paper, we argue that in order to assess the stock investment channel, it is critical to consider heterogeneity among households regarding their participation in the stock market and the amount of stock investment. Accordingly, we develop a New Keynesian model with household heterogeneity which can account for the cross-sectional relation between income, saving and stock investment. A key feature of the model is the emergence of a group of high-income households who save a large fraction of their incomes, and do so primarily by adding to their stock portfolios. These households turn out to be critical to the transmission of monetary policy via aggregate investment, both through "direct" effects and through "indirect" equilibrium effects.[1]

We find that, due to both effects, the overall stock investment channel is quantitatively very powerful. Moreover, the strength of the channel depends on the income distribution, as those at the top are much more likely to become stock investors. Related, we find that over the last few decades the stock investment channel has strengthened considerably, as

[1]The model also captures the direct and indirect channels of the transmission via *consumption*, as studied in the literature. As explained by Kaplan, Moll and Violante (2017), the consumption channels work via different types of households (unconstrained and liquidity-constrained households, respectively) and work in opposite directions, offsetting each other partially. By contrast, the direct and indirect effects of the stock investment channel that we highlight both work via the same category of households (stock investors) and push in the *same* direction, reinforcing each other. As a result, this channel becomes highly sensitive to the population share of stock investors. We will expand extensively on this point, starting in Section 2 with two simplified models.

incomes became less equal and stock market participation increased.

Before presenting the model, we provide aggregate time-series evidence which sheds light on the potential importance of the stock investments for the pass-through of monetary policy. This evidence suggests that much of the decline in aggregate output following a monetary tightening is driven by investment rather than consumption. Related to this finding, we also show that households reduce their net investments into equity-focused mutual funds following a monetary tightening. Finally, we show that the net investment inflows into equity-based funds predict changes in aggregate investment into physical capital. All three patterns are consistent with an important role for stock investments, although the precise importance of this channel vis-à-vis other channels can only be teased out cleanly within a model, as they operate simultaneously.

To discipline the extent of household heterogeneity in the model, we then discuss three key cross-sectional facts. First of all, most households do not participate in the stock market. Therefore, the stock investment channel operates only via a minority of the population, although over time the participation rate has increased. Second, stock market participants are not representative of the population. Indeed, they tend to be located at the upper echelons of the income distribution, see Porterba and Samwick (1995). We document the relation between income and stock market participation in the Survey of Consumer Finances. Third, high-income households save a relatively large fraction of their incomes, as there is a strong negative relation between income and expenditure rates, see also Dynan, Skinner and Zeldes (2004); Straub (2017). We use data from the Consumer Expenditure Survey, to discipline this relation in the model.

We design the model to account for these facts. The model incorporates heterogeneity in permanent income, as well as idiosyncratic unemployment risk. Households can save into fully liquid, interest-bearing assets as well as into stock market funds, which are subject to a linear withdrawal tax, and are therefore relatively illiquid.[2] To account for the positive relation between income, stock market participation and saving rates, we introduce an "infrequent" consumption good, which households can enjoy only during specific periods and which enters the utility function as a luxury good vis-à-vis regular consumption. With such consumption goods we have in mind large, but relatively rare expenditures which are typically the preserve of the rich, for example exclusive medical or old-age care, tuition for elite education, starting capital for a private business, or large donations.

The infrequent good creates an additional saving motive, which is particularly relevant

[2]In the U.S., households face a capital gains tax when selling stocks, which is particularly high when the assets are held for less than a year. Moreover, many U.S. households save in stocks via retirement accounts (IRA or 401(k)), which come with hefty early withdrawal penalties.

to high-income households, given its luxury nature. Hence, the model predicts that high-income households have relatively high saving rates. Moreover, given that infrequent goods are consumed only rarely, households tend to save for such goods using relatively illiquid assets which offer higher returns, i.e. stocks. Due to this feature, the model is also able to generate a high degree of wealth inequality, and in particular a fat-tailed wealth distribution, as observed in the data.

At any point in time, the population of households in the model can be categorized into three groups who display distinctly different saving behavior. First, there are households who save, but only into liquid, interest-bearing assets. They do so for precautionary reasons, as households face unemployment risk. We label these households "emergency savers" and they react to changes in the interest rate via intertemporal substitution of consumption, the conventional channel in the New Keynesian model. A second group of households has hit a borrowing constraint, due to becoming unemployed. These "hand-to-mouth" households do not respond directly to changes in interest rates, but react heavily to changes in income.

The third group of households saves not only in bonds but also into stocks and we label them "stock investors". They have high incomes and a high propensity to save into stocks. The stock investors' trade-offs regarding the amount of stock purchases are characterized by an Euler equation. This is in line with empirical evidence in Vissing-Jorgensen (2002) who shows that a frictionless Euler equation for stocks fits the micro data well, once the estimation sample is restricted to include only those households who participate in the market.

The behavior of the stock investors turns out to be pivotal for the transmission of monetary policy to the macro economy. Because they have the option to rebalance the amount of saving going into stocks versus liquid assets, their consumption is relatively unresponsive to changes in interest rates. For the same reason, their investment into stocks tends to react strongly when interest rates change. Moreover, stock market participants tend to invest marginal income flows into their stock portfolios, which creates the feedback from household income to investment mentioned above.

After calibrating the model to the US economy, we simulate the macroeconomic effects of a monetary policy shock and find that capital investment accounts for much of the decline in aggregate output, in line with the empirical evidence. We then ask to what extent these macro responses are driven by the portfolio decisions of stock investors. To this end, we conduct two exercises. First, we decompose the response of aggregate investment and find that rebalancing behavior accounts for a substantial part of its decline. The remaining part is mostly due to the equilibrium decline in aggregate income, which further reduces stock investments.

Second, we consider a counterfactual version of the baseline model in which we shut down variations in stock investment, while keeping the steady-state aggregates and distributions unaltered. This implies that monetary policy transmits only through consumption. We find that in the counterfactual, not only the decline in aggregate output is much smaller than in the baseline model, but also consumption falls less persistently. Therefore, the stock investment channel not only matters for aggregate output directly via investment, but also less directly via consumption.[3]

In the final part of the paper, we study how the transmission of monetary policy via stock investments interacts with inequality. In the model, inequality in wealth and consumption increases following a monetary tightening, and we show that this increase is driven by the portfolio decisions of stock investors. Vice versa, the presence of inequality matters for the impact of monetary policy on macroeconomic aggregates, since distributional factors determine the rate of stock market participation and the amount of stock investments.

Since inequality has been trending upwards during the last few decades, the model implies that the macroeconomic effects of monetary policy have changed. To study the extent of this change, we compare a version of the model calibrated to the 1980s to a version calibrated to 2000s.[4] The model endogenously predicts an increase in stock market participation, as incomes in the upper half of the income distribution are lifted. We find that since the 1980s the effects of monetary policy – in particular on investment – have strengthened considerably with the rise in inequality and stock market participation.

We build on a literature which developed New Keynesian models with household heterogeneity and liquidity frictions, which emphasizes households who make a corner decision for liquid assets (i.e. the borrowing-constrained), see Auclert (2019); Debortoli and Galí (2017); Gornemann, Kuester and Nakajima (2016); Hagedorn, Luo, Manovskii and Mitman (2019); Kaplan, Moll and Violante (2017); Luetticke (2020); McKay, Nakamura and Steinsson (2016); McKay and Reis (2016); Ravn and Sterk (2020); Auclert, Rognlie and Straub (2020), and many others. We highlight the importance of incomplete insurance markets and household heterogeneity in stock investments. Our analysis thereby complements a literature which considers the propagation of monetary policy in models with heterogeneity and financial frictions on the firm side, as in e.g. Bernanke, Gertler and Gilchrist (1999) and Ottonello and Winberry (2018). Finally, the presence of the infrequent good relates to stud-

[3]For robustness, we consider various extensions of the model, including one in which firms face financial frictions and household savings can reach firms via both debt and equity markets. We find that results are either not affected at all or somewhat dampened, see Section 4.1 and Appendix 3 for details.

[4]Holm (2020) studies the effects of an increase in household income risk on the strength of monetary transmission. In our model experiments, we keep income risk constant, but consider shifts in the distribution of permanent income.

ies which consider savings motives that are not traditionally found in incomplete-markets models, see for instance Ameriks, Briggs, Caplin, Shapiro and Tonetti (2020), Campbell and Hercowitz (2019), and Straub (2017).

2 Insights from two simple models

A key point of this paper is that the stock investment channel is highly sensitive to household heterogeneity. This point can be understood by contrasting two highly stylized heterogeneous-agents models, one with a standard consumption channel and another one with the stock investment channel instead. Let $Y = C + I$, i.e. aggregate income is the sum of consumption and investment expenditures.

In model 1, we focus on monetary transmission via consumption and therefore fix investment ($dI = 0$). Thus, model 1 abstracts from the stock investment channel. A fraction $htm \in [0, 1]$ of the population are "hand-to-mouth", i.e. their consumption is unaffected by interest rates, but responds one-for-one to changes in income. Consumption of the remaining households responds to interest rates according to their Elasticity of Intertemporal Substitution, $EIS = -\frac{\partial C/C}{\partial R/R} > 0$, but does not react to changes in income.[5,6] Other than this, the two types are identical. Aggregation gives: $dC = -(1-htm) \cdot \frac{C}{R} \cdot EIS \cdot dR + htm \cdot dY$. Here, the first term captures the "direct effect" of a change in interest rates, whereas the second term captures the consumption response to a change in income. Solving the model gives the total response of aggregate consumption to the interest rate: $\frac{dC/C}{dR/R} = -\frac{1-htm}{1-htm} EIS = -EIS$, where we used that $dC = dY$.

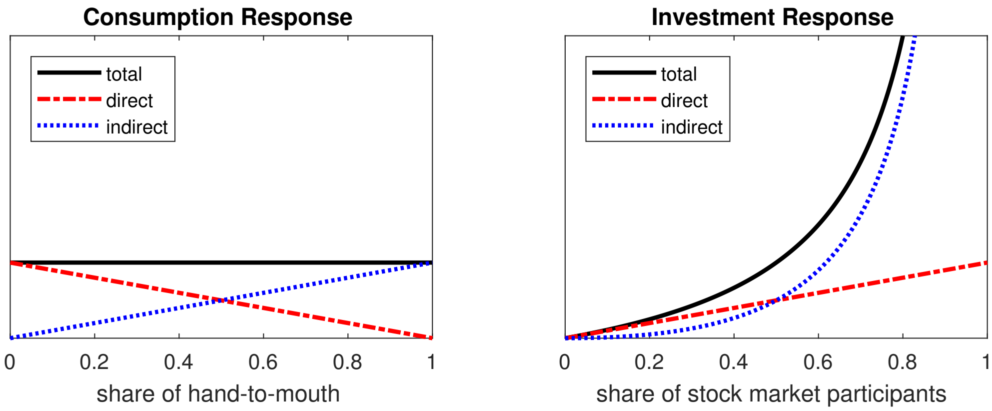
In model 2 we instead focus on investment and assume that households keep consumption fixed (so that $dC = 0$). Thus, this model abstracts from the consumption channels of monetary policy. A fraction $si \in [0, 1]$ of the population consists of stock market investors. We denote their interest elasticity of stock investment by $IEI = \frac{dI/I}{dR/R} < 0$ and their marginal propensity to invest in stocks by $MPI \geq 0$. Aggregation gives $dI = si \cdot \frac{I}{R} \cdot IEI \cdot dR + si \cdot MPI \cdot dY$. The first term again captures the direct effect, which operates via rebalancing of investments between stocks and interest-bearing assets. Solving the model gives $\frac{dI/I}{dR/R} = \frac{si}{1-MPI \cdot si} IEI$, using that $dI = dY$.

Figure 1 illustrates the transmission in the two models. The left panel shows that in model 1, a higher share of hand-to-mouth weakens the direct effects of an interest rate change on aggregate consumption, but strengthens the indirect effects, as emphasized by

[5] We consider a static model and hence the expression for the EIS omits future consumption. One can think of the model experiment as a purely transitory monetary shock, leaving future consumption unaffected.

[6] That is, their Marginal Propensity to Consume (MPC) equals zero. In models with permanent-income consumers, the MPC typically equals the interest rate, and is therefore close to zero at short horizons.

Figure 1: Effect of an interest rate change on aggregate consumption and investment.



Note: Left panel: elasticity of aggregate consumption w.r.t. the interest rate in simple model 1. Right panel: elasticity of aggregate investment w.r.t. the interest rate in simple model 2.

Kaplan et al. (2017). However, on net the two forces cancel out exactly here and the overall response is unaffected by the heterogeneity.

By contrast, the investment response (model 2, right panel) is unambiguously increasing in the share of stock market participants. This happens because an increase in the participation rate strengthens *both* the direct effects and the indirect income effects, the latter in a highly convex way due to equilibrium feedbacks. Following an increase in interest rates, stock investors rebalance their portfolio away from stocks. This reduces aggregate investment, and therefore aggregate output and income. The reduction in income in turn feeds back into even lower stock investment, and so on. The strength of both the initial effect and the equilibrium feedback is proportional to the stock market participation rate. Thus, when considering the transmission of monetary policy through investment, heterogeneity matters not only for the mix of channels, but also for the aggregate effects.

Finally, note that in the amplification mechanism in this model, marginal propensities to consume play no role. In the quantitative model, there will be an additional amplification mechanism related to the interaction between investment and liquidity-constrained households with high marginal propensities to *consume*, as analyzed recently by Auclert et al. (2020).[7]

[7] See also Bilbiie, Kanzig and Surico (2020) for related analysis on this additional mechanism, emphasizing the role of capital income inequality.

3 Empirical evidence

Before introducing the full model, we present empirical evidence on the effects of monetary policy on households' stock investments, based on a time-series approach. We also discuss empirical patterns regarding heterogeneity in stock market participation and investments across households, which will be used to impose discipline on the full model.

3.1 Time-series evidence

3.1.1 Responses to a monetary policy shock

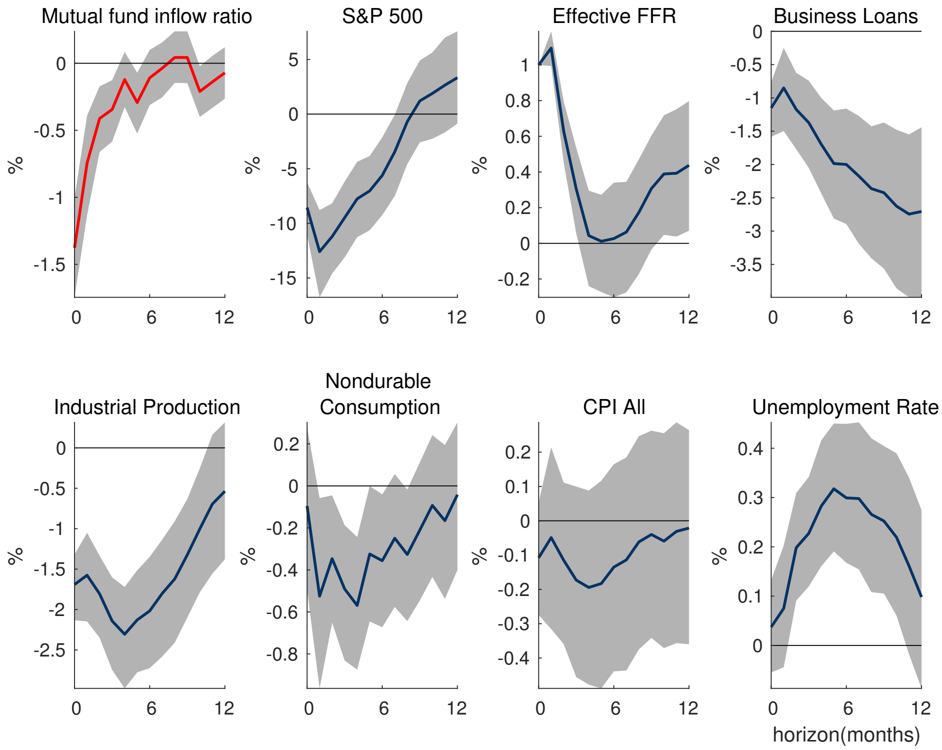
To obtain a better sense of the potential relevance of the stock investment channel, we consider the empirical effects of a monetary policy shock. A key variable of interest is the amount which households invest in stocks. We obtain data on this from the Investment Company Institute (ICI), which collects data on mutual fund flows covering the vast majority of regulated mutual funds in the United States. We consider the net inflow into equity-focused mutual funds, which is defined as the amount of new investment into the fund minus withdrawals.[8] Importantly, this variable is not directly affected by changes in stock valuations. Therefore, the variable gives direct insight into the amounts of income which households set aside for stock investment. We scale the variable by the lagged value of total net assets in the funds, but we obtained similar results when results are not scaled.

The empirical methodology follows Miranda-Agrippino and Ricco (2018), who use high-frequency changes in interest rates around FOMC decisions to identify exogenous monetary policy shocks, but correct for information effects using the Fed's Greenbook forecasts. Responses are then estimated using a Bayesian local projection, based on monthly data over the period 1985-2014. Figure 2 shows the responses of a number of macro and financial variables to a 100bp increase in the Federal Funds Rate. On the macro side, the responses are in line with the conventional wisdom in the literature. A monetary tightening leads to a substantial fall in real activity (industrial production) and in prices, and an increase in unemployment. Non-durable consumption also declines, but much less than the decline in industrial production, which falls by about three to five times as much. This indicates that a large part of the decline in output following a monetary tightening can be attributed to investment into physical capital.[9]

[8]Reported as net new cash flow, it is equal to new purchases of mutual fund shares, plus net exchanges, minus redemptions.

[9]The responses plotted do not include aggregate investment into physical capital since this variable is not available at a monthly frequency. However, it is a common finding in the literature that investment responds much more strongly to monetary policy shocks than consumption (see for instance Christiano, Eichenbaum and Evans (2005)). We have verified this result based on an alternative specification on quarterly data.

Figure 2: Empirical responses to a monetary tightening.

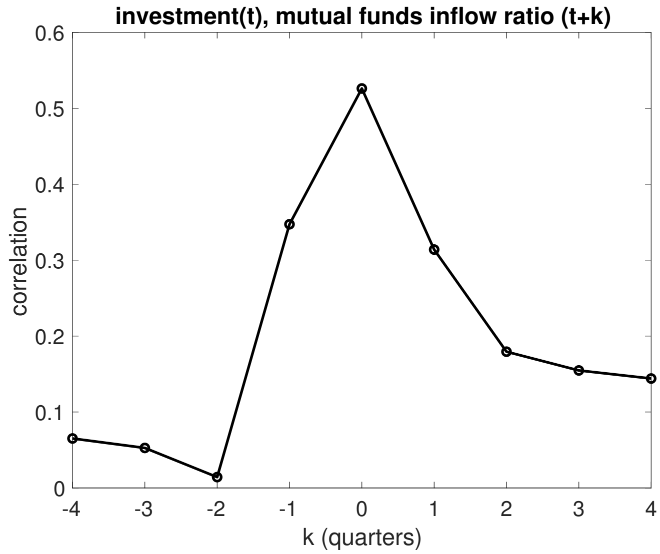


Source: Investment Company Institute, FRED.
Note: Horizontal axis is monthly horizon in all panels. "Mutual fund inflow ratio" is the net inflow into equity funds defined as in the text, rescaled by lagged net total assets. All US Equity funds, according to ICI definition. Aggregate time series defined with the following FRED codes: S&P 500 (S&P 500), Business Loans (BUSLOANS), Industrial Production (INDPRO), Real Nondurable consumption (DNDGRA3M086SBEA), CPI all items (CPIAUCSL), Unemployment rate (UNRATE). Sample period is 1985:1-2014:12, and a pre-sample 1969:1-1984:12 is used to inform the priors. 12 lags as in Miranda-Agrippino and Ricco (2018). The shock is taken from Miranda-Agrippino and Ricco (2018) and normalized to induce a 100 basis point increase in the effective Fed Funds rate. Shaded areas are 90% confidence bands.

Particularly informative for the mechanism outlined in this paper, we show in red how a monetary policy contraction implies a substantial decline in the net inflow of investments into the stock market funds. Thus, a monetary policy shock induces households to either pull out more funds from their stock portfolio and/or invest less into stock market funds. Quantitatively, the response is substantial: the reduction in the net inflow corresponds to more than 1 percent of the total value of the funds. The tightening also leads to a fall in stock prices, as measured by the S&P 500 index, which is consistent with evidence in Bernanke and Kuttner (2005).

These empirical results are consistent with the idea that tight monetary policy depresses capital investment, as investment into stocks decline. However, one may wonder if the rebalancing behavior towards interest-bearing assets, e.g. bank accounts, might lead to an

Figure 3: Equity fund inflows and physical capital investment: dynamic correlations.



Note: Sample: 1984Q1:2014Q4. "Mutual funds inflow ratio" is the net inflow into equity funds defined as in the text, rescaled by lagged net total assets. All US Equity funds, according to ICI definition. Both the inflow and total net assets are aggregated from monthly to quarterly frequency, and then we consider the ratio of net inflow to total net assets lagged by one quarter.

increase in bank lending to firms. To assess this possibility we also consider the response of bank loans to businesses, obtained from the Flow of Funds. We find that, following a monetary tightening, business lending actually declines. Thus the decline in equity available to firms does not appear to be offset by an increase in bank lending.[10]

3.1.2 Mutual fund flows and capital investment

An important element of the Mundell-Tobin narrative is that a decline in stock market investments by households ultimately reduces investments into physical capital. While the responses to a monetary policy shock discussed above are consistent with such a link, we now assess whether the connection holds more generally. To this end, Figure 3 plots the dynamic correlation between mutual fund inflows from the ICI, and real aggregate capital investment from the National Income and Product Accounts.

Figure 3 shows that the two variables correlate positively. Considering the dynamic patterns, we observe that mutual fund flows lead aggregate capital investment by one quarter. This is consistent with the idea that a reduction in stock investments by households depresses the amount of funds that are available for capital investment. The actual decline in physical investment might occur with some lag due to planning constraints or adjustment costs.

[10] We also find that nonfinancial corporate debt (i.e.: debt securities and loans) falls.

3.2 Cross-sectional evidence

While the time series evidence above suggests that stock investments matter for the transmission of monetary policy, their quantitative importance can only be precisely isolated in a model. The simple model described in the previous section suggests that the stock investment channel may be highly sensitive to household heterogeneity regarding the extensive and intensive margin of stock investments.

In this subsection, we document a number of cross-sectional patterns which will impose empirical discipline on our full-blown heterogeneous-agents model, presented in Section 4.

3.2.1 Income and stock market participation

We first investigate how stock market participation varies with income in the U.S., and how this relationship has changed over time. To this end, we use data from the Survey of Consumer Finances (SCF). Our measure of stock market participation includes direct ownership of stocks, but also indirect ownership via mutual funds. We focus on the years 1988 and 2000, since during this period there was an important increase in stock market participation. Moreover, the cyclical state of the US economy was similar in those two years.[11] Across the population, the stock market participation rate increased from 25 percent in 1988 to 44 percent in 2000. Whilst there was a strong increase, it continued to be the case that the majority of the population does not participate in the stock market.

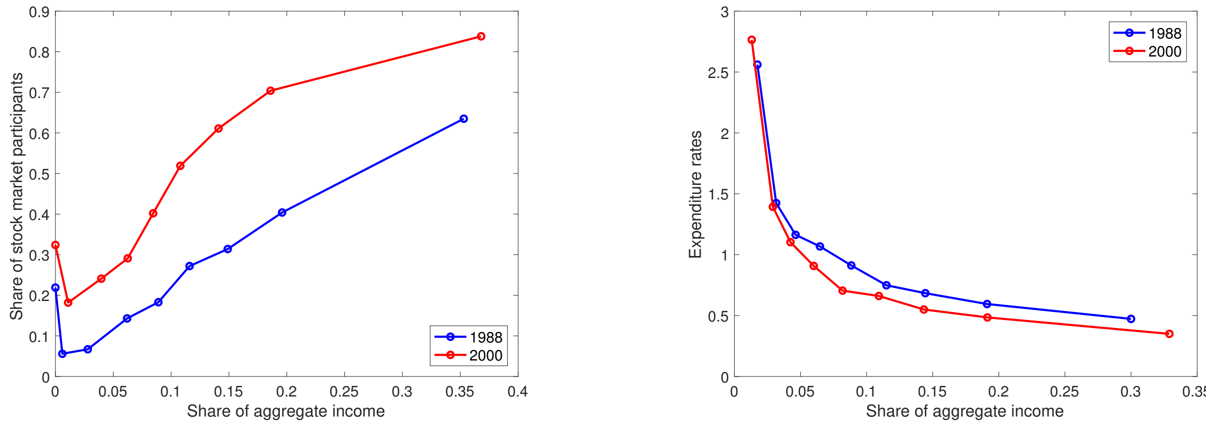
The left panel of Figure 4 plots income versus stock market participation rate, by labor income decile (indicated by markers). Labor income is measured as wage income after-tax and unemployment transfers and the horizontal axis indicates the share of aggregate income of the various deciles. The figure shows that stock market participation rate is strongly increasing in income, except for the low end of the income distribution.[12] In 1988, the participation rate across income deciles ranged from less than 10 percent to more than 60%. By 2000, this relationship had shifted upwards and the participation rate ranged from slightly below 20 percent to almost 85 percent.

Closer inspection of Figure 4 reveals that the increase in participation was disproportionately driven by households with incomes above the median, in particular by those in the 60-80 percentiles of income. This suggests that the increase in stock market participation might have been related to the increase in income inequality that was observed in the US

[11] Also, 1988 is the first year in the SCF that allows us to construct a measure of stock market participation that includes IRAs and 401k's mostly invested in stocks, as outlined in Appendix 1. Stock market participation plateaued after 2000.

[12] The data for lowest two deciles overlap precisely since the households at bottom 20 percent all have zero labor income. This group includes retirees, which explains the drop in participation.

Figure 4: Stock market participation and expenditure rates by income decile.



Note left panel: Source: Survey of Consumer Finances. We define as stock market participant a household that reports in the SCF at least one of the following: a positive amount of directly held stocks, a IRA account that is "mostly in stocks", a 401k account that is "mostly in stocks". Income is defined as wage income, plus unemployment transfers minus federal income tax. Each dot represents an income decile in the relevant year.
Note right panel: Source: Consumer Expenditure Survey. In each year, we classify households according to deciles of income. Then we compute the average consumption and income at each decile and year, and plot their ratios. All moments are weighted by CEX weights. For the definitions of (regular) consumption and income, see main text and Appendix 1. The lowest decile is not shown in the figure. The expenditure rates at that decile were 69.2 in 1982 and 75.2 in 2000. Those bottom deciles accounted for 0.01% and 0.06% of aggregate income respectively.

since the 1980s.

3.2.2 Income and the amount of saving

Having established that the means of saving vary strongly with income, we now turn to the relation between the income level and the fraction of income that goes into saving versus expenditures. To this end, we turn to the Consumer EXpenditure survey (CEX), from which we can compute a household's expenditure rate, defined as the ratio of consumption to income.

The right panel of Figure 4 plots aggregate expenditure rates for income deciles. The horizontal axis again plots the share of the income deciles in aggregate income. The measure of consumption expenditures is detailed in Appendix 1. It includes expenditures made by households on a fairly regular basis, including categories such as food, but also durables such as cars. However, it excludes expenditures which are only incurred infrequently, during specific periods in peoples' lives, for instance elderly health care or college tuition fees.[13] In the model, both regular and infrequent expenditures will be present, but they will play a separate role.

The panel shows that the expenditure rate is strongly declining in income, which indicates that high-income households save a much larger fraction of their income. This

[13]Such infrequent expenditures accounted for about 20 percent of total expenditures in the 1988.

observation echoes previous findings of Dynan et al. (2004) and Straub (2017), who show that the negative relation holds for a wide range of expenditure categories and also using proxies for permanent income rather than current income. The figure also suggests that although stock market participants are only a minority of the population, they do account for a large share of aggregate saving.

We also look at how the relationship between expenditure rates and income has changed over time. To account for potential downward trend in consumption over time in the CEX (Aguiar and Bils (2015)), we rescale the expenditure rates by the NIPA aggregate counterpart.[14] By 2000, the curve had slightly shifted downwards.

4 The full model

Having presented the cross-sectional empirical evidence, we now describe the full model. There is a continuum of households indexed by $i \in [0,1]$ and a continuum of goods firms. Other actors in the economy are a central bank, a fiscal authority, a labor service firm and a stock market mutual fund. Time is discrete and indexed by t.

Households. Households differ permanently in terms of their productivity levels as workers, denoted by $Z(i)$. In addition, they face unemployment risk. When employed, a household freely sets its labor supply, denoted by $N_t(i)$, but when unemployed a household cannot work in the market, i.e. $N_t(i) = 0$. Transitions between employment and unemployment occur according to exogenous probabilities.

Households maximize the expected present value of utility flows, which is given by:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t(i)^{1-\sigma_C} - 1}{1-\sigma_C} + \mathbf{1}_t^H(i)\varphi \frac{H_t(i)^{1-\sigma_H} - 1}{1-\sigma_H} - \zeta \frac{N_t(i)^{1+\kappa}}{1+\kappa} \right\}, \quad \beta \in (0,1), \quad \sigma_C, \sigma_H, \varphi, \zeta, \kappa > 0.$$

Here, $C_t(i)$ denotes "regular" consumption, $H_t(i)$ denotes "infrequent" consumption, and $\mathbf{1}_t^H(i) \in \{0,1\}$ is an indicator function which equals one if the households experience a period in which infrequent expenditures make a difference to their well-being. We assume that the arrival of such an period is an i.i.d. event which occurs with a probability $\delta \in (0,1)$. Moreover, we assume that $\sigma_H < \sigma_C$, which makes the infrequent good a luxury good. In light of the data, we think of the infrequent good as expenses which tend to be incurred by relatively wealthy households during specific stages of the life cycle, such as high-end health care, elderly care, education fees, see also Straub (2017), and possibly also bequests, see

[14]Each expenditure rate in the right panel of Figure 4 is rescaled by the ratio of aggregate consumption to income ratio in the CEX and the same ratio in the NIPA, at the relevant quarter.

De-Nardi (2004). The presence of such goods creates an additional savings motive, which is most pertinent for highest-income households, given their luxury nature.[15] The third term in the utility function captures disutility from labor supply.

The net non-asset income of a household is given by

$$Y_t(i) = \mathbf{1}_t^e(i) Z(i) \widetilde{w}_t N_t(i) + (1 - \mathbf{1}_t^e(i))\Theta - T_t + D_{w,t},$$

where $\mathbf{1}_t^e(i)$ is an indicator for whether the household is employed or not, $\widetilde{w}_t$ is the wage rate per efficiency unit of labor, $\Theta > 0$ is home production when unemployed and T_t is a lump-sum government tax. $D_{w,t}$ are dividends from the labor service firm, to be explained later.

Households can hold one-period nominal liquid assets ($B_t(i) \geq 0$), which one can think of as deposits, and can also hold shares in stock market funds, the value of which is denoted by $A_t(i) \geq 0$. Note that the household cannot borrow in any of the two assets. Deposits are fully liquid, whereas liquidation of stock market funds requires a cost given by a fraction $\tau \in (0, 1)$ of the liquidated amount. We model this cost as a tax, as it is meant to capture early withdrawal penalties on retirement accounts as well as capital gains taxes. Importantly, the cost is only paid when liquidating stocks. We do not assume any cost of saving *into* stocks, as no taxes are levied at that point and transaction fees tend to be small.

The budget constraint of the household, in real terms, is given by:

$$C_t(i) + H_t(i) + A_t(i) + B_t(i) = Y_t(i) + (1 + r_t^A) A_{t-1}(i) + \frac{1 + r_{t-1}^B}{1 + \pi_t} B_{t-1}(i) - X_t(i),$$

where r_t^A is the ex-post real return on stock market funds, r_t^B is the nominal interest rate on liquid assets issued in period t, $\pi_t = \frac{P_t}{P_{t-1}} - 1$ is the net rate of inflation, and $X_t(i) \equiv \tau \max\left\{(1 + r_t^A) A_{t-1}(i) - A_t(i), 0\right\}$ denotes the cost of liquidating stocks.

Timing: the decisions of a household are taken in two stages. In stage 1, the household learns its employment status and decides on the amount of regular consumption, labor supply, bonds and stocks. In stage 2, the household learns whether it has an infrequent expenditure opportunity or not (i.e. it learns $\mathbf{1}_t^H(i)$), and if so it chooses the amount of such expenditures. In stage 2, the household can re-adjust its bonds and stock holdings, but not regular consumption and labor supply. This two-stage setup circumvents artificial effects on labor supply and consumption when the infrequent expenditure shock occurs.[16]

[15] That said, also lower income households make such expenditures in the model, only in much smaller amounts. We will discuss this in detail below.

[16] An alternative setup that achieves this would be to assume a cap on the household's time endowment and hence on labor supply.

Labor service firms. We introduce nominal wage stickiness. This is not essential for the mechanism, but it helps to generate more realistic cyclical properties of dividends and stock prices. Towards this end, we introduce a labor service firm, owned by the households, which can also be thought of as a labor union. The firm buys effective units of labor at a nominal price $\widetilde{w}_t$ from the households, differentiates it, and sells it at a nominal price w_t to the firms. The differentiation happens according to a Dixit-Stiglitz production function, where ε_w denotes the elasticity of substitution between labor varieties. However, wage changes come with a quadratic cost of adjustment cost, governed by a parameter γ_w.

We further assume that the government gives a proportional subsidy on the firm's labor input, denoted by τ_w, as well as a lump-sum tax $T_{w,t}$ used to finance the subsidy.[17] Dividends of the labor service firm are distributed directly and equally to households. In real terms they are given by:

$$D_{w,t} = (w_t - \widetilde{w}_t(1-\tau_w))\, N_t - Adj_{w,t} - T_{w,t},$$

where $Adj_{w,t} = \frac{\gamma_w}{2}\left(\pi_{w,t}+1\right)^2 N_t$ is the wage adjustment cost and $\pi_{w,t} = \frac{W_t}{W_{t-1}} - 1 = \frac{w_t}{w_{t-1}}\Pi_t - 1$ denotes nominal wage inflation. Optimal wage setting leads to the following New Keynesian wage Phillips curve:

$$1 - \varepsilon_w + \varepsilon_w \frac{\widetilde{w}_t}{w_t}(1-\tau_w) = \gamma_w\left(\pi_{w,t}+1\right)\pi_{w,t} - \gamma_w \beta \mathbb{E}_t\left[\frac{N_{t+1}}{N_t}\left(\pi_{w,t+1}+1\right)\pi_{w,t+1}\right].$$

Goods firms. There are three types of goods firms: a representative intermediate goods producer, a continuum of monopolistically competitive intermediate goods price-setters, and a competitive representative final goods firm.

The intermediate goods producer operates a production technology given by $Y_t = K_t^{\alpha} N_t^{1-\alpha}$, $\alpha \in (0,1)$ where K_t and N_t denote, respectively, capital and effective labor inputs used by the firm, with $N_t = \int_i Z(i)N_t(i)di$. The firm owns capital and decides on the amount of investment, subject to adjustment costs, and hires labor on a competitive market. Capital accumulation equation reads as follows: $K_{t+1} = (1-\delta^K)K_t + \left[1 - \Omega(I_t/I_{t-1})\right] I_t$, where $\Omega(I_t/I_{t-1}) = \frac{\omega}{2}(\frac{I_t}{I_{t-1}} - 1)^2$ is an investment adjustment cost following Christiano et al. (2005), and $\delta^K \in (0,1)$ is the depreciation rate of capital.[18] The dividends of the producers are given by $D_{p,t} = \widetilde{P}_t K_t^{\alpha} N_t^{1-\alpha} - w_t N_t - I_t$. Producers maximize the expected present value of dividends and discount the future at a stochastic discount factor $\Lambda_{t,t+1}$.

A continuum of monopolistically competitive intermediate goods price-setters buy the

[17] We will calibrate the subsidy such that dividends of the labor service firm are zero in the steady state.

[18] For an analysis of capital adjustment costs (as opposed to investment adjustment costs) in a heterogeneous-agents New Keynesian model, see Alves, Kaplan, Moll and Violante (2019).

intermediate good Y_t, and differentiate it into varieties indexed by $j \in [0,1]$. The intermediate goods are assembled by a representative final goods firms into a homogeneous good, according to the production function $Y_t = \left(\int_0^1 Y_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$,where $\varepsilon > 1$ is the elasticity of substitution between varieties. Profit maximization of the final goods firms leads to the demand constraint $Y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\varepsilon} Y_t$, where $P_t(j)$ is the price of good j and $P_t = \left(\int_0^1 P_t(j)^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}$ is the aggregate price index. The final good can be used for regular consumption, infrequent consumption, for capital investment, and for adjustment and liquidation costs.

Intermediate goods price-setters operate a linear technology and face a quadratic cost of price adjustment given by $Adj_t(j) = \frac{\gamma}{2}\left(\frac{P_t(j)-P_{t-1}(j)}{P_{t-1}(j)}\right)^2 Y_t$, where $\gamma \geq 0$ is a parameter which governs the cost of price adjustment. The dividends of the firm are given by (in real terms) $D_{r,t}(j) = \frac{P_t(j)}{P_t} Y_t(j) - \widetilde{P}_t Y_t - Adj_t(j)$. Price-setting firms maximize the expected present value of dividends subject to the demand constraint, and discount the future with $\Lambda_{t,t+1}$. We exploit symmetry across firms, and drop the firm index j from now on. The firms' maximization problem leads to the following New Keynesian Phillips Curve for goods prices:

$$1 - \varepsilon + \varepsilon \widetilde{P}_t = \gamma\left(\pi_t + 1\right)\pi_t - \gamma \mathbb{E}_t \Lambda_{t,t+1}\left[\left(\pi_{t+1} + 1\right)\pi_{t+1}\frac{Y_{t+1}}{Y_t}\right],$$

where the price at which intermediate goods producers sell their good, $\widetilde{P}_t$, acts as a marginal cost for intermediate goods price-setters.

Stock market funds. Stock market funds own all types of goods firms. Let NI_t is the real net flow of household investment into the fund. The flow budget constraint of the fund is given by:

$$Q_{r,t}S_{r,t} + Q_{p,t}S_{p,t} = \left(D_{r,t} + Q_{r,t}\right)S_{r,t-1} + \left(D_{p,t} + Q_{p,t}\right)S_{p,t-1} + NI_t$$

where $S_{r,t}$ ($S_{p,t}$) is the amount of equity shares held by the mutual fund in the representative price setter (goods producer). . For each type of firm i, $Q_{i,t} = \sum_{k=1}^{\infty} \Lambda_{t,t+k} D_{i,t+k}$, $i \in \{r, p\}$, is the real, end-of-period stock price of the representative firm, after dividend payouts. The stochastic discount factor satisfies $1 = \mathbb{E}_t \Lambda_{t,t+1} \frac{D_{p,t+1}+Q_{p,t+1}}{Q_{p,t}}$ and $1 = \mathbb{E}_t \Lambda_{t,t+1} \frac{D_{r,t+1}+Q_{r,t+1}}{Q_{r,t}}$.

We normalize $S_{r,t} = S_{p,t} = 1$. The flow budget constraint then reduces to $-D_{r,t} - D_{p,t} = NI_t$. Note that D can be negative. We think of $-D$ as net equity inflows into the firms. Combining this equation with the firm budget constraint helps understanding why in the data there is a strong correlation between capital investment and the inflow into the mutual fund, as documented in Section 3. A reduction in household net investments into the fund,

NI, prompts a reduction in net firm equity inflows, which shrinks firms' investment. We come back to this point in the following sections.

The net mutual fund inflow can be decomposed as:

$$NI_t = \int A_t(i)di - \left(1 + r_t^A\right) \int A_{t-1}(i)di, \tag{1}$$

where $\int A_t(i)di$ is the stock of mutual fund shares held by households in the aggregate, at the end of the period and after the realization of the expenditure shock. The real return generated by the fund satisfies:

$$r_t^A = \frac{D_{r,t} + Q_{r,t} + D_{p,t} + Q_{p,t}}{Q_{r,t-1} + Q_{p,t-1}} - 1.$$

Government. We assume that the government is indebted and targets a fixed amount of government debt $\overline{B}$, letting taxes adjust. The government's budget constraint is given by:

$$\frac{1 + r_{t-1}^B}{1 + \pi_t} \overline{B} = \overline{B} + T_t.$$

Finally we assume monetary policy is set according to a simple rule for the interest rate:

$$\frac{1 + r_{t-1}^B}{1 + \overline{r}^B} = \left(\frac{1 + \pi_t}{1 + \overline{\pi}}\right)^{\xi} z_t,$$

where z_t is an exogenous monetary policy shock which follows an AR(1) process.

Market clearing. Clearing of the market for liquid assets, labor, capital, and goods implies, respectively, that:

$$\int_i B_t(i)di = \overline{B},$$

$$\int_i Z(i)N_t(i)di = \int_j N_t(j)dj = N_t,$$

$$\int_j K_t(j)dj = K_t,$$

$$I_t + \int_i C_t(i)di + \int_i H_t(i)di + Adj_t + Adj_{w,t} + O_t = K_t^{\alpha} N_t^{1-\alpha} + u_t \Theta,$$

where u_t is the unemployment rate and $O_t = \tau\delta\left(1 + r_t^A\right) \int A_{t-1}(i)di$ is the liquidation cost. We formally define the equilibrium in Appendix 2.

4.1 Extensions

While the baseline model is arguably quite rich, it might still miss some relevant channels. In particular, firms are financed exclusively via equity. Moreover, household saving into liquid assets cannot directly flow to firms. We discuss four possible extensions, all affecting the intermediate goods producers, who own capital.

First, we could allow firms to issue corporate debt, held by the mutual fund. This, however, would not change anything in the model. Since Modigliani-Miller theorem holds, because there are no financial imperfections on the firm side, corporate debt and equity are perfect substitutes.[19]

Second, we could allow firms to borrow in the liquid asset, without the intermediation of the fund but subject to an exogenous borrowing limit. Provided that the interest rate on liquid assets still lies below the firm's discount factor, as in the baseline, this would also have no effect. Firms relatively high discount rate would drive them against the borrowing constraint. Hence, at the margin any financing would happen via equity from the fund.

Third, we consider a cash in advance constraint that affects producers, in the following form: $\nu \widetilde{P}_t Y_t \leq M_{t+1}$, where M is the amount of corporate cash. In the literature, similar constraints have been motivated by a timing mismatch between firms' cost and revenue flows (see Jermann and Quadrini (2012)). Corporate cash earns the same real return as deposits held by households, and it is in fixed supply such that $\int_i B_t(i)di + M_t = \overline{B}$. This extension introduces two new channels. First, household liquid savings can reach the firm, potentially dampening the investment channel of monetary policy. Second, firms are now themselves subject to a rebalancing motive, which may strengthen transmission. The net effect is uncertain; we explore it quantitatively in Appendix 3, and find that financial constraints slightly dampen the investment response to a monetary policy tightening, albeit making it more persistent.

A fourth possible extension could entail allowing household savings to boost bank lending to firms. While this might deliver similar implications to the cash in advance constraint, it would be at odds with the empirical contraction of business loans following a monetary policy tightening. In contrast, we find that corporate cash falls, in the data as well as in the model.[20]

[19] Note that, in this version, household liquid assets and corporate debt are not perfect substitutes, since only the former can be held by the households.

[20] We define corporate cash as the sum of currency, checkable deposits, time and saving deposits, and money market mutual fund shares, in the nonfinancial corporate business sector. Monetary policy shocks are identified with the quarterly series from Romer and Romer (2004).

5 Calibration and steady-state properties

We now parameterize the baseline model and discuss its qualitative and quantitative properties in the steady-state equilibrium without aggregate uncertainty.

5.1 Calibration

The baseline economy is calibrated to match micro and macro empirical moments in the 1980s. In Section 7.3 we will recalibrate the model to the 2000s and study the effects of the change in the income distribution and stock market participation since the 1980s. The length of a period in the model is set to one quarter. We first discuss the externally calibrated parameters, and then turn to parameters which are jointly calibrated to target moments in the data. Table 1 lists all the parameters while Table 2 shows the model fit. Below we discuss the parameters by category.

I. Preferences. Regarding regular consumption, we assume a risk aversion coefficient of $\sigma_C = 1$, a conventional choice in the literature. This choice implies that the parameter controlling the utility curvature with respect to the infrequent good must lie between zero and one, i.e. $0 \leq \sigma_H < \sigma_C = 1$, since we assume the infrequent good is a luxury. Empirically, this parameter is difficult to estimate as, by construction, these goods are only consumed rarely. We set $\sigma_H = 0$, i.e. we assume linear utility with respect to the infrequent good. This choice helps the model to generate a fraction of non-participants in the stock market, as in the data, as well as high saving rates at the top of the income distribution. It also creates computational advantages. We will explain these points below. The level parameter pertaining to the utility of infrequent expenditures, φ, is internally calibrated, jointly with other parameters and will be discussed further below. The same is true for the subjective discount factor (β). The probability of infrequent expenditure δ is also internally calibrated, exploiting that in equilibrium households fully liquidate their stocks when such a moment occurs (see further discussion below). The Frisch Elasticity of labor supply, $\frac{1}{\kappa}$, is set to 1, following convention in the macro literature. The weight on the labor supply component of utility, ζ, is set such that households work on average 33% of the time.

II. Technology. Turning to technology, the elasticity of production with respect to capital, α, is set to 0.33, while the depreciation rate of capital is set to 0.025 (10% per year). The latter is in line with the average ratio of gross fixed capital formation over nonfinancial assets in the US business sector between 1950 and 2017. Following much of the New Keynesian literature, we set demand elasticity ϵ to 10, implying a profit share of 10%. The price adjustment cost parameter, γ, is set to imply an average price duration of about three quarters in the Calvo equivalent of the model. The wage stickiness parameters is calibrated to imply an average duration of one year, corresponding to annual wage contracts. Finally, we set the wage subsidy $\tau_w = \frac{1}{\epsilon_w}$, such that $w = \widetilde{w}$ and $D_w = 0$ in steady state. We calibrate the parameter on the investment adjustment costs, ω, to match the empirical response of aggregate output.[21]

Table 1: Parameter values.

Parameter	**Description**	**Value**	**Target/Source**
I. Preferences			
σ_C	curvature regular consumption	1	convention
σ_H	curvature infrequent consumption	0	see text
φ	level infrequent expenditure	2.22	internally calibrated
δ	prob. infrequent expenditure	0.024	liquidation rates
κ	inverse Frisch elasticity	1	convention
ζ	disutility of labor	10.5	avg hours worked: 1/3
β	subjective discount factor	0.98	internally calibrated
II. Technology			
α	capital share	0.33	labor share: 63%
ϵ	elasticity of substitution goods varieties	10	profit share: 10%
ϵ_w	elasticity of substitution labor varieties	10	
γ	price adjustment cost	51.9	avg. price duration: 3q
γ_w	wage adjustment cost	101.89	avg. wage duration: 4q
τ_w	wage subsidy	0.1	wage dividends: 0
δ_k	depreciation rate capital	0.025	investment (FoF)
ω	investment adjustment costs	0.029	output IRF
III. Policy			
ξ	coefficient Taylor rule	1.5	convention
$\overline{\pi}$	long-run inflation target	0	net inflation rate: 0
IV. Asset Markets			
τ	liquidation cost mutual fund shares	0.29	internally calibrated
$\overline{B}$	supply liquid assets	0.057	real interest rate: 0.01
IV. Idiosyncratic income			
p_{ue}	unemployment outflow probability	0.8	job finding rate (CPS)
p_{eu}	unemployment inflow probability	0.042	unemployment rate: 0.05
Θ	home production	0.6	internally calibrated
Z_i	permanent productivities	[1.438 1.442 1.447 1.451 1.455 1.853 1.929 1.983 2.094 2.276]	internally calibrated

[21] A monetary policy shock that increases the interest rate by 100 basis points decreases aggregate output in the model and industrial production in the data by 1.6% in the first quarter.

III. Policy. We assume the central bank targets a steady-state rate of inflation of zero percent. The elasticity of the nominal interest rate with respect to inflation in the Taylor rule, ξ, is set to 1.5, in line with values typically considered in the New Keynesian literature and empirical estimates.

IV. Asset markets. The liquidation cost τ and the supply of liquid assets, $\overline{B}$ are internally calibrated (see below).

V. Idiosyncratic income. The employment process is calibrated based on data from the Current Population Survey. In particular, we set the job-finding probability (p_{ue}) to 80%. The probability of becoming unemployed (p_{eu}) is calibrated such that the steady state unemployment rate is 5%. The remaining parameters pertaining to idiosyncratic income are internally calibrated.

VI. Internally calibrated parameters. We internally calibrate the probability of an infrequent expenditure δ, the liquidation cost τ, the discount factor β, home production when unemployed Θ, the utility parameter for infrequent expenditures φ, and the supply of liquid assets, $\overline{B}$. In addition, we calibrate the productivity types. Below we discuss the moments that we target in the calibration, relating them to the parameters which are most closely related.

Regarding τ, we rely on information on effective liquidation cost for direct and indirect ownership of stocks. Liquidating directly held stocks in the US entails a capital gains tax that varies between 0% and 20%. Using the average duration implied by the calibrated value of δ, and the steady state return on illiquid assets, the implied average τ is 0.2.[22] Liquidation cost for stocks indirectly held through 401k or IRA accounts is, however, much higher. Besides a 10% penalty from early withdrawal, the liquidated amount is subject to income taxation. The highest marginal income tax rate was 70% in 1980 and 39.6% in 2000. As a result, we target an average liquidation cost of 30%, in between our estimates for directly and indirectly held stocks.

Considering δ, we target a liquidation probability such that on average liquidation occurs every 10 years. This target is based on various sources pointing at the average time households hold a stock market account. Argento, Bryant and Sabelhaus (2015) find a 8.6% annual penalized withdrawal rate from 401k account. Other research finds that the likelihood of withdrawing from 401k accounts before 59.5 years of age varies greatly over time and individuals' age, but it is no more than 9% at annual rate. Calvet, Campbell and Sodini (2009) investigate individual portfolio dynamics using Swedish data. They find an

[22] Consider \$1 that is invested in stocks and kept invested for 44 quarters. The quarterly return on that investment is a steady state r_a of 1.62%. A 20% capital gains tax implies $\tau = \frac{0.2\left(1.0162^{44}-1\right)}{1} = 0.2$.

average exit rate from risky assets markets of 3.1% a year between 2000 and 2002. This would imply a quarterly withdrawal rate of 0.008. Taking together, these estimates imply a high average duration of mutual fund accounts. We pick a parameter towards the lower bound of these estimates, to take into account that direct ownership of stocks is likely to have a much shorter duration than indirect ownership.

The discount factor β, home production when unemployed Θ, the slope of utility derived from infrequent expenditures ϕ and the supply of liquid assets, $\overline{B}$ are jointly related to the following four targeted moments: (i) the capital output ratio, (ii) the real interest rate, (iii) the ratio of total household assets to output, (iv) the average consumption loss after 6 months of unemployment. The empirical capital output ratio is computed as the ratio between business-sector nonfinancial assets over GDP, averaged between 1950 and 2017. The real interest rate is targeted to be 1 percent per year. Total households assets are instead computed as households' net worth minus consumer durables. In the baseline calibration we target the average between 1950 and 1990. We further target a 16% consumption loss after 6 months of unemployment, in line with evidence in Browning and Crossley (2001).

The final part of the calibration regards the permanent income types. We include 10 productivity types in total. Given our focus on the upper half of the income distribution, we use 5 types for the top quartile of income (each with a population share of 5 percent), and 5 types for the bottom three quartiles (each with a population share of 15 percent).

We set their productivity levels such that, in equilibrium, households in the top quartile of income participate in the stock market. This target is based on data from the 1988 SCF, as shown in Figure 4. The productivities of the five types at the top are set such that we match their expenditure rates in 1988, as shown in Figure 5.[23] The productivities of five bottom types are equally spaced between about 20 percent above the home production and 20 percent below the productivity of the fifth type from the top.

Table 2 shows the fit of the model with respect to the targeted and untargeted moments. The model generates an immediate consumption loss upon unemployment which is in line with empirical findings by Ganong and Noel (2019). The aggregate ratio of regular consumption expenditures to after-tax labor income is close to the NIPA equivalent in 1988, although the model overstates the quantitative importance of infrequent expenditures in the aggregate. Given limited stock market participation, the high saving rates of the stock

[23] Consistent with the CEX data, income is measured as the average over the past year. Also, income is defined as labor income after taxes and transfers, both in the model and in the data. We also account for the fact that home production when employed, Θ, is not entirely accounted for by transfers in the CEX. Hence, we make use of the fact that, in 1988, average transfers in the CEX were 12 percent of average after-tax labor income. We rescale income of the unemployed in the model by this common factor. This implies that 16 percent of Θ is accounted for as transfers and thus included in our computations of income.

Table 2: Model fit.

	Model	**Data**	**Data source**
I. targeted:			
Capital to output ratio	1.80	1.87	Flow of Funds
Households assets to output ratio	3.36	3.35	NIPA
Consumption loss 6 months after job loss	16.3%	16%	Browning and Crossley (2001)
Average duration of stock market holding	1/0.024	1/0.025	see text
Average liquidation cost	0.28	0.30	see text
Expenditure rates (top 5 demi-deciles)	[0.44 0.52 0.57 0.61 0.69]	[0.44 0.51 0.57 0.60 0.65]	CEX/NIPA
Stock market participation rate	24.4%	24.9%	SCF (1988)
II. Not targeted:			
Consumption loss upon unemployment	8%	6%	Ganong and Noel (2019)
Investment to output ratio	0.18	0.19	Flow of Funds
$\frac{C}{Y}$	0.86	0.92	NIPA (1988)
$\frac{H}{Y}$	0.38	0.20	NIPA (1988)
$\frac{C+H}{Y}$	1.24	1.12	NIPA (1988)

Note: C stands for aggregate regular consumption expenditures, H aggregate infrequent consumption expenditures and Y aggregate after-tax labor income. See Appendix 1 for data description. Capital and household assets ratios are relative to annual output.

investors help to replicate the empirical ratio of investment to GDP. Finally, we note that the implied steady state real return on mutual fund shares, r^A, is 1.62 percent per quarter, or 6.7 percent per year.

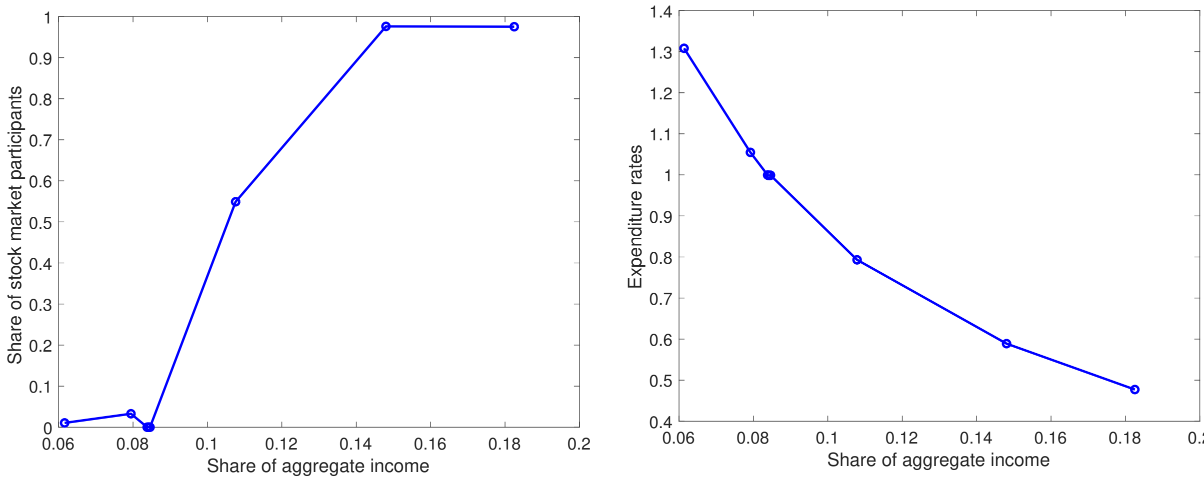
5.2 Saving behavior

We now discuss the saving behavior of the households in the model and shed more light on the ability of the model to account for the empirical relation between income, expenditure rates and stock market participation.

The left panel of figure 5 shows the relation between income and stock market participation in the model. Only households in the upper quarter of the income distribution participate in the stock market. The relation with income is sharper than in the data, but nonetheless captures a very salient empirical pattern.[24] The right panel of figure 5 shows the relation between income and expenditure rates in the model. The model generates the declining, convex relation present in the data (see Figure 4), even though in the calibration

[24]To weaken the correlation between income and stock market participation, one could introduce for example heterogeneity in the ability to invest (financial literacy), although this would be unlikely to have strong implications for the key mechanisms at play in the model.

Figure 5: Stock market participation and expenditure rates by income decile in the model.



Note: Monte Carlo simulation of the stationary distribution over 1 million households. Each dot is a decile of after-tax labor earnings, including unemployment benefit as explained in the main text. For each decile, we compute the stock market participation rate in the left panel, and the ratio of average consumption to average after-tax labor earnings in the right panel. Expenditure rates are computing using regular consumption C. The horizontal axis plots the decile after-tax labor earnings as a fraction of its aggregate value.

only the expenditure rates in the top quartile of the distribution were directly targeted.

The model also generates a large degree of wealth dispersion. In particular, it generates a fat right tail, a well-known feature of the data which standard incomplete-markets models fail to generate. In fact, the model even somewhat overpredicts the degree of wealth inequality at the top as shown in Table 3, which compares the model-generated wealth distribution to an empirical counterpart from the SCF.

How does the model generate these patterns? To understand this, it is important to recall the luxury nature of the infrequent expenditure good. This implies that there is a level of regular consumption at which households become *satiated*. As we will show formally below, household consumption never exceeds this satiation level. Once the satiation point is reached, any additional income is put into saving, generating low expenditure rates, which then become decreasing in income as observed in the data. Moreover, beyond the satiation point households do not further increases their liquid assets. Instead, they invest all marginal income into stocks. While being relatively costly to liquidate, stocks generate higher returns in equilibrium and therefore offer a relatively attractive way of long-term saving.

Stocks are liquidated when an infrequent expenditure moment arises, and thus the amount of time until liquidation is exponentially distributed. Until liquidation, stock market wealth grows exponentially at a rate of at least r^A (and even more so during periods when a household actively adds to its stock market wealth), giving rise to a fat-tailed wealth distribution, see e.g. Jones (2015). Therefore, the model endogenously generates a high de-

Table 3: Wealth inequality

	Model	**Data**
90th-10th percentile log range	7.12	5.63
Share of wealth held by top 10%	91.1%	77.5%
Share of wealth held by top 1%	49.4%	35.6%
Share of wealth held by top 0.1%	21.4%	13.6%

Note: Monte Carlo simulation of the stationary distribution over 1 million households. Wealth in the model is defined as the end of period sum of liquid and illiquid assets b and a. In the data, it is the sum of stock holdings (defined, as previously, as direct holding of stocks plus 401k and IRA mostly in stocks), checking and saving accounts, MM mutual funds, certificates of deposits and U.S. saving bonds in 1988 in the SCF. Quantile ranges are differences of percentiles of logged variables.

gree of wealth inequality that is not inherited from the income distribution or targeted in the calibration procedure.[25] Without satiation, in contrast, employed households would accumulate savings up to a certain target level of saving, and subsequently have a zero saving rate.[26]

Below the satiation level, households do not invest into stocks, although they may own stocks that were purchased previously but not yet liquidated. Households with low levels of permanent productivity never reach the satiation point.[27] Hence they have relatively high expenditure rates and do not participate in the stock market.

It can further be shown that in the calibrated model the following properties hold. First, households who lose their job spend their liquid savings within the first quarter of unemployment and hence become borrowing-constrained. This is true even when their stock wealth is high. The model is thus able to generate "wealthy hand-to-mouth households". Second, households liquidate stocks only when an infrequent expenditure opportunity arises, which gives rise to high saving rates at the top of the income and wealth distribution, leading to high wealth inequality. Third, when an infrequent expenditure opportunity arises, households spend all their liquid savings and stocks on the infrequent good. Due to this property, the wealth distribution is stationary. In Appendix 2 we present analytical conditions which can be used to verify if this is the case, given a certain calibration. There, we also discuss the details of the numerical solution strategy.

[25] In the literature, high wealth inequality is sometimes generated by including an income process which includes a special, transitory income state with exceptionally high income, which in turn generates a strong precautionary saving motive among those with high income. This type of income process however is considered at odds with the data.

[26] Fagereng, Holm, Moll and Natvik (2019) show that, even at the top of the wealth distribution, median net saving rates are positive.

[27] In the calibrated model households in the upper quartile of the productivity distribution reach the satiation point already in the first quarter of employment, but this is not necessarily the case in general.

Why is there a satiation point in consumption? The presence of the satiation point can be observed from the first-order conditions. Given $\sigma_H = 0$ and the three properties described above, the Euler equation associated to the liquid asset is given by:

$$C_t(i)^{-\sigma_C} \geq \delta\varphi + (1-\delta)\beta\mathbb{E}_t \frac{1+r_t^B}{1+\pi_{t+1}} C_{t+1}(i)^{-\sigma_C},$$

See Appendix 2 for a derivation. The condition binds with equality when the household is not liquidity-constrained. In that case, the marginal cost of saving, i.e. the marginal utility with respect to regular consumption, is equal to the benefit, given by the right-hand side. With probability δ, an infrequent expenditure will be made at the end of the period, in which case the households will spend the liquid asset and receive a utility flow φ. With the complement probability, the household will have more liquid wealth at the beginning of the next period. Note that when we set $\delta = 0$ (no infrequent expenditures) this equation reduces to a standard Euler equation for nominal, liquid assets.

The first-order condition for households saving into stocks can be expressed as:

$$\begin{aligned} C_t(i)^{-\sigma_C} &\geq \delta(1-\tau)\varphi + (1-\delta)\beta\mathbb{E}_t(1+r_{t+1}^A)C_{t+1}(i)^{-\sigma_C} \\ &= \mathbb{E}_t \sum_{j=0}^{\infty} \delta(1-\delta)^{j-1}\beta^j \prod_{k=0}^{j}(1+r_{t+k}^A)(1-\tau)\varphi. \end{aligned}$$

The right-hand side equals the benefit of saving into stocks. Here, $\delta(1-\delta)^{j-1}$ is the probability that a household will liquidate in j periods from the present, because of the arrival of an infrequent expenditure opportunity. Moreover, $\prod_{k=0}^{j}(1+r_{t+k}^A)$ is the compounded stock return up to that point. When the household liquidates, it pays a liquidation cost equal to a fraction τ of the liquidated amount. The remainder is spent in the infrequent good, delivering a utility flow φ per unit.

The equation binds when households save into stocks; in this case, the right-hand side does not depend on any individual-specific variable, implying a satiation level for consumption $C_t(i)$. Vissing-Jorgensen (2002) shows that a standard Euler equation for stocks fit the data well, once the sample is restricted to include only stock market participants. This is also the case in our model.[28]

[28] Quantitatively, the constant $\delta(1-\tau)\varphi$ is less than 5 percent of the marginal utility of (regular) consumption. It is small because the probability of an infrequent expenditure, δ, is low. Indeed, in the model, we estimate a sensitivity of regular consumption growth to growth in the real return on the mutual fund equal to 0.97, very close to the parametrized EIS. Note further that the constant term $\delta(1-\tau)\varphi$ drops out when linearizing the equation.

6 Heterogeneous responses to changes in interest rates and income

Before analyzing quantitatively how changes in monetary policy affect equilibrium outcomes in the model, we discuss qualitatively how different groups of households respond to changes in interest rates and income. This helps to better understand the direct and indirect channels of monetary policy, and the relation between the full model and the simple model discussion in Section 2. To this end, it is useful to divide the population into three categories:

1. *Hand-to-mouth*: households who are liquidity constrained
2. *Emergency savers*: households who are not liquidity-constrained, and save only into liquid assets
3. *Stock investors*: households who are not liquidity-constrained, and save into both liquid assets and stocks

In the calibrated model, the hand-to-mouth households are all unemployed, i.e. they are at the bottom of the labor income distribution (although they may have substantial income from stock ownership). Emergency savers are all employed but are not at the satiation point for consumption and liquid assets, either because they belong to a productivity type which never gets satiated or because they have not yet accumulated enough liquid wealth to be satiated. Finally, stock investors are all employed and have reached the satiation point. The distribution of households across the three categories is endogenous, and that individual households may switch between categories over time.

The three categories of households respond very differently to changes in interest rates and income. Consumption of the hand-to-mouth does not react to changes in interest rates, but is highly sensitive to changes in income. This is due to the binding liquidity constraint. By contrast, consumption of the emergency savers does respond to changes in interest rate, via an intertemporal substitution channel. On the other hand, their consumption is relatively insensitive to marginal fluctuations in income, as they can adjust their liquid saving. The distinction between these two household types has been emphasized extensively in the literature. Kaplan et al. (2017) point out that the presence of hand-to-mouth households weakens the direct effect of monetary policy on aggregate consumption, but strengthens the indirect consumption effects, see also Section 2.

Our analysis instead highlights the stock investors and their role in the aggregate *investment* response. At the margin, these households can freely allocate their saving between stocks and liquid assets. It turns out that they respond to monetary policy in yet a very different way than the other two categories. In particular, they respond to changes in interest rates via a portfolio rebalancing channel. We can derive the following result (see the Appendix 2 for a proof):

Proposition 1. *(direct effect on investment) For any stock investor it holds that (i)* $\frac{\partial C_t(i)}{\partial r_t^B} = \frac{\partial N_t(i)}{\partial r_t^B} = 0$ *and (ii)* $\frac{\partial B_t(i)}{\partial r_t^B} = -\frac{\partial A_t(i)}{\partial r_t^B} > 0$.

The proposition states that consumption and labor supply of the stock investors does not react directly to a change in the interest rate. The reason is that these households are at the satiation point of consumption. Instead, they respond to an increase in the interest rate by investing more into liquid assets and less into stocks. This does not mean that they liquidate stocks; they simply invest less into their stock market funds. Quantitatively, the strength of the rebalancing response depends on a number of factors, including the liquidity frictions present in the model, the degree of risk aversion, and the extent of idiosyncratic income risk. Among stock investors, the rebalancing response is heterogeneous, due to heterogeneity in permanent income.

The rebalancing behavior has direct implications for aggregate investment. Using the budget constraints of the mutual fund and of the intermediate goods producer we can derive the following expression for the partial-equilibrium change in aggregate investment with respect to a change in the gross nominal interest rate:

$$\frac{\partial I_t}{\partial r_t^B} = \int_{i \in si} \frac{\partial A_t(i)}{\partial r_t^B} di,$$

where $i \in si$ denotes a stock investor. The term on the right-hand side is the total rebalancing response of stock investors, which depends directly on the population share of stock investors. Note further that the above equation corresponds very closely to the direct effect in the simple model of Section 2.[29]

Aside from this direct rebalancing effect, monetary policy also affects aggregate investment via an indirect income effect. Consider an unanticipated and transitory income flow, denoted $\widetilde{Y}_t$, adding to the right-hand side of the household budget constraint. We can derive the following result:

Proposition 2. *(indirect effect on investment) For any stock market investor it holds that (i)* $\frac{\partial C_t(i)}{\partial \widetilde{Y}_t} = \frac{\partial N_t(i)}{\partial \widetilde{Y}_t} = \frac{\partial B_t(i)}{\partial \widetilde{Y}_t} = 0$ *and (ii)* $\frac{\partial A_t(i)}{\partial \widetilde{Y}_t} = 1$.

See the Appendix 2 for a proof. Proposition 2 states that stock investors invest marginal income flows entirely in their stock portfolios, i.e. their marginal propensity to invest in

[29] The main difference is that in Section 2 we derived an elasticity rather than a derivative.

stocks equals one. This property follows again from the fact that the stock investors are at the satiation point of consumption, which is associated with their high saving rates. From the combined budget constraints, it now directly follows that:

$$\frac{\partial I_t}{\partial \widetilde{Y}_t} = \int\limits_{i \in si} \frac{\partial A_t(i)}{\partial \widetilde{Y}_t} di = si,$$

i.e. the indirect income effect on aggregate investment is simply equal to the population share of stock investors, si. Again, the expression corresponds closely to the indirect effect on investment in the simple model of Section 2.

Taken together, the two results suggest the following transmission channel: an increase in the interest rate directly induces stock investors to rebalance their saving away from stocks, which depresses aggregate investment. This in turn leads to a fall in aggregate income, to which stock investors respond by further cutting on stock purchases. This feeds back into a further decline in investment, and so forth. This is precisely the transmission channel that is at play in the second simple model of Section 2. In the next section, we will analyze this transmission channel quantitatively.[30]

7 Quantitative results

We now present simulations of the full model, in order to quantify the importance of the investment channel of monetary policy, and of the underlying effects. We then study the importance of the channel for inequality, and also how distributional trends have affected the power of monetary policy.

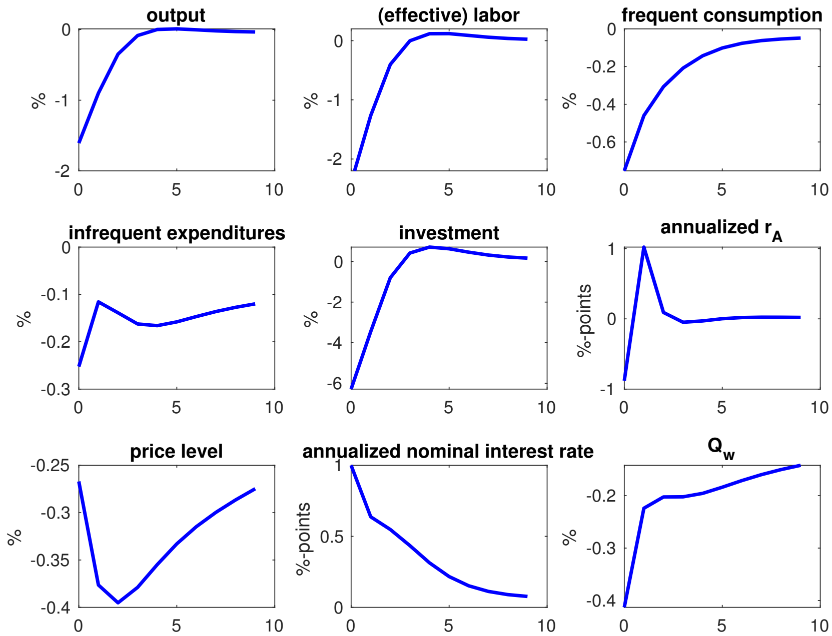
7.1 Aggregate effects of a monetary policy shock

We first consider the aggregate effects of an unexpected monetary policy shock, creating a jump in z_t which is then gradually reversed, with a persistence coefficient of 0.5. The shock is scaled such that the annualized nominal interest rate increases by 100 basis points on impact.

Figure 6 shows the responses of the main aggregate variables, and discuss them in light of the data. Recall that the adjustment cost has been calibrated such that the model generates a fall in output of 1.6 percent, as in the empirical responses shown in Figure 2. In the model, consumption falls by about 0.75 percent, which is comparable to the decline in

[30] Equilibrium channels also affect the consumption response of stock market investors, via a change in the expected real return on stock market funds, although this consumption effect will turn out to be small.

Figure 6: Model responses to a monetary policy tightening



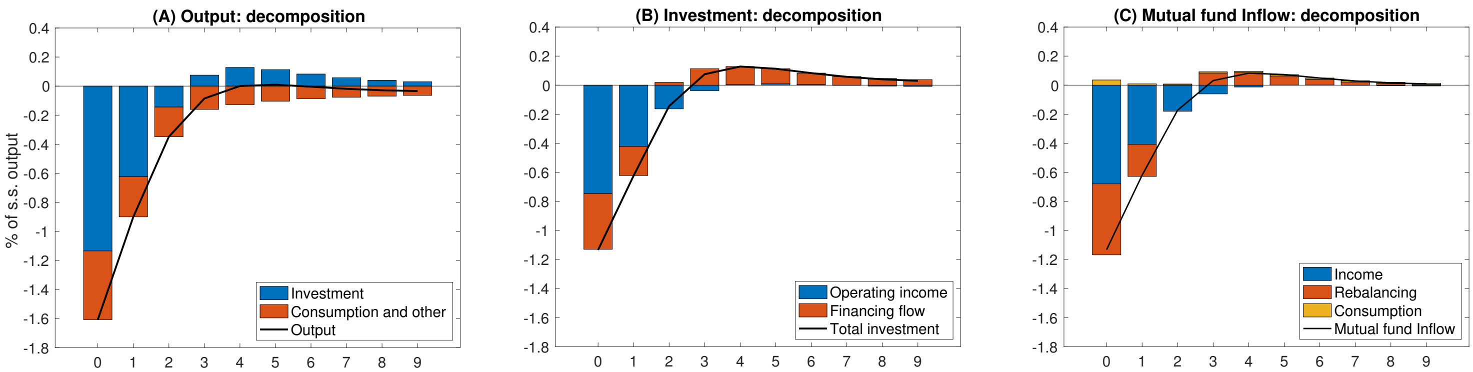
Note: Horizontal axes denote quarters. Shock hits in quarter 0.

consumption in the data, although somewhat larger than the point estimates. Given that the output response in the model is driven by consumption and investment, this implies that the model does a reasonable job in predicting the relative importance of consumption versus investment. If anything, the model somewhat overstates the importance of consumption. Even so, there is a still large decline in investment, of about 6.3 percent.

The response of the nominal price level in the model is somewhat larger than the point estimate in the data, although the latter is surrounded by a large degree of statistical uncertainty. Stock prices fall much less in the model than in the data. Perhaps this is not too surprising, since models of the macro economy typically have difficulties in generating realistic asset prices. Kekre and Lenel (2020) argue that the introduction of heterogeneity in risk preferences in a heterogeneous-agents New Keynesian model helps to rationalize the response of asset prices to monetary policy shocks.

Decomposition of aggregate output and investment. To understand the transmission of monetary policy in the model, we now deconstruct the responses of aggregate output and investment, see Figure 7. The left panel shows that investment accounts for most of the decline in aggregate output, leaving a relatively modest role for consumption, as discussed above. To understand the drivers of the investment response, we decompose it using the flow budget constraint of the intermediate goods producer, which implies investment can be decomposed as the sum of *financing flows* ($NI_t + D_{r,t}$, i.e. the amount mutual funds have

Figure 7: Decomposition of aggregate responses



Note: Horizontal axes denote quarters following the shock. Vertical axes are % of steady state output in all panels.

available for investments, which equals their net inflow plus price-setter dividends), and the intermediate producers' *operating income* before depreciation ($\widetilde{P}_t Y_t - w_t N_t$). The middle panel of Figure 7 shows that both margins decline following a monetary tightening. That is, following a monetary tightening mutual funds invest less into firms, due to a decline in stock investments by households. In addition, revenues of the firms fall more than their wage costs, i.e. operating income declines.

Finally, we focus our attention on the gross inflow from households to the fund, and use the households' aggregated budget constraint to decompose it as:[31]

$$IN_t = \underbrace{\int_{i\in\mathcal{S}} Y_t(i)}_{\text{household income}} - \underbrace{\int_{i\in\mathcal{S}} C_t(i)}_{\text{consumption}} - \underbrace{\int_{i\in\mathcal{S}} (B_t(i) - \frac{1+r^B_{t-1}}{1+\pi_t} B_{t-1}(i))}_{\text{rebalancing}},$$

where $\mathcal{S}$ is the set of stock investors. The right panel of Figure 7 reveals that the rebalancing behavior of the stock investors accounts for roughly 40% of the initial decline in the investment inflow. Intuitively, the increase in the real return on liquid assets induces stock market investors to tilt their portfolios away from mutual fund shares.

The remainder of the fall in inflows is mostly driven by an "indirect effect" due to decline in income; changes in consumption of the stock investors play almost no role. Intuitively, the monetary contraction reduces aggregate demand, and hence aggregate income. As explained in the previous section, stock investors respond to a decline in income by reducing their investment into stocks. This response creates a powerful equilibrium feedback effect, as the decline in aggregate income triggers a further fall of investment demand, which triggers a

[31]The net inflow into the fund, NI_t, subtracts outflows to IN_t.

further decline in aggregate demand and income, and so on. To appreciate the centrality of the stock investors in this feedback loop, note that the decline in aggregate income itself is mostly driven by investment. Also, note that the stock investors receive a disproportionate share of aggregate labor income as they are more productive.

Implications for other aggregate variables. Having shown that the stock investment channel is important for aggregate output and investment, we now turn to its relevance for other macroeconomic variables. To this end, we consider a counterfactual version of the model in which we fix households' saving into the mutual fund at their steady-state values, dropping the Euler equations for stock purchases. We thereby shut down the Tobin-Mundell channel completely, as well as any equilibrium amplification effects that operate via stock purchases. At the same time, we keep the steady-state aggregates and distributions precisely the same as in the baseline model.[32]

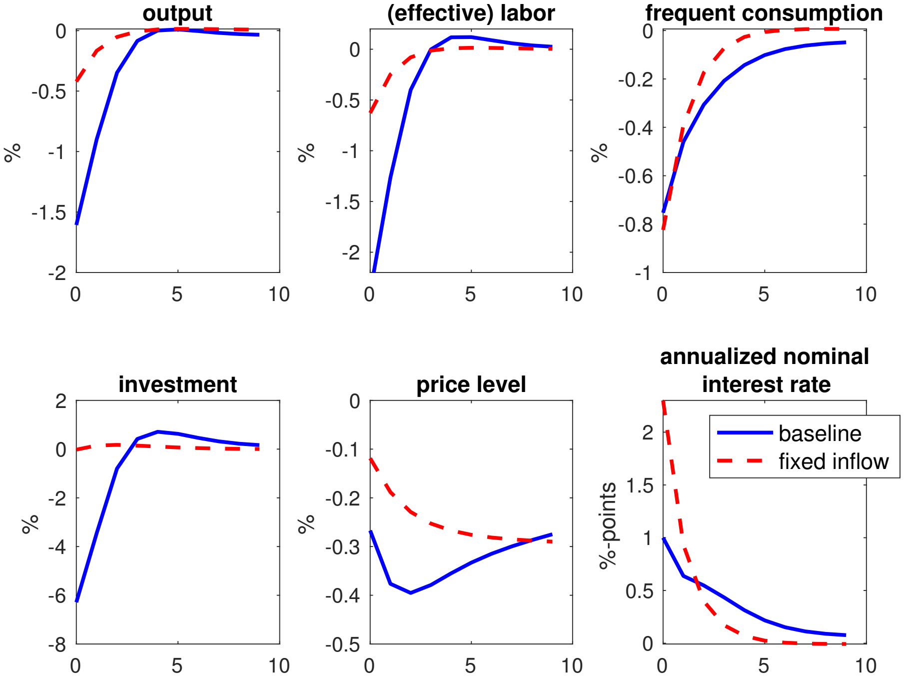
Let us first revisit the effects on aggregate output and investment. Figure 8 shows the responses to a monetary policy tightening in the counterfactual model, together with the baseline. As expected, the decline in aggregate output is much smaller in the counterfactual, even though the increase in the nominal interest rate is actually larger than in the baseline. Also, the investment response is very muted compared to the baseline, as mutual fund inflows account for almost all of the investment response in the baseline. Consistent with the decomposition shown above, we thus find that mutual fund inflows are central to the response of aggregate output and inflation.

Now let us consider other macro variables. In the counterfactual, the decline in consumption is initially similar to the baseline, but reverts back to the steady state more quickly. Thus, the equilibrium feedback effects triggered by the stock investment channel matter not only for investment, but also for consumption. Finally, note that the inflation dynamics are also quite different in the counterfactual. Without the investment channel, the initial drop in inflation is much smaller, but the decline is more persistent.

We conclude that the stock investment channel –and the equilibrium feedback effects operating via stock investment— account for much of the joint dynamics of all key macroeconomic variables following a monetary policy shock. Quantitatively, these channels dominate the consumption channels often emphasized in the literature.

[32] That is, households' saving into the mutual fund are set to the choice they would have made in the absence of aggregate shocks, but given their histories of idiosyncratic shocks. Note that investment can still fluctuate due to time-variation in mutual fund outflows. This effect, however, is very small and therefore aggregate investment remains almost constant in the counterfactual model.

Figure 8: Model responses to a monetary policy tightening: baseline and fixed gross mutual fund inflow.



Note: Horizontal axes denote quarters following the shock.

7.2 The effects of monetary policy on inequality

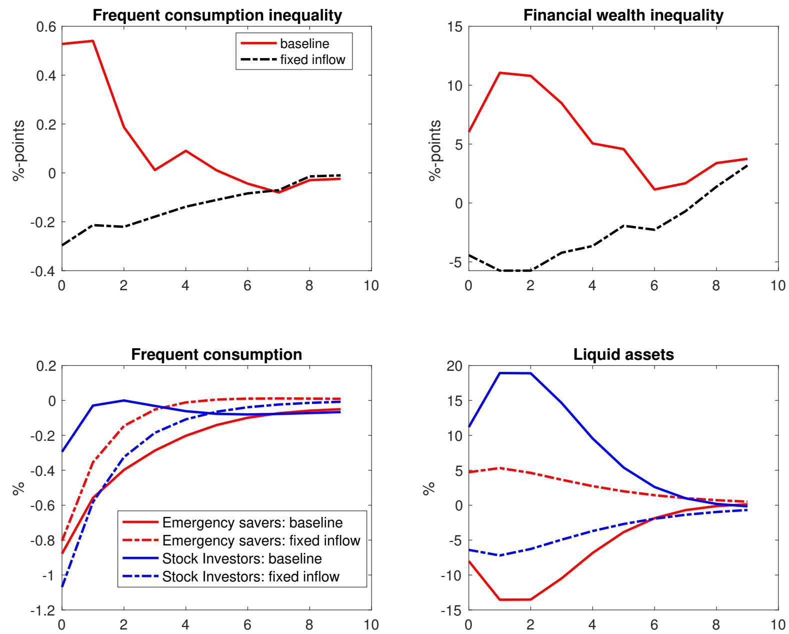
Having studied the macroeconomic effects on monetary policy, we now explore the role of stock investors for the impact of monetary policy changes on inequality.

The top panels of Figure 9 show the responses to a monetary policy shock of inequality in consumption and wealth, both measured as the log difference between the 90th and the 10th percentile of the distribution. Each of the two measures of inequality increases following a monetary tightening. The increase in consumption inequality is consistent with empirical evidence in Coibion, Gorodnichenko, Kueng and Silvia (2017). Regarding wealth inequality, we estimated the empirical response to a monetary policy shock ourselves, using new data from the Distributional Accounts, provided by the Federal Reserve Board. The results, shown in Appendix 5, are in line with the model: a monetary tightening raises wealth inequality substantially.[33]

To explore the role of the investment channel in driving the inequality responses in the model, we consider again the counterfactual version in which the stock investment inflow is shut down. Figure 9 shows that, without this channel, both measures of inequality

[33]Quantitatively, the increase in wealth inequality in the data is somewhat smaller than in the model, which might have to do with the fact that the decline in stock prices in the model is smaller than in the data. We show the empirical response of financial wealth inequality in Appendix 5.

Figure 9: Responses to a monetary tightening.



actually *decline*. Thus, the stock investment channel is the key reason why a monetary tightening increases inequality in the baseline model. To help understand why this is the case, Figure 9 also shows responses for the emergency savers and the stock investors in the baseline model. The bottom right panel shows the responses for liquid assets held by the two groups. The stock investors increase their liquid wealth holdings, as they rebalance away from stocks following an increase in the interest rate. These liquid assets are sold to them by the emergency savers, who thus dissave in liquid wealth and hence they become less wealthy. Given that emergency savers are mostly located in the bottom half of the wealth distribution, and stock investors in the upper half, wealth inequality increases. This effect dominates the fall in illiquid wealth for stock investors, which is quantitatively less sizeable given that the fall in the savings into the fund is small relatively to the stock of wealth. In the counterfactual without the investment channel, the rebalancing effect does not occur and wealth inequality falls.

The differential consumption responses of the two groups, shown in figure 9, explain why consumption inequality increases too. Stock market investors are at the satiation point in consumption and therefore adjust their consumption only mildly when monetary policy tightens. The slight decline that does occur is due to the fact that stock returns are expected to increase in the medium run. By contrast, consumption of the emergency savers drops much more sharply and hence the distribution of consumption spreads out. First, they respond to the increase in interest rates by substituting consumption intertemporally. Moreover, they further reduce consumption through an indirect income effect. In the counterfactual version of the model with fixed inflow, stock investors are not allowed to absorb the monetary policy shock through a portfolio rebalancing. In turn, they aggressively cut on consumption, even more than emergency savers. This implies consumption inequality falls, as shown in the top left panel. Moreover, it implies that stock investors become net sellers of liquid assets, inducing a mild fall in wealth inequality too.

7.3 Increased stock market participation and the power of monetary policy

During the late 1980s and the 1990s, there was a large increase in stock market participation, as shown earlier. Moreover, over this period there was a strong shift of the income distribution, pushing up incomes mostly at the upper half of the distribution. We now explore how these changes have altered the impact of monetary policy on the macro economy. In particular, we recalibrate the model to the year 2000 and study how the effects of monetary policy change, relative to the 1980s version of the model.

To recalibrate the model, we note that the expenditure rate at the 75th percentile of income in 1980s was 0.65, as employed in the calibration. In 2000, that expenditure rate was associated with the 65th percentile of income. We use this statistic to discipline our increase in income, and show that we are able to generate a sizable increase in stock market participation.

Specifically, we pick permanent productivities such that 35% of the households are potentially satiated. We recalibrate permanent productivities in order to match the CEX (NIPA-adjusted) expenditure rates at the top 35% of income in 2000.[34] We then fix all the remaining parameters to their 1980 values with two additional exceptions. First, we decrease τ to 20%. We motivate a decrease in liquidation cost based on two considerations. First, equity mutual fund expense ratios have been steadily falling over time. Second and foremost, the top income marginal tax rate was 39.6% in 2000, compared to 70% in 1980, implying a lower liquidation cost for indirectly held stocks as in a 401k account. Finally, we adjust $\bar{B}$ to leave the real return on liquid assets unchanged. The new equilibrium real return on stocks is 1.30%.

Table 4 shows how our experiment performs with respect to empirically observed trends.

[34] In particular, we target the top 7 demi-deciles. Then we pick 7 permanent productivities associated with satiated people and assign 5% employment population share each.

Table 4: Shift of the income distribution: model fit

	Model		**Data**	
	1988	2000	1988	2000
Expenditure rates (top demi-deciles)	[0.44 0.52 0.57 0.61 0.69]	[0.32 0.41 0.48 0.49 0.52 0.59 0.70]	[0.44 0.51 0.57 0.60 0.65]	[0.31 0.41 0.48 0.49 0.52 0.58 0.65]
Average liquidation cost	0.28	0.20	0.30	0.20
Households assets to output ratio	3.36	3.90	3.35	3.97
Stock market participation rate	24.4%	34.1%	24.9%	43.8%
90th-10th percentile wealth	7.12	7.60	5.63	6.38
$\frac{C}{Y}$	0.86	0.75	0.92	0.89
$\frac{H}{Y}$	0.38	0.49	0.20	0.24
$\frac{C+H}{Y}$	1.24	1.24	1.12	1.13

Note: The first two rows define the moments explicitly targeted in the calibration exercise for 2000. C stands for aggregate regular consumption expenditures, H aggregate infrequent consumption expenditures and Y aggregate after-tax labor income. See Table 2 for data sources and Appendix 1 for data description.

In the first two rows we show the calibration targets, while below we report the over-identified moments. First, we note that the model is able to generate a sizeable increase in stock market participation rate, although we fall short relatively to the data. It is reasonable to expect that additional factors other than shifts in the income distribution have also contributed to this trend.[35] Moreover, the model generates the increase in the ratio of household net worth to GDP that has taken place since the late 1990s. Wealth inequality goes up in the model as well as in the data, albeit by a smaller amount. Finally, the shift in the income distribution is consistent with a higher share of infrequent consumption expenditures to income, although we predict a concurrent substitution away from regular consumption, which is less strongly supported by the data.[36]

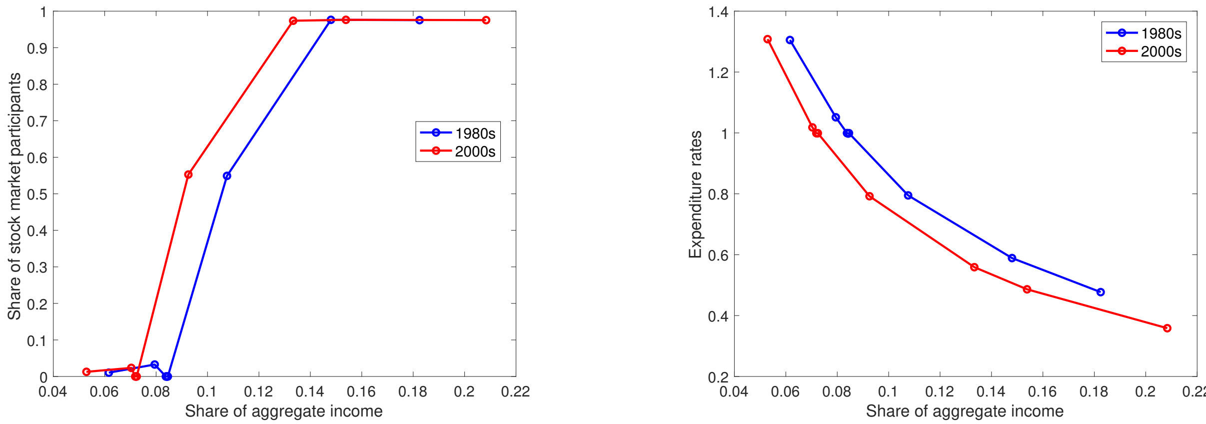
Figure 10 shows how the model is consistent with two empirical facts shown in section 2. First, the increase in stock market participation rate is driven by the upper middle-class, around the 60-80th percentile of income. Second, the relationship between expenditure rates and income shift downwards and stretches horizontally as income inequality increases.

Table 5 compares the impact of a monetary policy shock on macroeconomic variables in

[35] In particular, it seems likely that increased awareness on the tax benefits of 401k accounts (and other retirement accounts) played a role as well. The use of such accounts started with the discovery of a tax loophole in the 1980s.

[36] The recalibration also implies an increase of the investment to GDP ratio of 2 percentage points, between 2000 and 1980. In unreported results we recalibrate δ_k to keep the ratio constant. While the overall output response to a monetary policy tightening is slightly dampened, this comes entirely from consumption, since investment falls even more. Hence, our finding that the investment channel strengthens as inequality increases is confirmed.

Figure 10: Income distribution experiment



the 1980s and the 2000s version of the model. In the latter version, the decline in aggregate output is substantially larger, even though the increase in the nominal interest rate is much smaller. The larger decline in output is driven by investment, since consumption response is slightly smaller than under the 1980s calibration. Finally, inflation falls more in the 2000s version, which explains why the nominal interest rate increases by less, given the interest rate rule.

Thus, the investment channel has strengthened considerably since the 1980s, which can be understood from the increase in the stock market participation rate over that period. The latter is in turn driven by the change in the distribution of permanent income. Therefore, we find that changes in income inequality can directly impact on the power of monetary policy, as such changes affect the stock market participation rate.

8 Conclusion

What role do stock investors play in the transmission of monetary policy to the real economy? We have studied this question using an incomplete-markets New Keynesian model which accounts endogenously for the limited participation in the stock market, the relation between stock market participation and income, and the relation between income and saving behavior, as observed in micro data.

A key point in this paper is that stock investment is a crucial component of the monetary transmission mechanism, which is quantitatively more important than transmission via consumption. In response to a monetary policy tightening, stock holders rebalance their saving away from stocks, as hypothesized by Mundell and Tobin more than half a century ago. We also find that the amount of stock investment responds strongly to equilibrium

Table 5: Model responses to a monetary policy tightening: income distribution experiment

	1980s	2000s	2000s (rescaled)
Nominal interest rate (bp)	100	40	100
Output (%)	-1.61	-1.85	-4.62
Consumption (%)	-0.75	-0.65	-1.62
Investment (%)	-6.29	-7.41	-18.5
Price level (%)	-0.27	-0.35	-0.87

Note: First quarter response. The responses of the nominal interest rate and the inflation rate are annualized.

feedback effects, which amplify the rebalancing effects. We supported these findings with empirical evidence showing that households save less into stock market funds following a monetary tightening.

A second main point is that the stock investment channel is very sensitive to heterogeneity across households, in particular regarding participation in the stock market, which in turn depends heavily on income inequality. Our findings therefore highlight a new dimension of household heterogeneity which matters directly for monetary policy. Indeed, we found that the rise in stock market participation observed over the last few decades has strengthened the effects of monetary policy on the real economy. Vice versa, we found that the presence of heterogeneity in stock holdings also matters for the effects of monetary policy on inequality.

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Appendix 1: data

We use three main data sources: the Consumer Expenditure Survey (CEX), the Survey of Consumer Finances (SCF) and the National Income and Product Accounts (NIPA).[37]

In both the CEX and NIPA, we distinguish between *regular* and *infrequent* consumption expenditures, to draw an analog with the model.

We define infrequent expenditures, in NIPA, as health care, education and social services. Health care service expenditures include outpatient services, as well as hospital and nursing home services. We do not include durable health expenditures such as therapeutic medical equipment as well as nondurable such as pharmaceutical products. Similarly, education expenditures included are only those accruing to services (i.e.: higher education tuition fees), and exclude durables such as books. Social services expenditures are the sum of child care, social assistance (i.e.: homes for the elderly) and social advocacy. We apply the NIPA definitions to the CEX as closely as possible. We also exclude financial services and insurance expenditures, given their peculiar trend increase during the period of financial liberalization. We also exclude imputed rent both from consumption and income definitions. Mortgage interest is deducted from imputed rent in NIPA, hence we exclude this category both in the NIPA and the CEX. We also disregard pension and social insurance contributions, both from the CEX and NIPA (in the latter they are subtracted from personal income). Table 6 summarizes our classification.

In the NIPA, we define income as the sum of wages and salaries, and personal current transfer receipts. Then we subtract personal current taxes, which are mainly made up of federal and state income taxes. Similarly, our definition of income in the CEX is salary income plus other income[38] and food stamps, to which we subtract federal, local and state taxes (net of refunds).

All our variables in the CEX are deflated by CPI and winsorized at the top and bottom 1%. Whenever computing moments of the distribution or aggregates, we use CEX population weights. Income information is asked in the second and fifth interview of the CEX, and refers to the previous 12 months. We follow the same approach in the model. Moreover, when constructing Figure 1, we restrict the sample to interviews 2 and 5.

We use the SCF to document facts on stock market participation. We define as stock market participant a household that reports in the SCF at least one of the following: a positive amount of directly held stocks, a IRA account that is "mostly in stocks", a 401k

[37] Data on mutual fund inflows is taken from the Investment Company Institute (ICI), as explained in the main text.

[38] This includes supplemental security income, Railroad retirement income, unemployment and welfare compensation, other money income such as cash scholarships.

Table 6: Consumption expenditures classification

NIPA classification	*regular* expenditures	*infrequent* expenditures
Nondurable goods	✓	
Durable goods	✓	
Rental of tenant-occupied nonfarm housing	✓	
Household utilities	✓	
Transportation services	✓	
Recreation services	✓	
Food services and accommodation	✓	
Communication services	✓	
Professional and other services	✓	
Personal care and clothing services	✓	
Household maintenance	✓	
Net foreign travel	✓	
Health care services		✓
Social services		✓
Education services		✓

account that is "mostly in stocks". To be in line with CEX and the model, income in the SCF is defined as wage income, plus unemployment transfers minus federal income tax. The resulting after-tax income is censored at 0, because negative values represent federal taxes not paid on wage income, such as early 401k withdrawals.

Appendix 2: model details

Household's decision problem

Consider the household's decision problem in stage 1 of a period (i.e. after aggregate shocks and labor market shocks have realized, but before the household has learned whether has an infrequent expenditure opportunity, i.e. $\mathbf{1}_t^H(i)$). The maximization problem can be formulated as:

$$V_t(A_{t-1}(i), B_{t-1}(i), Z(i), \mathbf{1}_t^e(i)) = \max_{C_t(i), N_t(i)} \frac{C_t(i)^{1-\sigma_C}}{1-\sigma_C} - \zeta \frac{N_t(i)^{1+\kappa}}{1+\kappa} + \mathbb{E}_t \widetilde{V}_t(C_t(i), N_t(i), A_{t-1}(i), B_{t-1}(i), Z(i), \mathbf{1}_t^e(i), \mathbf{1}_t^H(i))$$

Here, $\widetilde{V}_t$ denotes the value in stage 2, i.e. when the household has learned $\mathbf{1}_t^H(i)$, which can be expressed as:

$$\widetilde{V}(C_t(i), N_t(i), A_{t-1}(i), B_{t-1}(i), Z(i), \mathbf{1}_t^e(i)), \mathbf{1}_t^H(i))) = \max_{A_t(i), B_t(i), H_t(i), X_t(i)} \varphi \mathbf{1}_t^H(i) H_t(i) + \beta \widetilde{\mathbb{E}}_t V_{t+1}(A_t(i), B_t(i), Z(i), \mathbf{1}_{t+1}^e(i))$$

$$s.t.$$

$$\begin{aligned}
C_t(i) + H_t(i) + A_t(i) + B_t(i) =& Y_t(i) + (1 + r_t^A)A_{t-1}(i) + \frac{1 + r_{t-1}^B}{1 + \pi_t} B_{t-1}(i) - X_t(i) \\
Y_t(i) =& \mathbf{1}_t^e(i)Z(i)w_t N_t(i) + (1 - \mathbf{1}_t^e(i))\Theta - T_t + D_{w,t} \\
X_t(i) =& \tau \max\left\{(1 + r_t^A)A_{t-1}(i) - A_t(i), 0\right\} \\
A_t(i), B_t(i), H_t(i), \geq 0, &
\end{aligned}$$

where $\widetilde{\mathbb{E}}_t$ denotes the expectations operator conditional on information available in stage 2, where we have used the assumed linear utility with respect to the infrequent good (see section 5.1 for a discussion on this).

Suppose now that the three outcomes stated in Section 5.2 hold (below we will present conditions to verify this). In that case, the first-order conditions for consumption and labor supply chosen in stage 1 can be expressed as:

$$\begin{aligned}
C_t(i) &= \mathbf{1}_t^e(i)\frac{1}{\sigma_C}\left(\mathbb{E}_t\lambda_t(i)\right)^{\frac{1}{\sigma_C}} + (1 - \mathbf{1}_t^e(i))(\frac{1 + r_{t-1}^B}{1 + \pi_t} B_{t-1}(i) + \Theta - T_t + D_{w,t}), \\
N_t(i) &= \mathbf{1}_t^e(i)\left(\frac{1}{\zeta}Z(i)w_t\mathbb{E}_t\lambda_t(i)\right)^{\frac{1}{\kappa}},
\end{aligned}$$

where $\mathbb{E}_t\lambda_t(i)$ is the expected value of the Lagrange multiplier of the budget constraint in stage 2 (which depends on the realization of $\mathbf{1}_t^e(i)$). Note that in the first condition, the term $\frac{1+r_{t-1}^B}{1+\pi_t}B_{t-1}(i) + \Theta - T_t + D_{w,t}$ is the consumption of an unemployed household, which equals after-tax home production plus any available liquid wealth (implying that the agent hits the liquidity constraint).

Now consider stage 2. The first-order condition for liquid assets, $B_t(i)$, can be expressed as:

$$\begin{aligned}
\lambda_t(i) &\geq \mathbf{1}_t^H(i)\lambda_t^{\mathbf{1}_t^H(i)=1} + (1 - \mathbf{1}_t^H(i))\lambda_t^{\mathbf{1}_t^H(i)=0}, \\
&= \mathbf{1}_t^H(i)\varphi + (1 - \mathbf{1}_t^H(i))\beta\widetilde{\mathbb{E}}_t\frac{\partial V_{t+1}(i)}{\partial B_t(i)}
\end{aligned}$$

where we have used that in the event of $\mathbf{1}_t^H(i) = 1$ any marginal wealth is spent on the infrequent good, delivering a marginal utility flow φ, whereas under the complementary event $\mathbf{1}_t^H(i) = 0$, marginal wealth is saved.[39] Under the three conditions, this equation

[39]Stock market investors save into both liquid assets and stocks. Portfolio optimization implies that for

binds with equality for those households who are employed.

Taking expectations of the above equation at stage 1 gives:

$$\mathbb{E}_t \lambda_t(i) \geq \delta\varphi + (1-\delta)\beta\mathbb{E}_t \frac{\partial V_{t+1}(i)}{\partial B_t(i)}$$

Now consider the envelope condition:

$$\frac{\partial V_t(\cdot)}{\partial B_{t-1}(i)} = \frac{1+r^B_{t-1}}{1+\pi_t}\mathbb{E}_t\lambda_t = \frac{1+r^B_{t-1}}{1+\pi_t} C_t(i)^{-\sigma_C}$$

Plugging in envelope condition in the first-order condition for $B_t(i)$, after leading it one period) gives the following Euler equation for liquid assets:

$$C_t(i)^{-\sigma_C} \geq \delta\varphi + (1-\delta)\beta\mathbb{E}_t \frac{1+r^B_t}{1+\pi_{t+1}} C_{t+1}(i)^{-\sigma_C}, \tag{2}$$

which binds with equality for the employed, under the 3 conditions. The unemployed households choose $B_t(i) = 0$.

Next consider the choice for illiquid assets (stocks). The first-order condition for $A_t(i)$, can be expressed as:

$$\mathbb{E}_t\lambda_t(i)(1+r^A_t) \geq \delta(1-\tau)(1+r^A_t)\varphi + (1-\delta)(1+r^A_t)\beta\mathbb{E}_t \frac{\partial V_{t+1}(i)}{\partial A_t(i)},$$

which binds with equality for those households who are saving into stocks (i.e. stock market investors).

Now consider again the envelope condition:

$$\begin{aligned} \frac{\partial V_t(\cdot)}{\partial A_{t-1}(i)} &= \delta(1+r^A_t)(1-\tau)\varphi + (1-\delta)(1+r^A_t)\beta\frac{\partial V_{t+1}(\cdot)}{\partial A_t(i)} \\ &= \sum_{j=0}^{\infty} \delta(1-\delta)^{j-1}\beta^j(1-\tau)\varphi\prod_{k=0}^{j}(1+r^A_{t+k}) \\ &= \mathbb{E}_t\lambda_t(s)(1+r^A_t) \end{aligned}$$

where in the third equality, $\mathbb{E}_t\lambda_t(s)$ denotes the expected Lagrange multiplier of stock market investors. The second equality makes clear that $\frac{\partial V_t(\cdot)}{\partial A_{t-1}(i)}$ is the same for all households. These households all have the same level of consumption, which is at its satiation point, and therefore also have the same value of the Lagrange multiplier. Leading the above equation

them $\widetilde{\mathbb{E}}_t \frac{\partial V_{t+1}(i)}{\partial B_t(i)} = \widetilde{\mathbb{E}}_t \frac{\partial V_{t+1}(i)}{\partial A_t(i)}$. For the remaining households it holds that $\widetilde{\mathbb{E}}_t \frac{\partial V_{t+1}(i)}{\partial B_t(i)} > \widetilde{\mathbb{E}}_t \frac{\partial V_{t+1}(i)}{\partial A_t(i)}$.

by one period and plugging it into the first-order condition for $A_t(i)$ gives:

$$\mathbb{E}_t\lambda_t(s)(1+r_t^A) = \delta(1+r_t^A)(1-\tau)\varphi + (1-\delta)(1+r_t^A)\beta\mathbb{E}_t\lambda_{t+1}(s)(1+r_{t+1}^A)$$

Using that $\mathbb{E}_t\lambda_t(s) = C_t(s)^{-\sigma_C}$, we arrive at the following Euler equation for stocks, for the stock market investors:

$$C_t(s)^{-\sigma_C} = \delta(1-\tau)\varphi + (1-\delta)(1+r_t^A)\beta C_{t+1}(s)^{-\sigma_C} \quad (3)$$

The households in the categories 1 and 2 all save exactly zero into stocks, i.e. they set

$$A_t(i) = (1-\mathbf{1}_t^H(i))(1+r_t^A)A_{t-1}(i).$$

Verifying the conditions in Section 5.2

We now present conditions to verify whether the three outcomes stated in Section 5.2 indeed hold in a steady state.[40] We consider each of the conditions in turn:

1. *Upon job loss, households fully liquidate their liquid assets, hitting the borrowing constraint in the first quarter of unemployment.* For this condition to hold it must be the case for any household it holds that

$$(\frac{1+r^B}{1+\pi}B_{t-1}(i)+\Theta-T)^{-\sigma_C} > \beta\,(1-\delta)\,\frac{1+r^B}{1+\pi}\left(p^{UE}(C_{t+1}^{\mathbf{1}^e_{t+1}(i)=1,B_t(i)=0}(i))^{-\sigma_C} + \left(1-p^{UE}\right)(\Theta-T)^{-\sigma_C}\right)\Big)+\delta\varphi$$

If this condition holds, then the household immediately hits the borrowing constraint. Here, $C_{t+1}^{\mathbf{1}^e_{t+1}(i)=1,B_t(i)=0}(i)$ is the consumption level of the household if it flows from unemployment into employment with zero liquid assets.

2. *Households do not liquidate any stock market wealth, unless they are presented with an infrequent expenditure opportunity.* For this property to hold it must be the case that even the households with the lowest levels of consumption do not wish to liquidate any stocks, which implies the following condition:

$$(1-\tau)(\Theta-T+D_w)^{-\sigma_C} < \frac{\partial V(\cdot)}{\partial A(i)} = C(s)^{-\sigma_C}.$$

3. *When presented with an infrequent expenditure opportunity, households fully liquidate*

[40] Since we consider small perturbation shocks, these conditions will also hold in a neighborhood of the steady state.

their stock market wealth and liquid assets. For this to be the case, the following two conditions must hold

$$\beta(1+r^b)(\Theta - T + D_w)^{-\sigma_C} < \varphi$$
$$\frac{\partial V(\cdot)}{\partial A(i)} = C(s)^{-\sigma_C} < \varphi(1-\tau)$$

The first condition states that even for the households with liquid wealth levels close to zero, the marginal utility from spending this wealth on an infrequent good exceeds the marginal utility of saving this wealth. Given that the marginal utility of consumption is declining in consumption, and consumption is increasing in wealth, the same holds true for households with higher levels of liquid assets. The second condition states that the marginal value of stock market wealth is always lower than the marginal value of liquidating wealth and spending it on the infrequent good. This is true regardless the level of stock market wealth, given that the marginal value of stock wealth always equals the marginal value of everyday consumption of the satiated households.

Proof of proposition 1 and 2

Proof. **Proposition 1.** (i). Households do not invest in stocks unless they are at the consumption max, so it holds that $C_t(i) = C_t(s)$. The first-order condition for illiquid assets, Equation (3), pins down $C_t(s)$ as a function of only expected returns on capital, so consumption is pinned down irrespective of the interest rate R_t. From the first-order condition it then directly follows that $\frac{\partial N_t(i)}{\partial R_t} = 0$. (ii). From the first-order condition for liquid assets, Equation 2, it follows that $\frac{\partial B_t(i)}{\partial R_t} > 0$. Given that $\frac{\partial C_t(i)}{\partial R_t} = 0$ and that R_t does not enter the budget constraint, it follows the budget constraint that $\frac{\partial B_t(i)}{\partial R_t} = -\frac{\partial S_t(i)}{\partial R_t}$. □

Proof. **Proposition 2.** Households do not invest in stocks unless they are at the consumption max, so it holds that $C_t(i) = C_t(s)$. The first-order condition for illiquid assets, Equation (3), pins down $C_t(s)$ as a function of only expected returns on capital, so consumption is pinned down irrespective of income Y_t. From the labor supply equation, this implies that also $N_t(s)$ is independent of income. Evaluating the liquid assets Euler equation for stockholders, we notice that $\frac{\partial B_t(s)}{\partial Y_t} = 0$. Hence, it follows from the budget constraint that $\frac{\partial A_t(s)}{\partial Y_t} = 1$. □

Equilibrium

Given the laws of motion for the exogenous states $\left\{z_t, Z, \mathbf{1}_t^e, \mathbf{1}_t^H\right\}$ and government policies $\{T_{w,t}, T_t\}$, the competitive equilibrium is defined as the joint law of motion for households' choices $\{C_t(i), H_t(i), N_t(i), B_t(i), A_t(i)\}_{i\in[0,1}$, producer choices $\{N_t, I_t\}$, aggregate quantities $\{Y_t, D_{p,t}, D_{r,t}, D_{w,t}\}$ and prices $\left\{r_t^A, r_t^b, \pi_t, \widetilde{P}_t, \pi_{w,t}, w_t, \widetilde{w}_t, Q_{p,t}, Q_{r,t}, q_t\right\}$, such that, in any period t:

1. Each household $i \in [0,1]$ maximizes the stage 1 and stage 2 value functions, outlined at the beginning of Appendix 2, subject to the constraints outlined there.

2. Labor service firms maximize wage dividends subject to the wage adjustment cost; final goods firms maximize profits; intermediate goods producers maximize the expected present value of dividends subject to their flow budget constraint; intermediate goods price-setters maximize the expected present value of dividends subject to the demand constraint, and price adjustment costs.

3. Stock market funds satisfy their flow budget constraint and the pricing condition on their real return.

4. The government budget constraint and the monetary policy rule hold.

Numerical solution method

We solve the model as follows. First, we find the steady state of the model, where the decisions of the households are solved using value function iteration. We then verify that the tractability conditions mentioned above hold. The tractability conditions do not only allow us to draw the analytical findings shown in the paper, but they also permit to solve the model using a perturbation method. Following Cui and Sterk (2018), we keep track of the wealth distribution in a parsimonious and yet accurate way. We group employed agents into cohorts that are indexed by the employment spell in the previous quarter. Within any cohort, a fixed fraction has become unemployed in the current quarter and behaves identically. Similarly, all agents that remain employed behave identically within a certain cohort. We set a total of 50 cohorts (i.e.: quarters) and group together the households with more than 50 quarters of employment spell. We verify that results are not sensitive with respect to this choice. Conceptually, each cohort corresponds to a state variable characterizing the wealth distribution.

Appendix 3: extensions

In this section we go back to the extension presented earlier in section 4.1, and show the quantitative role played by the new channels introduced by the firm-level cash in advance constraint. The first order conditions for labor and capital stock are:

$$w_t = (1-\alpha)\,\widetilde{P}_t \frac{Y_t}{N_t}\left[1-\nu+\nu\mathbb{E}_t\left(\Lambda_{t,t+1}\left(\frac{1+r_t^B}{1+\pi_{t+1}}\right)\right)\right]$$

$$q_t = \mathbb{E}_t\Lambda_{t,t+1}\left[(1-\delta_k)\,q_{t+1}+\alpha\widetilde{P}_{t+1}\frac{Y_{t+1}}{K_{t+1}}\left(1-\nu+\nu\left(\Lambda_{t+1,t+2}\left(\frac{1+r_{t+1}^B}{1+\pi_{t+2}}\right)\right)\right)\right]$$

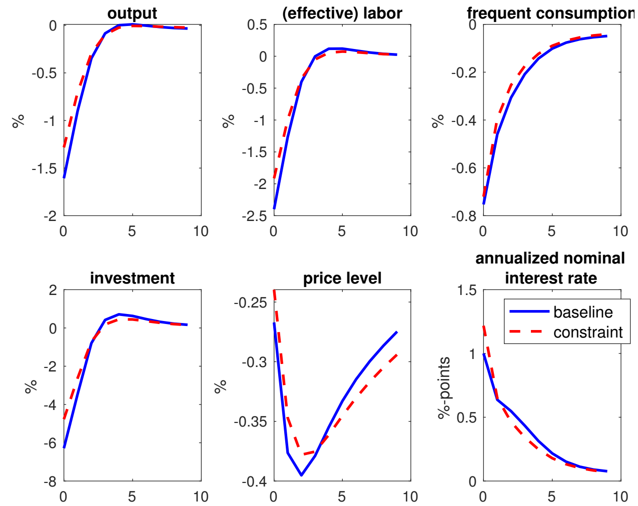
where Tobin's q is the shadow value of a unit of installed capital. Since $\Lambda_{t,t+1}\left(\frac{1+r_t^B}{1+\pi_{t+1}}\right) < 1$, the financial constraint introduces an additional cost of production. In order to produce more, a firm must hold more cash, which earns an interest rate that lies below the discount rate. An increase in the real interest rate decreases this cost, keeping the discount factor constant. Therefore, a tightening of monetary policy has the potential to loosen financial frictions, inducing the firm to increase its cash holdings, that now earn a higher interest rate, and thus making them able to sustain higher production. On the other hand, this firm-level rebalancing might imply a reduction in investment, for given resources. Moreover, household-level rebalancing implies a reduction in corporate cash, for a given interest rate, since government bonds are in fixed supply – recall that $\int_i B_t(i)di + M_t = \overline{B}$. The latter can be seen as a way to make households' liquid savings indirectly productive, similarly to bank lending.[41]

Figure 11 shows the overall quantitative effects of these different channels. Financial constraints act as an adjustment cost, dampening the response of output upon impact, and making the recovery more sluggish. This is in spite of the fact that a given monetary policy shock transmits into a larger increase in the nominal interest rate. Similarly, the price level falls by less upon impact, but then remains subdued by more and for longer.

While the response of consumption is slightly dampened, most of the additional sluggishness in output is driven by changes in the responsiveness of investment. To build further intuition on its drivers, we revisit, in Figure 12, the investment-level decomposition previously presented. As a result of the firm-level financial constraint, the contribution of investment to output dynamics slightly falls from 70 to 60 percent. Turning to the investment decomposition, the role played by financing flows - from the fund - is much larger.

[41] Business loans, however, empirically fall in response to a monetary policy tightening, which would make this interpretation of the model at odds with the data.

Figure 11: Model responses to a monetary policy tightening: firm-level financial constraint



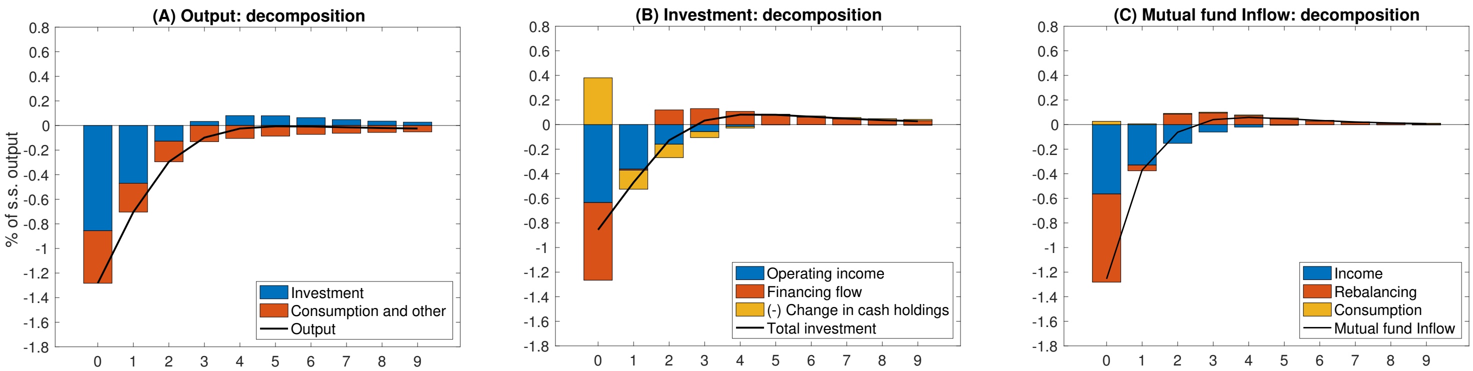
Note: Horizontal axes denote quarters. Shock hits in quarter 0. We set $\nu = 0.20$, which generates a ratio of corporate cash to quarterly GDP equal to 18%, as observed in 1988. Corporate cash as the sum of currency, checkable deposits, time and saving deposits, and money market mutual fund shares, in the nonfinancial corporate business sector.

Recall that this effect captures the reduction of stock market fund holdings by stock investors. On the other hand, however, there is a new important component, which consists of corporate cash dynamics. Upon impact, firms burn their cash holdings in order to free up resources. This dampens the fall in investment, although does not entirely overturn the financing flow effect coming from the stock market fund. In other words, cash provides a source of internal financing which can partially counteract a reduction in external finance (i.e.: equity).[42] In the following periods, however, cash dynamics are tied to the real side of the firm's budget constraint. Cash adds an additional cost of production: as firms rebuild their production capacity, they have to simultaneously accumulate cash. This subtracts resources from investment, making its recovery more sluggish.

Finally, we turn to the household-level channels behind the investment response. The role of rebalancing increases to 66% upon impact, but it is very short-lived. The sluggishness of inflow is entirely driven by general equilibrium income effects. Note that the mutual fund inflow itself is less sluggish than without financial constraint. Indeed, what drives the overall additional persistence is corporate cash.

[42]Note that the fall in gross inflow into the fund, shown in the right panel, is basically the same as the sum of the financing flow and operating income components of the fall in investment, similarly to the baseline model. It is the cash burn that makes the pass-through imperfect, thus reducing the correlation between investment and mutual fund inflow below 1, as shown empirically in figure 3.

Figure 12: Decomposition of aggregate responses: financial constraint



Note: Horizontal axes denote quarters following the shock.

Appendix 4: Representative-agent models

A. Standard representative-agent model. In this section we consider a representative agent model. The representative household's decision problem reads:

$$max_{C_t,K_{t+1},I_t,N_t}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{C_t{}^{1-\sigma_C}-1}{1-\sigma_C}-\zeta\frac{N_t{}^{1+\kappa}}{1+\kappa}\right\}, \quad \beta\in(0,1), \quad \sigma_C,\zeta,\kappa>0.$$

$$s.t.$$

$$C_t+I_t+B_t=\widetilde{w}_tN_t+r_t^KK_t+\frac{1+r_{t-1}^B}{1+\pi_t}B_{t-1}-T_t+D_{w,t}+D_t$$

$$K_{t+1}=(1-\delta^K)K_t+\left[1-\Omega(I_t/I_{t-1})\right]I_t$$

Thus, the household now directly owns the capital and the equity in the firms. Hence, there is no mutual fund. For simplicity there is a single type of intermediate goods firms. The first order condition for investment, however, is the same as in the main text, with investment subject to adjustment costs Ω. To keep this model as standard as possible, we fix the supply of liquid assets to zero. Note also that there is no unemployment in this model. The first-order conditions for K_{t+1}, B_t, and N_t, respectively to the above decision problem are, respectively:

$$C_t{}^{-\sigma_C}=\beta\mathbb{E}_t\left(\left(\left(1-\delta^K\right)\frac{q_{t+1}}{q_t}+\frac{r_{t+1}^K}{q_t}\right)C_{t+1}{}^{-\sigma_C}\right)$$

$$C_t{}^{-\sigma_C}=\beta\mathbb{E}_t\left(\frac{1+r_t^B}{1+\pi_{t+1}}C_{t+1}{}^{-\sigma_C}\right)$$

$$\widetilde{w}_tC_t{}^{-\sigma_C}=\zeta N_t^{\kappa}$$

The remainder of the model is the same as the baseline.

We recalibrate the depreciation rate of capital, δ_k, such that the capital - output ratio is the same as in the baseline heterogeneous-agent model. Moreover, we adjust ζ such that the household works 33% of the time.

B. Representative-agent model with infrequent expenditures, liquidation costs. We now consider a representative agent which includes infrequent expenditures and liquidation costs, as in the baseline, but abstracts from heterogeneity. To this end, we assume that the household consists of a continuum of members. After production and consumption of frequent goods has taken place, the household members separate and each receive an equal fraction of the households assets, i.e. an equal share to the household's liquid assets, the capital, and firm equity. Then, a fraction δ of the members receives an infrequent expenditure opportunity. Acting in their own interest, a member will liquidate all its asset claims and spend the proceeds on the infrequent good. However, liquidation of firm equity and capital requires a liquidation cost, equal to proportion τ of the liquidated amount, as in the baseline. When making central decisions, the household takes the utility of infrequent expenditures into account. The decision problem reads (assuming linearity w.r.t. the infrequent good, as in the baseline):

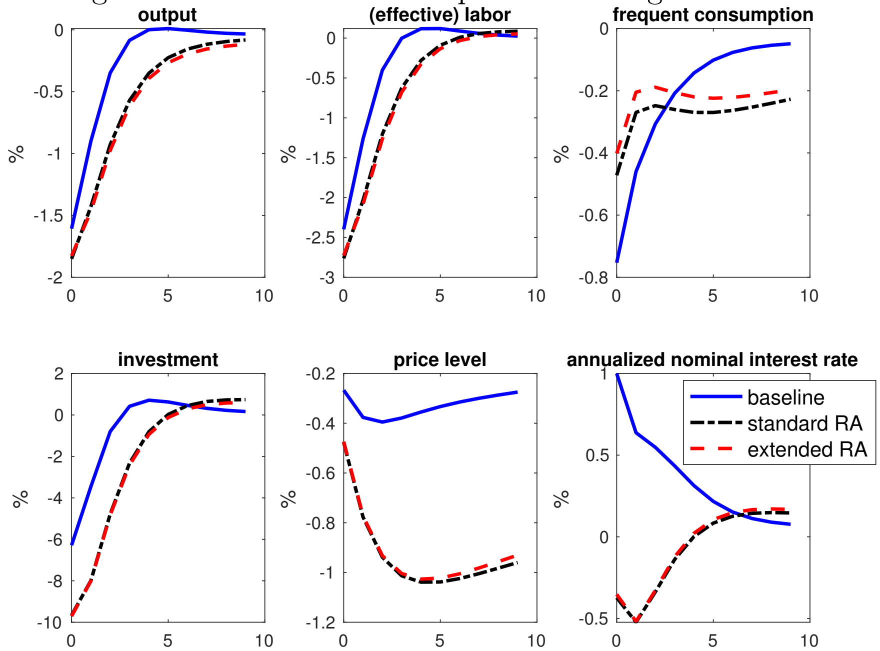
$$max_{C_t,H_t,K_{t+1},I_t,,N_t}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{C_t^{1-\sigma_C}-1}{1-\sigma_C}+\varphi H_t-\zeta\frac{N_t^{1+\kappa}}{1+\kappa}\right\},\quad \beta\in(0,1),\quad \sigma_C,\zeta,\kappa>0.$$

$$s.t.$$

$$\begin{aligned}
C_t+H_t+X_t+I_t+B_t+T_t-D_{w,t}-D_t &= \widetilde{w}_tN_t+r_t^KK_t+\frac{1+r_{t-1}^B}{1+\pi_t}B_{t-1}\\
H_t &= \delta\left(B_t+(1-\tau)K_{t+1}+(1-\tau)Q_t\right)\\
X_t &= \tau\left(K_{t+1}+Q_t\right)\\
K_{t+1} &= \left(1-\delta^K\right)K_t+\left[1-\Omega(I_t/I_{t-1})\right]I_t
\end{aligned}$$

where the two last constraint capture, respectively, the behavior of the household members, after they have split, and the liquidation cost. Substituting out H_t and X_t , we can write

Figure 13: Baseline versus representative-agent version



Note: Horizontal axes denote quarters following the shock. We recalibrate δ_k in the standard representative agent model to 0.0208, such that the capital output ratio is the same as in the benchmark model. We also recalibrate the disutility of labor, ζ, to 6.39, such that households work one third of the time. The recalibrated parameters are 0.0221 and 9.89, respectively, in the extended representative agent model. The shock in the baseline model is scaled such that the annualized nominal interest rate increases by 100 basis points on impact. The same shock is fed to the other models.

the problem as:[43]

$$max_{C_t,K_{t+1},I_t,N_t}\mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{{C_t}^{1-\sigma_C}-1}{1-\sigma_C}+\varphi\delta\left(B_t+(1-\tau)K_{t+1}+(1-\tau)Q_t\right)-\zeta\frac{{N_t}^{1+\kappa}}{1+\kappa}\right\},$$

$$s.t.$$

$$C_t+\delta B_t+\delta(1-\tau)\left(K_{t+1}+Q_t\right)+I_t+B_t-\widetilde{w}_tN_t-r_t^KK_t-\frac{1+r_{t-1}^B}{1+\pi_t}B_{t-1}+T_t-D_{w,t}-D_t=0$$

$$K_{t+1}-\left(1-\delta^K\right)K_t-\left[1-\Omega(I_t/I_{t-1})\right]I_t=0$$

This decision problem gives rise to the following first-order conditions for K_{t+1}, B_t, and N_t, respectively:

$$\left(1+\delta(1-\tau)\right){C_t}^{-\sigma_C}=\beta\mathbb{E}_t\left(\left(\left(1-\delta^K\right)\frac{q_{t+1}}{q_t}+\frac{r_{t+1}^K}{q_t}\right){C_{t+1}}^{-\sigma_C}\right)+\delta\varphi\left(1-\tau\right)$$

$$\left(1+\delta\right){C_t}^{-\sigma_C}=\beta\mathbb{E}_t\left(\frac{1+r_t^B}{1+\pi_{t+1}}{C_{t+1}}^{-\sigma_C}\right)+\delta\varphi$$

$$\widetilde{w}_t{C_t}^{-\sigma_C}=\zeta N_t^{\kappa}$$

[43]with $\beta\in(0,1)$ and $\sigma_C,\zeta,\kappa>0$.

The remainder of the model is the same as the standard representative agent model. We recalibrate δ_k and ζ here as well.

Figure 13 compares the impulse responses in our benchmark, heterogeneous-agent, model with the two representative agent versions of the model. First, we note little difference between the standard representative agent model, and the extended version that features infrequent expenditures and liquidation costs. In both models, the nominal interest rate drops following a monetary contraction. The representative agent model implicitly assumes a stock market participation rate of 100%. This is behind a much larger response in investment, compared to the baseline heterogeneous-agent model.

Appendix 5: empirical impulse responses to monetary policy shocks

We follow Cloyne, Ferreira and Surico (2020) and estimate the following equation:

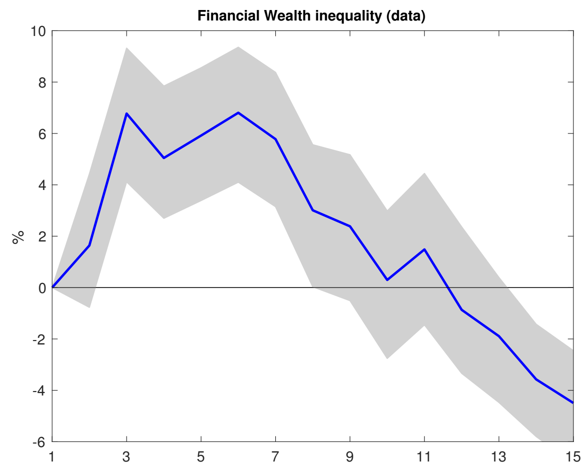
$$X_t = \alpha_0 + \alpha_1 trend + B(L)X_{t-1} + C(L)S_{t-1} + u_t$$

where X_t is the variable of interest (i.e.: wealth inequality). The monetary policy shocks are denoted by S. We use Cloyne et al. (2020) updated version of Romer and Romer (2004) shocks. Standard errors are bootstrapped using Mertens and Ravn (2013) recursive wild bootstrap.

In the following figure we show that, in the data, financial wealth inequality increases following a monetary policy tightening. As shown in section 7.3, the model can generate this thanks to the investment channel of stock market participation.[44]

[44] The findings shown in figure 9 are confirmed when defining financial wealth inequality in the same way as in the data, see figure 14.

Figure 14: Monetary policy shocks and wealth inequality



Note: Dynamic effects of a 100 basis point unanticipated interest rate increase. Data is from the Federal Reserve Board Distributional Financial Accounts. We construct financial wealth as the sum of Checkable deposits and currency, Time deposits and short-term investments, Money market fund shares, U.S. government and municipal securities, Corporate equities and mutual fund shares, and Equity in noncorporate business. Inequality is defined as the log difference between wealth held by bottom 50% and wealth of 90-99th percentiles of the population. 11 lags on both the dependent variable and the shocks. Grey areas are bootstrapped 90% confidence bands.