Monetary Policy, Wealth Inequality, and Lifecycle Dynamics*

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Abstract

Monetary policy changes bring redistributive consequences. This paper investigates how these redistributive effects vary across wealth and age groups and how persistent they are. We build a heterogeneous agent New Keynesian overlapping generations (HANK-OLG) model where households can save in liquid and illiquid assets. The model also allows various fiscal responses to monetary surprises and isolates households' responses to a monetary policy shock from adjustments in transfers, taxes, or government spending. We find that an expansionary monetary policy shock benefits younger households the most as the increased aggregate economic activity boosts their labor income. In contrast, older households whose primary income source is capital income suffer from a fall in the return of liquid assets while being limited in their ability to take advantage of higher wages.

Keywords: monetary policy, incomplete markets, portfolio choice, life-cycle.
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1 Introduction

Monetary policy conventionally focuses on macroeconomic aggregates with goals such as price stability, maximum employment, or sustained growth. However, monetary policy interventions almost inevitably affect individual households unevenly. Households differ in a multiplicity of dimensions, such as wealth, portfolio composition, sources of income, and age, among many others. These differences in individual characteristics imply that not everyone is equally affected by monetary policy changes. Their degree of exposition to monetary interventions depends, for example, on whether they rely more heavily on labor income than capital income, or whether they have a larger share of liquid assets in their portfolios (see for example Kaplan et al. 2018; Auclert 2019).

In this paper, we study the role of the lifecycle in shaping a differential incidence of monetary policy among households. For a given household, age has a crucial effect on their planning horizon, and taking the age dimension into account is critical in reproducing a realistic consumption-savings behavior. However, while it is true that variables such as income, wealth, or portfolio composition are closely related to an agent's point in their lifecycle, there are still substantial differences between households even after controlling by age. In this context, we quantitatively study the redistributive effects of monetary policy across households with different ages and wealth and across generations. In particular, this paper touches on several questions related to the transmission of monetary policy to individual households: Are any age or wealth groups that benefit more following a monetary policy shock? Is there any redistribution between age groups? How persistent are these effects for households with finite life spans? Which age groups are more responsive and contribute more to aggregate fluctuations?

To this end, we build a heterogeneous agent New Keynesian overlapping generations (HANK-OLG) model. In the model, households live for a finite number of periods, giving rise to a more realistic consumption-saving behavior over their lifetime. During their working life, households face uninsurable idiosyncratic risk alongside labor supply decisions, generating a rich distribution of households over asset holdings. As in Kaplan et al. (2018), households choose how to allocate their portfolios among two assets –liquid and illiquid– with a fixed cost of adjusting the illiquid asset holdings. Differences in portfolios across households, both in size and composition, generate unequal responses to a shock as households face distinct levels of liquidity risk (Kim, 2022b). In the model, inflation risk also affects households' portfolio choices. Liquid assets are nominal, and any shocks generating unexpected changes in inflation revalue households' balance sheets. An increase in inflation benefits net nominal debtors as the real value of debt falls through a debt-deflation effect (Auclert, 2019).

The role of fiscal policy is a key determinant of the distributional effects of monetary policy. Ricardian equivalence does not hold in our model, not only because of the presence of uninsurable idiosyncratic risk and occasionally binding borrowing constraints (Alves et al., 2020), but also because of its life-cycle dynamics. In our analysis, we consider various fiscal policy changes in response to monetary policy shocks that range from keeping government debt fixed to maintaining net public expenditure constant. Crucially, this allows us to isolate the distributional effects of monetary policy from changes in (1) fiscal instruments, such as taxes, transfers, or expenditure, and (2) the timing of such adjustments.

We calibrate the model to reproduce the most salient moments of the distribution of wealth, liquid assets, and illiquid assets in the 2007 Survey of Consumer Finances (SCF). We introduce a leptokurtic distribution of earnings shocks that matches the empirical findings in Guvenen et al. (2015). While not targeted, the model successfully explains the share of illiquid assets (as a fraction of total assets) across the distribution of households, both over wealth and age, in a way that resembles the data on individual households' portfolios.

Then, we simulate the model's response to a one-time, unexpected expansionary monetary policy shock. As discussed before, the fiscal policy response to monetary policy changes can potentially significantly affect how the economy and individual households respond to aggregate shocks. We start by assuming a perfectly elastic supply of government bonds, with taxes, transfers, and government expenditure remaining constant. Overall, the responses of macroeconomic aggregates are in line with the standard New Keynesian model. Expansionary monetary shocks increase economic activity as interest rates fall. More importantly, wages rise with the increasing labor demand required to satisfy the aggregate demand.

Households' responses to an expansionary monetary policy shock vary significantly by wealth and age. All households increase their consumption at the impact date. However, when comparing between age groups, we find that households that are younger on impact experience a substantially higher increase in their consumption relative to the old. More specifically, the increase in consumption of younger households is six times as much as the one for older agents. At the same time, younger households can have higher savings than their older counterparts, implying that the net worth of these younger households grows much faster, and remains higher, than in the absence of the monetary shock.

These differences in consumption and saving behavior across age groups are largely driven by younger households being able to respond more aggressively by increasing their labor supply for longer. This allows them to save at a higher pace. Despite older households observing a larger increase in their capital income at the impact date, the above-normal wealth for younger households implies that their capital income continues rising for several periods after the shock and remains persistently high as they age. In fact, we find that the increased consumption of younger households is highly persistent, as they can work for more years while wages are higher than in the stationary equilibrium. These results imply that younger households are the ones that contribute the most to the increase in aggregate consumption following an expansionary monetary shock.

We also show that considering the role of the life cycle and intra-generational heterogeneity in our benchmark model is crucial, from both a quantitative and qualitative standpoint, to evaluate the differential impact of monetary policy on individual households. In the absence of incomplete markets, the model would display a representative agent per cohort, while at the same time, it would eliminate any precautionary savings motives. The ensuing consumption response following an expansionary monetary shock is even larger for all households, as their marginal propensity to consume (MPCs) is larger than in our benchmark model. In the absence of a two-asset market structure, the model would fail in reproducing the share of hand-to-mouth households observed in the data. These households have little liquid assets and, thus, are more responsive to income changes and less sensitive to interest rate changes.

Our solution method may also be of independent interest. We develop a two-stage approach to solve the households' decision rules involving portfolio choice and endogenous labor supply decisions. With our approach, we first define an intermediate value function over cash-on-hand, where households solve for the optimal supply of labor and liquid assets. In the second stage, they choose whether to adjust their illiquid asset holdings and the degree of the adjustment in case it is optimal for them to do so. We apply this method in the context of our life-cycle model with a bivariate cross-sectional distribution of assets. Furthermore, the solution of the model's response to monetary shocks relies on perfect-foresight shocks. One advantage of using this approach, as opposed to other methods that linearize the model, is that our responses are more robust to large aggregate shocks, as it allows the distribution of households over assets to vary in a richer way.

Related Literature

This paper is related to several strands of the literature. First, our model economy builds on a growing literature that studies the interplay between monetary policy and heterogeneity. This literature has emphasized that the channels through which monetary interventions influence households' decisions can be dramatically different when accounting for realistic distributions of wealth and income. The empirical evidence in Coibion et al. (2017), Cloyne et al. (2020), and Holm et al. (2021) highlights the role of household heterogeneity in the transmission of monetary policy. Kaplan et al. (2018) and Alves et al. (2020) find that indirect effects dominate the role of intertemporal substitution in determining households' choices after a monetary shock. Auclert (2019) shows that the distribution of wealth in and of itself matters for the transmission of monetary policy, as not everyone is affected equally by these changes, while Acharya and Dogra (2020) emphasize the importance of accounting for the cyclicality of income risk. Our work extends this literature and focuses on the correlation between wealth, income, and consumption with age. The model economy let us to explicitly quantify how much individual households win or lose after a monetary policy shock and, notably, does so while carefully considering the role of portfolio and income composition.

Second, our paper is related to the literature examining the transmission of monetary policy in overlapping-generations models. Doepke and Schneider (2006) explores how inflationary episodes can redistribute wealth from old to young households, while Gornemann et al. (2021) discuss how wealth-rich and retired households are better off in an inflation-targeting regime. Wong (2021) finds that younger households benefit the most after an expansionary monetary policy shock because of their higher gains of refinancing their mortgages, which tend to have higher balances than the mortgages of older households. This makes the consumption of younger households more responsive to monetary innovations. Hu et al. (2023) stress the importance of using OLG models for the study of monetary transmission, as changes in interest rates generate asset substitution between government debt and capital, a mechanism not present in infinitely-lived agents models.

Notably, Braun and Ikeda (2021) and Bielecki et al. (2022) use life-cycle models to study the effects of monetary policy interventions on different age groups. These papers find that younger households' consumption increases more following an expansionary shock. While both of these papers incorporate a rich asset structure, with liquid and illiquid assets, they assume the existence of complete markets so that idiosyncratic risk can be perfectly insured. Thus, as opposed to ours, these models do not consider intra-generational heterogeneity in wealth, portfolios, or sources of income, dimensions that are crucial, together with age, to quantify the effects of monetary shocks on individual households.

Finally, our paper contributes to the work studying the fiscal-monetary policy mix. Bhandari et al. (2021) discuss the optimal fiscal-monetary policy, and propose a method to solve these policies in heterogeneous agents New Keynesian models, while Bhattarai et al. (2021) study the interplay between fiscal and monetary policy together with re-distributive policies. Alves et al. (2020) show that different assumptions about the fiscal response to monetary shocks, both in terms of timing and in terms of which fiscal instrument to use, can amplify the consumption response in a significant manner. In our paper, we also consider different response rules for fiscal policy and, importantly, discuss why the timing and horizon of any fiscal adjustment become a fundamental driver of individual households' responses in a life-cycle model.

The rest of the paper is structured as follows. Section 2 presents the model. Section 3 describes the calibration strategy and shows how well the model fits the observed distribution of wealth and portfolios across households of different ages and wealth. Section 4 examine the main results of the paper focusing on the age dimension, while Section 5 discusses the importance of each of our model elements. Section 6 offers some concluding remarks and proposes some ideas for future research.

2 Model

To study the disproportionate effects of monetary policy across different generations, we build a heterogeneous agent New Keynesian overlapping generations (HANK-OLG) model with two real assets: high-yield illiquid assets and low-yield liquid assets. The model economy is populated by (1) a measure of one of overlapping generations of households, (2) a representative final good producer that aggregates intermediate goods into the final good, (3) a set of monopolistically competitive intermediate goods producers that face quadratic price adjustment costs (à la Rotemberg, 1982), (4) a monetary authority that sets the nominal interest rate following a Taylor rule, and (5) a government that sets fiscal policy and issues government bonds.

2.1 Households

This is a life-cycle model where households live for a finite number of periods. Using j to index their years of life, they start working at $j = 1$, retire at J_r, and their last period is J. Households differ by age j, illiquid assets a, liquid assets b, idiosyncratic labor productivity ε, and in their subjective time discount factors $\beta \in \{\beta_l, \beta_h\}$ that is uniformly distributed.[1]

During their working lives, households face idiosyncratic productivity shocks ε and choose their labor supply n. These productivity shocks follow a finite-state Markov chain $\varepsilon \in \{\varepsilon_1, ..., \varepsilon_{n_\varepsilon}\}$, where $\Pr(\varepsilon' = \varepsilon_k | \varepsilon = \varepsilon_l) = \pi_{lk} \geq 0$ and $\sum_{k=1}^{n_\varepsilon} \pi_{lk} = 1$. Workers also receive a labor market experience premia $l(j)$, and are paid a real wage w per unit of effective labor. After retirement, households receive lump-sum social security benefits proportional to their last earnings shock $s(\varepsilon^{Jr-1})$.

Households can save using two assets: high-yield illiquid assets a and low-yield liquid assets b. The real return on illiquid assets r_t^a is higher than the real interest rate on liquid assets r_t^b. Following Kaplan et al. (2018), adjusting illiquid assets involves the following fixed adjustment cost

$$\xi(d, a) = \xi_0 |d| + \xi_1 \left| \frac{d}{a} \right|^{\xi_2} a, \tag{1}$$

where $\xi_0 > 0$, $\xi_1 > 0$, and $\xi_2 > 1$.[2] Here, $d = a' - (1 + r_t^a)a$ is the net deposit into illiquid assets. Households paying these costs adjust illiquid wealth to the desired value; otherwise, the ex-post return on illiquid assets and principal are re-invested in illiquid assets. Borrowing is only allowed in the liquid asset at the real rate of $r_t^{b-} = r_t^b + \varsigma$ and is subject to the borrowing limit $\underline{b}$.

Each period, a household makes the following discrete portfolio adjustment choice

$$v_{j,t}(a, b, \varepsilon, \beta) = \max \left\{ v_{j,t}^a(a, b, \varepsilon, \beta), v_{j,t}^n(a, b, \varepsilon, \beta) \right\} \tag{2}$$

where $v_{j,t}^a$ is the value of a household adjusting its illiquid assets, while $v_{j,t}^n$ is the value when a household dose not adjust its illiquid assets.

[1] Note that, for each household, a time discount factor is fixed over its lifetime. Preference heterogeneity is introduced to match the observed distribution of wealth, as in Krusell and Smith (1998), Krueger et al. (2016), and Kim (2022b).

[2] As in Kaplan et al. (2018), the first linear term determines the adjustment region, and the second convex term ensures the smooth adjustment of illiquid asset holdings.

Households' instantaneous utility function is $u(c,n)$, where c is consumption and n is labor. The Bellman equation of a household that adjusts its illiquid asset holdings is given by

$$v^{a}_{j,t}(a,b,\varepsilon,\beta) = \max_{\{c,n,a',b'\}} u(c,n) + \beta E_{\varepsilon}\left[v_{j+1,t+1}\left(a',b',\varepsilon,\beta\right)\right] \tag{3}$$

$$\text{s.t.} \quad c + d + b' \leq (1+r^{b}_{t})b + x - \xi(d,a) \tag{4}$$

$$d = a' - (1+r^{a}_{t})a \tag{5}$$

$$x = \begin{cases} (1-\tau_n)w_t l(j)\varepsilon n & \text{if } j < J_r \\ (1-\tau_n)s(\varepsilon) & \text{otherwise} \end{cases}$$

$$b' \geq \underline{b}, \quad a' \geq 0, \quad c \geq 0, \quad n \geq 0$$

where x is labor income before retirement and social security income after retirement, that are taxed at the rate τ_n.

Similarly, the Bellman equation of a household that does not adjust illiquid assets is given by

$$v^{n}_{j,t}(a,b,\varepsilon,\beta) = \max_{\{c,n,b'\}} u(c,n) + \beta E_{\varepsilon}\left[v_{j+1,t+1}\left(a',b',\varepsilon,\beta\right)\right] \tag{6}$$

$$\text{s.t.} \quad c + b' \leq (1+r^{b}_{t})b + x \tag{7}$$

$$a' = (1+r^{a}_{t})a \tag{8}$$

$$x = \begin{cases} (1-\tau_n)w_t l(j)\varepsilon n & \text{if } j < J_r \\ (1-\tau_n)s(\varepsilon) & \text{otherwise} \end{cases}$$

$$b' \geq \underline{b}, \quad c \geq 0, \quad n \geq 0.$$

2.2 Final Goods Produces

A competitive representative final good firm produces a homogeneous output Y_t by aggregating intermediate goods, indexed by $i \in [0,1]$, using a standard Dixit-Stiglitz aggregator

$$Y_t = \left[\int_0^1 y_{i,t}^{\frac{\theta-1}{\theta}} di\right]^{\frac{\theta}{\theta-1}} \tag{9}$$

where $\theta > 0$ is the elasticity of substitution. The profit maximization problem of this firm implies a demand for each variety $i \in [0,1]$ as

$$y_{i,t} = \left(\frac{P_{i,t}}{P_t}\right)^{-\theta} Y_t, \text{ where } P_t = \left(\int_0^1 P_{i,t}^{1-\theta} di\right)^{\frac{1}{1-\theta}}. \tag{10}$$

Here, P_t is the aggregate price index and $P_{i,t}$ is the price of intermediate good i.

2.3 Intermediate Goods Producers

Each intermediate good $i \in [0,1]$ is produced by a monopolistically competitive firm. An intermediate good producer hires capital $k_{i,t}$ and labor $n_{i,t}$ from competitive markets and produces output using the constant returns to scale production function

$$y_{i,t} = k_{i,t}^{\alpha} n_{i,t}^{1-\alpha}. \tag{11}$$

Given the competitive capital and labor markets, all the intermediate firms face a common rental rate of capital r_t^k and real wage w_t. This leads all intermediate firms to face the same real marginal cost

$$\varphi_t = \left(\frac{r_t^k}{\alpha}\right)^{\alpha} \left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}. \tag{12}$$

We assume that intermediate firms set the price of their goods subject to a quadratic price adjustment cost à la Rotemberg (1982)

$$\frac{\psi_p}{2}\left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right)^2 Y_t. \tag{13}$$

Then, the profit maximization problem of an intermediate firm is given by

$$\max_{\{P_{i,t}\}} E_0 \sum_{t=0}^{\infty} \left(\frac{1}{1+r_{0,t}^a}\right) \left\{ \left(\frac{P_{i,t}}{P_t}\right)^{1-\theta} Y_t - \varphi_t \left(\frac{P_{i,t}}{P_t}\right)^{-\theta} Y_t - \frac{\psi_p}{2}\left(\frac{P_{i,t}}{P_{i,t-1}} - 1\right)^2 Y_t \right\} \tag{14}$$

where $\left(1 + r_{0,t}^a\right) \equiv \prod_{\tau=0}^{t} \left(1 + r_t^a\right)$ and $r_t^a = r_t^k - \delta$.

Solving the price-setting problem, we derive the nonlinear forward-looking New Keynesian Phillips curve

$$\pi_t\left(1+\pi_t\right)=\left(\frac{1-\theta}{\psi_p}\right)+\left(\frac{\theta}{\psi_p}\right)\varphi_t+E_t\left(\frac{1}{1+r^a_{t+1}}\right)\pi_{t+1}\left(1+\pi_{t+1}\right)\frac{Y_{t+1}}{Y_t} \tag{15}$$

where $\pi_t = P_t/P_{t-1} - 1$ is the net inflation rate.[3]

2.4 Monetary Authority

We assume that monetary policy follows a conventional Taylor rule for the nominal interest rate on liquid assets

$$\left(\frac{1+i_t}{1+\bar{i}}\right)=\left(\frac{1+\pi_t}{1+\overline{\pi}}\right)^{\phi_\pi}\exp\left(\epsilon^i_t\right) \tag{16}$$

where $\phi_\pi > 1$. Here, $\bar{i}$ is the steady-state nominal interest rate, $\overline{\pi}$ is the inflation target, and ϵ^i_t is a monetary policy shock.[4] The real return on liquid assets is given by the Fisher equation: $r^b_t = i^b_t - \pi_t$.

2.5 Government

The government supplies liquid assets B_t as a form of government bonds.[5] Labor income and social security benefits are taxed at the rate $\tau_n > 0$. Government revenue is used to finance social security benefit payments, interest payments on debt, and government spending $G_t \geq 0$. Every period, the government budget constraint holds:

$$B_{t+1}+G_t+\underbrace{\sum_{j=J_r}^{J}\int s\left(\varepsilon\right)d\mu_t}_{T\equiv\text{transfers}}=\underbrace{\tau_n\left(\sum_{j=1}^{J_r-1}\int w_t l(j)\varepsilon n d\mu_t+\sum_{j=J_r}^{J}\int s\left(\varepsilon\right)d\mu_t\right)}_{\Psi\equiv\text{taxes}}+\left(1+r^b_t\right)B_t+\Pi_t \tag{17}$$

where μ_t is the distribution of households defined over $(j, a, b, \varepsilon, \beta)$.

The current version of the model assumes that the government collects the aggregate intermediate firms' profits. We make such an assumption because, in contrast to the data, in the model profits are countercyclical, as is common in New Keynesian models.

[3] The derivation is available in Appendix A.

[4] Note that $\epsilon^i_t = 0$ in the steady state. We also assume that the inflation target is 0 in the steady state.

[5] $B_t < 0$ denotes government debt.

3 Taking the Model to the Data

In this section, we describe how we discipline our model using the data. We first discuss our calibration strategy. Next, we explain how we estimate the earnings process. Finally, we demonstrate that the model can explain the observed distribution of wealth, illiquid wealth, and liquid wealth as well as a realistic portfolio choice behavior of households of different wealth and age.

3.1 Calibration

We assume a model period of one year and calibrate the model economy to the 2007 U.S. economy.[6] Households enter the labor market at age 25, retire at age 65, and live until age 84 with certainty.

Households have an additive separable instantaneous utility function

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

with the coefficient of relative risk aversion $\gamma = 2$. As shown in Table 2, we calibrate ψ_l and ν to match the average hours worked and Frisch elasticity of labor supply of male workers. The social security function is given by

$$s(\varepsilon) = \delta_s w_0 \frac{\sum_{j=1}^{J_r-1} l(j)}{J_r - 1} \varepsilon \overline{n}$$

with a replacement rate of $\delta_s = 0.4$ and the average hours worked in the economy $\overline{n} = 0.3$. The social security is paid based on the steady-state equilibrium wage w_0 to reflect the fact that social security is proportional to the labor income when households work, not the current wage. Labor income is taxed at $\tau_n = 0.27$ (Domeij and Heathcote, 2004).

Following Bhandari et al. (2021), the elasticity of substitution for a final good producer is $\theta = 6$ and the parameter for the price adjustment cost function for intermediate firms is $\psi_p = 25$. The capital share of output is $\alpha = 0.36$, and the annual depreciation rate of capital is $\delta = 0.069$. We set the steady-state inflation rate to zero and the real

[6] In the real world, monetary policy changes at a higher frequency than a year. However, given that the model has a deterministic life-cycle, calibrating the model at a higher frequency requires a large state space for age, leading to the curse of dimensionality. Stochastic aging may alleviate the issue. (TBA)

return on liquid assets to $r_0^b = 2\%$. Lastly, we set the Taylor rule parameter ϕ_π to 1.5. See Table 1 for the summary of parameters set outside the model.

Table 1: Parameters set externally

Parameters	Value	Description
γ	Coefficient of relative risk aversion	2.0
δ_s	Replacement rate of social security benefits	0.4
τ_n	Labor income tax rate (Domeij and Heathcote, 2004)	0.27
α	Capital income share	0.36
δ	Capital depreciation rate	0.069
θ	Elasticity of substitution (Kaplan et al., 2018)	6.0
ψ_p	Price adjustment cost (Kaplan et al., 2018)	25
$\underline{b}$	Borrowing limit	-0.1
ϕ_π	Taylor rule coefficient (Kaplan et al., 2018)	1.5

We calibrate the remaining model parameters to match 9 moments in the data in Table 2. We first match the illiquid wealth-to-output ratio of 2.9 and the liquid wealth-to-output ratio of 0.26. Following Kaplan et al. (2018), illiquid wealth is measured as the sum of business equity, stocks, and net equity in non-residential real estate as well as net housing and net consumer durables.[7] Liquid assets include all deposits in transaction accounts (checking, savings, money market accounts, and call accounts), certificates of deposits, savings bonds, and directly held bonds minus revolving consumer credit. Given that a sampling unit in the SCF is a household, the total value of illiquid and liquid assets is divided by the average family size in 2007 to make it comparable to GDP per capita. The calibrated economy gives rise to a 6% return on illiquid wealth in the steady state when a 2% return on liquid wealth is targeted.

The model economy is also calibrated to match the two types of liquidity-constrained households: households with positive illiquid wealth but no liquid wealth and households with zero or negative net worth, which are comparable to the wealthy and poor hand-to-mouth households defined in Kaplan and Violante (2014).[8] Lastly, we target the net worth and liquid wealth Gini coefficients.

[7] Stocks are considered illiquid, as most of them are held in retirement accounts or involve management fees. Following Glover et al. (2020), money market mutual funds and quasi-liquid retirement accounts are included in stocks. To be consistent with the model economy, which does not involve collateralized borrowing, I measure residential property net of all debt secured by residential property (mortgages, home equity loans, and HELOCs) as illiquid wealth, as in Kaplan and Violante (2014). Using the net value of housing wealth, I abstract from the issuance of home equity loans, which provide liquidity. Introducing home equity loans in the model would provide an additional incentive to hold illiquid assets, making households somewhat less responsive to the fall in their expected return.

[8] Kaplan and Violante (2014) define wealthy hand-to-mouth households as those with liquid wealth less than half of their earnings but holding positive balances of illiquid wealth.

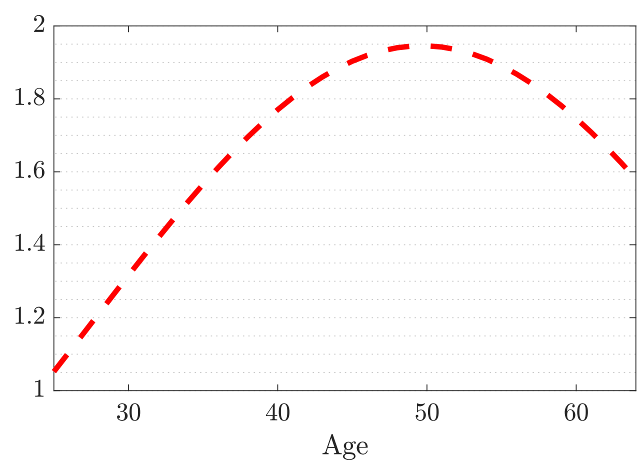
Table 2: Calibrated parameters

Parameters	Moments to match	Data	Model
β_l	Illiquid wealth to output ratio	2.87	2.31
β_h	Share of liquid asset to output	0.26	0.27
$\underline{b}$	Share of hhs holding illiquid wealth	0.82	0.86
ξ_0	Fraction of hhs with positive illiquid wealth but no liquid wealth	0.21	0.20
ξ_1	Fraction of hhs with zero or negative net worth	0.10	0.22
ξ_2	Wealth Gini	0.79	0.79
ς	Liquid Wealth Gini	0.91	0.90
ψ_l	Average hours worked	0.33	0.30
ν	Frisch elasticity of labor supply	0.48	0.50

3.2 Earnings Process

We estimate the earnings process using the 1968-2017 PSID data. The estimation procedure closely follows Kim (2022a). First, we estimate the labor market experience premia $l(j)$ by regressing log of earnings on time dummies, interaction term with time and college degree dummy, labor market experience, and labor market experience squared. Figure 1 shows the estimated labor market experience premia, that captures the hump-shaped earnings profile over the life cycle.

Figure 1: Labor market experience premia



The earnings shock process consists of both a AR(1) persistent component ε_p and a transitory component ε_t. Specifically,

$$\varepsilon = \varepsilon_p + \varepsilon_t$$

$$\varepsilon_p' = \rho\varepsilon_p + \nu$$

where $\varepsilon_t \sim N(0, \sigma_t^2)$ and $\nu \sim N(0, \sigma_p^2)$. Table 3 summarizes the estimated values for 2007.

Table 3: 2007 Earnings shock process estimates

ρ	σ_t^2	σ_p^2
0.97	0.087	0.057
(0.003)	(0.009)	(0.009)

Note: Standard errors are estimated using a block bootstrapping with 300 replications and are reported in parentheses.

3.3 Distribution of Wealth and Portfolio Choice

To show the model's performance for untargeted moments in the steady state, Table 4 compares the distribution of net worth, illiquid wealth, and liquid wealth in the 2007 SCF to those in the benchmark economy. Though we are targeting the net worth and liquid wealth Gini coefficients, the model economy reproduces observed quintile distributions of wealth, illiquid wealth, and liquid wealth reasonably well.

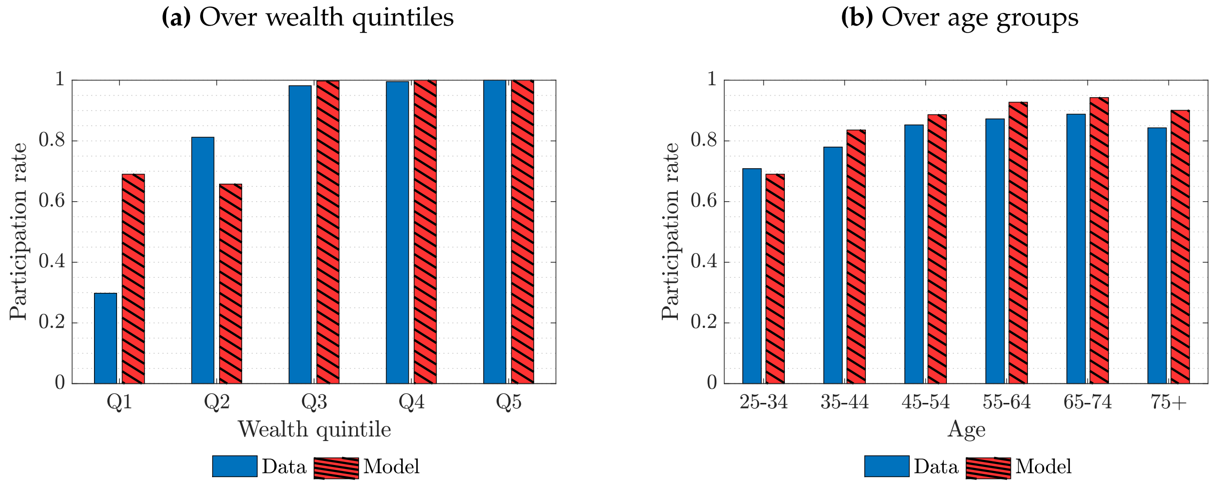
Table 4: Distribution of net worth, illiquid wealth, and liquid wealth

Net worth	Q1	Q2	Q3	Q4	Q5	Gini
2007 SCF	-0.3	1.4	5.7	14.1	79.1	0.78
Benchmark	-0.7	0.3	3.3	14.6	82.5	0.79
Illiquid wealth	Q1	Q2	Q3	Q4	Q5	Gini
2007 SCF	0.1	1.6	5.9	14.4	78.0	0.76
Benchmark	0.0	0.1	2.6	13.9	83.3	0.79
Liquid wealth	Q1	Q2	Q3	Q4	Q5	Gini
2007 SCF	-7.4	0.0	1.1	7.6	99.0	0.91
Benchmark	-3.4	-2.5	0.9	8.5	99.3	0.90

Note: Table 4 shows the share of net worth, illiquid wealth, and liquid wealth across wealth quintiles. It also reports the Gini coefficients in the 2007 SCF and model economies.

The calibrated model is also broadly consistent with the portfolio choice behavior of heterogeneous households. Figure 2 shows the fraction of households holding positive illiquid assets over wealth quintile (left panel) and over age groups (right panel) in the model and in the 2007 SCF data. The model successfully explains the increasing illiquid asset market participation rate as well as the hump-shaped life-cycle profile of the participation rate without targeting.

Figure 2: Participation rate in illiquid asset market



Note: Participation rate in illiquid asset market over wealth quintiles in the 2007 SCF (blue bars) and the benchmark economy (red bars).

Figure 3 further shows the average share of illiquid assets to total assets over wealth quintile (left panel) and age groups (right panel) in the model and the 2007 SCF data. Wealthy households hold more of their savings in illiquid assets as illiquid assets pay a higher return than liquid assets and they can easily afford adjustment costs. Households also exhibit the hump-shaped life-cycle profile for the share of illiquid wealth. As young households build their savings, they increase their investment in high-yield illiquid assets and then liquidate these after retirement.

4 Quantitative Results

To study the redistributive effects of monetary policy, we simulate the model economy with a one-time, unexpected expansionary monetary policy shock. This section discusses how aggregates and heterogeneous households respond to this monetary shock.

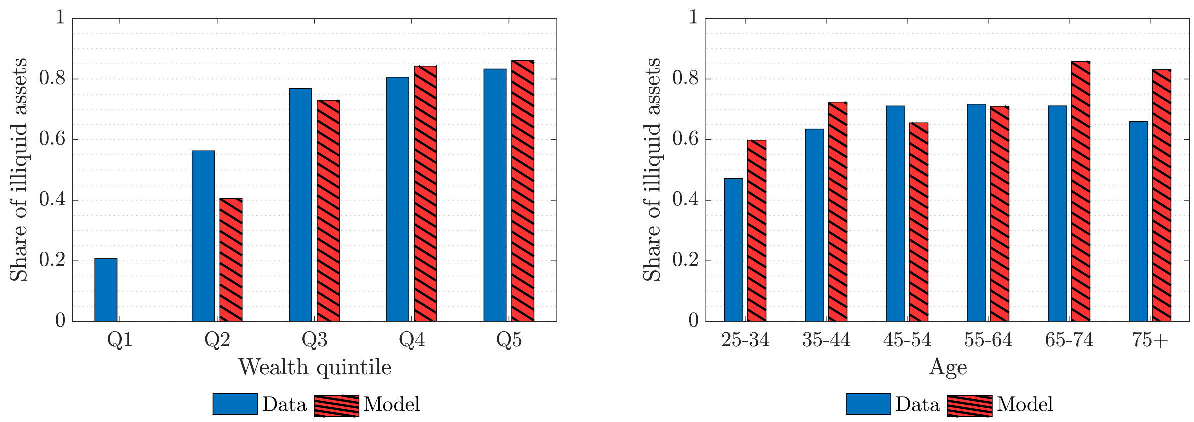
4.1 Aggregate Responses

Figure 4 presents the responses of macroeconomic aggregates and prices to an expansionary 100-basis-point (annualized) monetary policy shock for a 20-year horizon.[9] Panel

[9] For now, we also assume that there is a perfectly elastic supply of government bonds. Thus, the real return on liquid assets is determined by the policy rate and inflation dynamics.

Figure 3: Share of illiquid assets to total assets

(a) Over wealth quintiles **(b)** Over age groups



Note: The average shares of illiquid assets as a fraction of total assets over wealth quintiles in the 2007 SCF (blue bars) and the benchmark economy (red bars).

A displays the responses of the liquid interest rate, the real return to illiquid assets, and inflation rates to the monetary innovation. Panel B shows the corresponding time path for aggregate quantities and the real wage. As in standard canonical New Keynesian models, the presence of nominal price rigidities causes the marginal cost of intermediate goods firms to rise, which in turn increases aggregate demand. This leads to an increase in both labor and capital inputs and their prices (the real wage and the real return to illiquid assets), which allows households to work more and accumulate more illiquid assets (i.e., a rise in investment). A fall in the real interest rate on risk-free bonds, combined with a rise in overall income, causes households to increase their consumption. Finally, the increased demand also leads to an rise in the rate of inflation. In general, the responses of the macroeconomic variables in Figure 4 are broadly consistent with those in the empirical literature.[10]

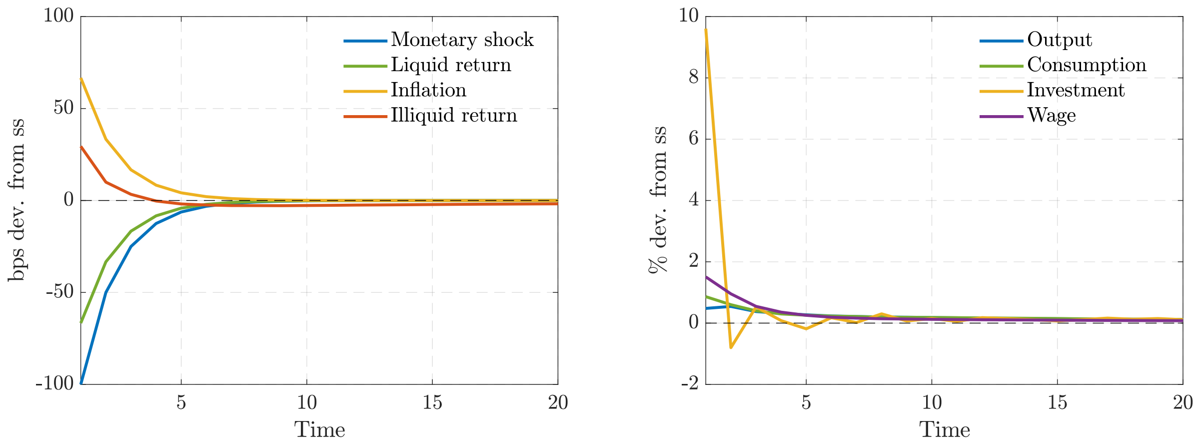
4.2 Monetary Policy and Lifecycle Dynamics

Now, we discuss the distributional effects of monetary policy shocks across different age groups. To this end, we simulate a large number of households over the transition. In particular, we simulate the existing cohorts at the time the shock hits and follow them over time in two different economies—one that experienced the expansionary monetary

[10]The investment response is much larger than the empirical counterpart since we do not allow for investment or capital adjustment costs in our model.

Figure 4: Responses of key aggregate variables to a monetary shock

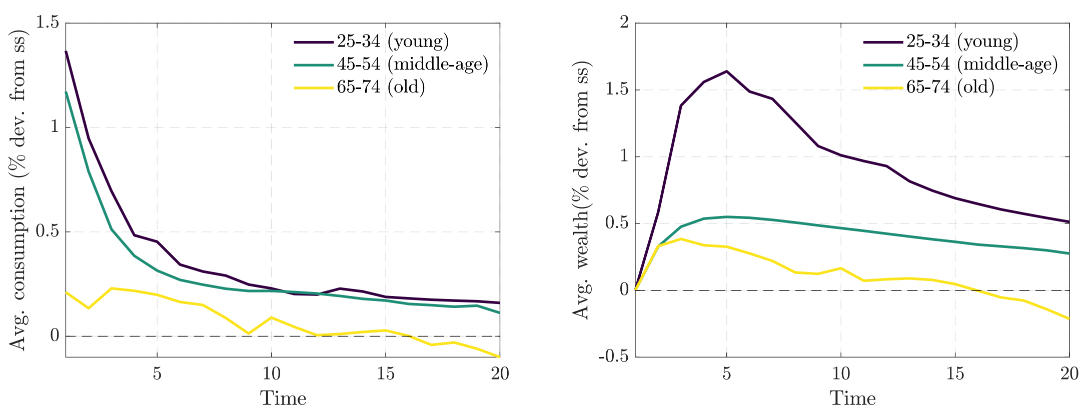
(a) Monetary shock, returns, inflation **(b)** Aggregate quantities and wages



Note: Responses of key aggregate variables to an expansionary 100-basis-point (annualized) monetary policy shock while assuming perfect foresight. Panel A of displays the responses of the liquid interest rate, the real return to illiquid assets, and inflation rates to the monetary innovation. Panel B displays the corresponding time path for aggregate quantities and the real wage.

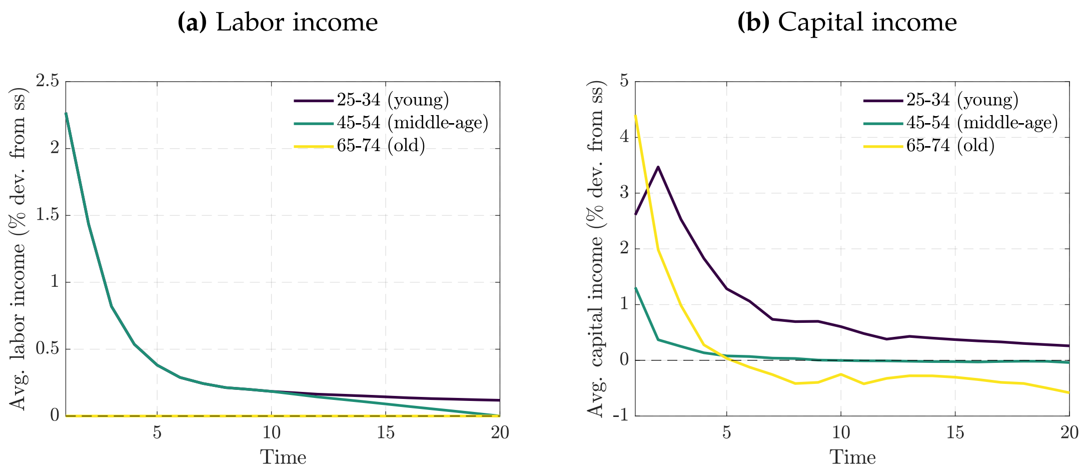
Figure 5: Responses of consumption and net worth by age groups

(a) Consumption **(b)** Net worth



Note: Responses of average consumption and average net worth for three age groups — young (25-34), middle-age (45-54), and old (65-74). Age groups are fixed to the ones on the impact date.

Figure 6: Responses of labor and capital incomes by age groups



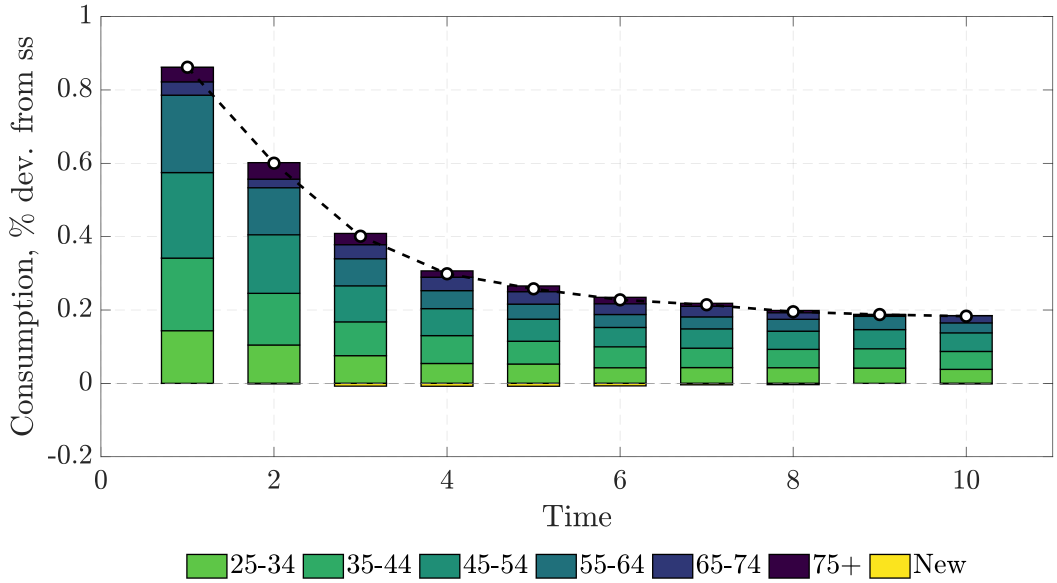
Note: Responses of average labor and capital incomes by three age groups—young (25-34), middle-aged (45-54), and old (65-74). Age groups are fixed to the ones on the impact date.

policy shock and another without any shock. We then calculate the deviation of the averages in each cohort following a monetary policy shock compared to the counterfactual economy that would not experience a monetary policy shock. In this way, we are comparing an equivalent group of households, while perfectly controlling for life-cycle effects over time.

How does an expansionary monetary policy shock affect households with different levels of wealth and age? To answer this question, we simulate a large number of households and track their decisions over the transition. Figure 5 presents the percentage change in average consumption and net worth (Panels (A) and (B), respectively) across different age groups with a monetary shock relative to when there is no monetary change. We consider three age groups: young (25-34), middle-aged (45-54), and old (65-74). Here, the households in each age group remain the same along the transition, with their age being the one they had on impact.

Figure 5 also reveals a novel quantitative insight into the distributional effects of monetary policy over the age dimension. As shown on Panel (A), an expansionary monetary policy shock benefits younger households the most in terms of the consumption response even though most households increase their consumption on the impact date. The on-impact consumption response of the young is around 1.3 percent while that of the old is around 0.2 percent. Interestingly, as shown in Panel (B), young households

Figure 7: Contribution to aggregate consumption response by cohorts



Note: Contribution rates to the total consumption variation for each cohort. Age groups are fixed to the ones on the impact date.

also save a larger fraction of their income than the old, which leads to faster growth in net worth over their lifetime than without a monetary policy shock.

The results found in Figure 5 imply that the young should earn a higher lifetime income than the old to enjoy an increased level of consumption and higher savings. Figure 6 confirms these findings. Figure 6 shows the percentage change in average labor and capital incomes (Panels (A) and (B), respectively) for the same three age groups. As Panel (A) shows, an expansionary monetary policy allows young households to earn a higher labor income while those aged between 64-75 have no change in earnings as they have already retired from the labor market. In addition, according to Panel (B), the response of capital income for the young is persistent while that of the old is short-lived and negative around five years after the shock. Accordingly, the increase in the lifetime labor and capital income is more pronounced for younger households so that they can consume more and accumulate significantly more wealth.

We next explore how much each cohort contributes to the aggregate consumption response. Figure 7 shows the fraction of the aggregate consumption response explained by the response of each age group. It follows that young households contribute more to the response of aggregate consumption than the old. On impact, the youngest cohort (households aged 25-34) accounts for around 18 percent of the total consumption change while the contribution rate for households aged between 65 and 74 is less than five percent. This is mainly because the young have a relatively high level of consumption and benefit from the increased return on illiquid assets and wages, as discussed above. It should be noted that this result is still robust in longer horizons. For example, the contribution of younger households to aggregate consumption is still much larger than the old (21 percent vs. 11 percent) 10 years after the shock.

5 Discussion

5.1 Heterogeneous Persistent Effects

Our results so far hint that there might be persistent effects of monetary policy shocks for cohorts, especially for the young. To see these more clearly, we compute the cumulative changes in consumption and labor earnings for three 10-year windows after the shock hits, which are reported in Table 5. According to the upper panel of Table 5, during the first 10 years, younger households increase their consumption by 0.5 percent. But even after two decades, the effect of the monetary policy shock on the young is lingering, generating an additional 0.13 percent increase in consumption. For old households, this effect is less persistent: the cumulative change in consumption for the first 10 years is 0.15 percent while it decreases to 0.01 for the next 10 years. This is mainly driven by the fact that younger households work for longer years at higher wages, as shown in the bottom panel of Table 5. This helps younger households build higher levels of wealth that they can consume over longer horizons in their lifetime.[11]

5.2 Role of the Model Features

We discuss the role of the key model features in the results. For this, we compare the impact responses in the benchmark economy to those in two different models—one without idiosyncratic income risk and the other where households only save in liquid capital. Table 6 reports on-impact responses of some key variables in the three models. Recall that, in the benchmark economy, the consumption response for the young is much larger than the old's as wage increases for many years following the monetary policy

[11] We do not report changes in cumulative capital income in this table. Not surprisingly, they are also positive and persistent for the young mainly due to the persistent labor earnings.

Table 5: Changes over remaining lifetime by age groups

	Horizon (years)		
	1-10	11-20	21-30
Changes in cumulative consumption			
Young (25-34)	0.50	0.19	0.13
Middle-age (45-54)	0.43	0.17	0.09
Old (65-74)	0.15	0.01	–
Changes in cumulative earnings			
Young (25-34)	0.60	0.14	0.09
Middle-age (45-54)	0.68	0.09	0.00
Old (65-74)	0.00	0.00	–

Note: Percentage change in cumulative average consumption and labor for a given horizon in each age group. The old (households aged 65-74) have already retired from the labor market. Age groups are fixed to the ones on the impact date.

shock. This implies that the MPC is much higher for the young than the middle-aged and old, as shown in the bottom panel of Table 6, because they would not have enough time to build their savings and they are more likely to be liquidity constrained.

At this stage of our analysis, the reader may wonder whether the main results are attributed to the lifecycle channel or income risk channel. We find that the lifecycle channel plays an important role in driving heterogeneous consumption responses to a monetary policy shock. As shown in Table 6, the main results are still robust in the model without income risk in that the consumption response is relatively large for the young and so are their MPCs. However, it is worth noting that the income risk channel is quantitatively important: consumption increases even more for the young and middle-aged in the absence of income risk compared to the benchmark economy mainly because there are no precautionary savings motives in this model.[12]

What do we gain from the two-asset model relative to a one-asset counterpart? When households can only save in perfectly liquid capital, the aggregate consumption response is larger than that in the benchmark economy due to a sharp increase in the equilibrium wage. Thus, in this counterfactual economy, workers enjoy a higher level of income than those in the benchmark economy. However, the impact MPCs are much smaller in this economy because, without the two-asset structure, we do not have any wealthy hand-to-

[12]Of course, income risk is a crucial ingredient for the model to replicate reasonable household heterogeneity observed in the data.

Table 6: Impact Responses: Three Models

	Benchmark	No inc risk	One asset
Prices			
Liquid return, $r^b(\Delta$ pp$)$	-0.66	-0.66	-0.66
Illiquid return, $r^a(\Delta$ pp$)$	0.29	0.38	0.39
Wage, w	1.50	1.55	2.25
Consumption	0.86	0.88	1.02
Consumption young (25-34)	1.37	1.82	1.97
Consumption middle (45-54)	1.17	1.73	1.51
Consumption old (65-74)	0.21	0.25	0.03
Implied dyn. MPC$\equiv \frac{\Delta C}{\Delta Y}$	0.45	0.42	0.29
MPC young (25-34)	0.85	0.81	0.55
MPC middle (45-54)	0.56	0.67	0.35
MPC old (65-74)	0.07	0.16	0.01

Note: The impact responses in the benchmark economy and two different models—one without idiosyncratic income risk ("No inc risk") and the other where households only save in liquid capital ("One asset").

mouth households which account for almost 20 percent of households in the benchmark economy. Without their presence, overall MPCs are relatively small.

6 Concluding Remarks

In this paper, we discuss the redistributive effect associated with monetary policy. In particular, we focus on the role of the life cycle in transmitting the effects of monetary shocks to different groups of households. We build a New Keynesian overlapping generations model where heterogeneous households face uninsurable idiosyncratic risk and can save in liquid and illiquid assets.

Using our model, we find that monetary policy has redistributive effects among different age groups and that those effects tend to persist over time. In particular, younger households benefit from expansionary monetary policy shocks, as labor income increases with a boost in economic activity from a monetary easing. In contrast, older households, which tend to hold more financial assets and rely more heavily on their capital income, experience a contraction in the return on liquid assets while being limited in their ability to take advantage of higher wages. As a result, their consumption responds less after an expansionary monetary policy shock.

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A Derivation of New Keynesian Phillips curve

The first-order condition of equation Eq. (15) is

$$(\theta-1)\left(\frac{P_{i,t}}{P_t}\right)^{-\theta}\frac{Y_t}{P_t}=\theta\varphi_t\left(\frac{P_{i,t}}{P_t}\right)^{-\theta-1}\frac{Y_t}{P_t}-\psi_p\left(\frac{P_{i,t}}{P_{i,t-1}}-1\right)\frac{Y_t}{P_{i,t-1}} \tag{A.1}$$

$$+E_t\left(\frac{1}{1+r^a_{t+1}}\right)\psi_p\left(\frac{P_{i,t+1}}{P_{i,t}}-1\right)\frac{P_{i,t+1}}{P_{i,t}}\frac{Y_{t+1}}{P_{i,t}} \tag{A.2}$$

Imposing a symmetric equilibrium condition $P_{i,t}=P_t$ for all $i\in[0,1]$ and $\pi_t=\frac{P_t}{P_{t-1}}-1$, the equation (A.2) can be written as

$$(\theta-1)\frac{Y_t}{P_t}=\theta\varphi_t\frac{Y_t}{P_t}-\psi_p\pi_t\frac{Y_t}{P_{t-1}}+E_t\left(\frac{1}{1+r^a_{t+1}}\right)\psi_p\pi_{t+1}(1+\pi_{t+1})\frac{Y_{t+1}}{P_t} \tag{A.3}$$

$$(\theta-1)=\theta\varphi_t-\psi_p\pi_t\left(1+\pi_t\right)+E_t\left(\frac{1}{1+r^a_{t+1}}\right)\psi_p\pi_{t+1}(1+\pi_{t+1})\frac{Y_{t+1}}{Y_t} \tag{A.4}$$

The New Keynesian Phillips curve is

$$\pi_t\left(1+\pi_t\right)=\left(\frac{1-\theta}{\psi_p}\right)+\left(\frac{\theta}{\psi_p}\right)\varphi_t+E_t\left(\frac{1}{1+r^a_{t+1}}\right)\pi_{t+1}(1+\pi_{t+1})\frac{Y_{t+1}}{Y_t} \tag{A.5}$$

At the stationary equilibrium,

$$\overline{\pi}\left(1+\overline{\pi}\right)=\frac{1+r^a}{r^a}\left[\left(\frac{1-\theta}{\psi_p}\right)+\left(\frac{\theta}{\psi_p}\right)\overline{\varphi}\right] \tag{A.6}$$

where $\overline{x}$ is the steady-state value for a variable x.