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HANK Comes of Age: Monetary Policy with Heterogeneous Overlapping Generations

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Abstract

We study the transmission and distributional effects of monetary policy in an environment where consumption-saving choices reflect both precautionary motives and life-cycle considerations. Age emerges as a key state variable that links multiple dimensions of heterogeneity: young households tend to have low wealth, high marginal propensities to consume, and strongly procyclical hours. In our quantitative model that matches these facts, monetary policy operates primarily by stimulating investment, boosting labor demand for young workers who consume most of their additional income. Wealthy retirees are affected by the repricing of financial assets and persistently low future returns. However, the effect on the consumption and welfare of most retirees is small because they hold little financial wealth.

Keywords: HANK, Heterogeneous Agents, Life-Cycle Dynamics, Monetary Policy, Redistribution.

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1 Introduction

A growing literature has convincingly argued that the transmission of monetary policy works in large part through mechanisms that representative agent models omit or subdue.[1] Households have different levels of savings allocated to different assets, different work arrangements with different sensitivities to the business cycle, and different propensities to consume out of income and wealth. Heterogeneity in these characteristics interacts with general equilibrium movements in labor income, asset prices, and fiscal policy, generating indirect effects that can be more important than intertemporal substitution, the key channel in traditional New Keynesian models. Households experience substantial changes in all these characteristics as they age.[2] Yet the heterogeneous agent New Keynesian (HANK) models commonly used to quantify the indirect transmission channels rely on infinite-horizon or perpetual-youth frameworks that abstract from life-cycle considerations.

In this paper, we argue that accounting for the life-cycle dynamics of households yields new insights into the transmission and distributional effects of monetary policy. We use a novel overlapping generations HANK model to study the dynamic effects of an unexpected monetary expansion. Age is a useful empirical anchor for calibrating the model and it also helps reproduce important non-targeted moments. At the macro level, the model's account of monetary policy transmission is different from that of nested specifications that omit life-cycle dynamics and heterogeneity: firm investment and the induced labor demand for young, low-income households are at its core. At the micro level, the model produces rich characterizations of heterogeneous consumption responses, welfare effects, and the mechanisms behind them. The rest of this section describes our four main contributions.

Our first contribution is a parsimonious overlapping generations HANK model (OLG-HANK) with several attractive properties for analyzing monetary and fiscal policy. The model is parsimonious in the sense that households have a single asset account and homogeneous preferences. It provides a good fit for the distributions of labor income, consumption, and net financial wealth over the life cycle. It implies an average annual marginal propensity to consume (MPC) of 0.33, while matching the aggregate ratio of financial assets to labor income of 3.46. It also reproduces several facts about the co-movement of individual MPCs with wealth, age, and labor income exposures to aggregate fluctuations, as well as the persistence of hand-to-mouth status. These successes reflect the model's main age-specific ingredients: a nonlinear income process that we take from Arellano et al. (2017) and Janssens and McCrary (2023), a non-homothetic bequest motive as in Carroll (2002) and De Nardi (2004), and micro-level sensitivities of labor earnings to aggregate fluctuations that we estimate using Swedish administrative records.

Our second contribution is a sequential study of how life-cycle forces and within-cohort inequality shape the transmission of monetary policy. We begin by removing all sources of within-cohort heterogeneity, leading to a model we call OLG-NK. Further eliminating aging and stochastic mortality yields a standard representative agent New Keynesian model

[1] See, for example, Auclert (2019) and Kaplan et al. (2018).

[2] Doepke and Schneider (2006), Adam and Zhu (2016), Greenwald et al. (2022), Pallotti et al. (2023), and Fagereng et al. (2025) find heterogeneous exposure to inflation, asset prices, and interest rates across the life cycle; Clark and Summers (1981), Sabelhaus and Song (2010), Jaimovich et al. (2013), and Guvenen et al. (2017) document age dependence in the exposure to labor market fluctuations.

(RANK). We calibrate the three models to produce similar aggregate responses to an expansionary monetary policy shock. Nonetheless, different mechanisms actuate the aggregate consumption response in each model.

In RANK, transmission operates solely through intertemporal substitution. In OLG-NK, homogeneous cohorts follow the empirical age profiles of average income and wealth: they are patient, high-earning savers who start with little wealth but reach old age with assets worth many times their income. Young workers are more exposed to labor markets and wealthy retirees are more exposed to asset returns. Nonetheless, all households are close to permanent income consumers because they are unconstrained for most of their lives and know with certainty they will become wealthy. Therefore, while labor income and asset return effects on aggregate consumption increase in magnitude, they offset each other almost perfectly and intertemporal substitution remains responsible for almost all of the aggregate consumption response. In OLG-HANK, by contrast, most households hold far less wealth than their cohort's average. MPCs are higher on average, vary more, and correlate more strongly with changes in earnings, making the labor income channel much stronger. Because many households go through life with little savings, the intertemporal substitution and interest income channels are much weaker. In sum, labor income effects contribute the most to consumption, followed by intertemporal substitution, with negative asset return effects playing the smallest role.

The interaction between investment and the labor market experiences of young, low-income households emerges as a key gear of monetary transmission in OLG-HANK. We use Auclert et al.'s (2020) general equilibrium decomposition to identify the forces that start monetary policy transmission. In RANK and OLG-NK, transmission hinges primarily on rich households pulling consumption forward in response to lower interest rates. In OLG-HANK, by contrast, most of the impetus comes from the fall in the user cost of capital, which induces firms to invest and demand more labor, raising household earnings. Crucially, the incidence of the additional labor earnings, which we estimate using Swedish administrative data, is highly uneven: for example, a 26-year-old in the lowest income decile is more than 15 times more exposed than a 55-year-old in the middle deciles. As a result, the additional earnings accrue disproportionately to young, low-income, low-wealth households with high marginal propensities to consume, generating additional demand and amplification. This channel accounts for the lion's share of the aggregate consumption response at all horizons in our model—a pattern that does not arise in RANK, in OLG-NK, or in a variant of OLG-HANK with evenly distributed earnings changes.

Our third contribution is a dissection of monetary transmission across age groups. Both the magnitude and the causes of consumption responses vary over the life cycle. Young households hold little wealth and are highly exposed to labor market fluctuations; their consumption rises the most, almost entirely because their labor earnings increase. Middle-aged households are accumulating assets for retirement and have earnings that are less sensitive to aggregate conditions, making intertemporal substitution the dominant channel for them. Retirees exhibit heterogeneous responses depending on their wealth, which is very unevenly distributed. Most have less than one and a half years of income saved and are little affected by the shock. Others hold many years' worth of income in assets, making them sensitive to changes in asset returns—real asset appreciation, nominal asset erosion, and the prospect of lower future returns. In our baseline specification, the negative interest income effect from lower future returns leads wealthy retirees to reduce consumption slightly. In an alternative specification where equity returns match empirical responses to monetary shocks (OLG-HANK-plus), the initial rise in equity prices more than offsets the effect of lower future returns, causing these households to increase consumption as well.

Our last contribution is an examination of the welfare effects of monetary policy shocks across and within generations. Unexpected expansions benefit young cohorts by raising their labor income, and indebted young households also gain from inflation eroding the real value of their debt. Older cohorts lose on average from lower real returns on their assets. These losses are borne by the wealthy old; most old households are little affected and may even benefit from a looser government budget. In our baseline specification, an unexpected 25-basis-point easing redistributes welfare from high-wealth old households, whose losses are worth 2.2 percent of a year's consumption, to low-wealth young households, whose gains are worth 3.2 percent. We find that the welfare conclusions for wealthy retirees are highly sensitive to asset price responses: in OLG-HANK-plus, these households benefit as well.

Related literature. Each of our contributions fits within a broader literature.

In our model, households save to finance their retirement, to insure against income shocks, and to leave bequests.[3] An extensive literature has studied each of these motives (for example, Modigliani, 1986; Carroll, 1997, 2002; Gourinchas & Parker, 2002; De Nardi, 2004). Other papers have explored what features of a model can or cannot reproduce empirically plausible levels of economic inequality (for example, Quadrini & Rios-Rull, 1997; De Nardi, 2015; Benhabib & Bisin, 2018; Stachurski & Toda, 2019; Kaymak et al., 2022; Gaillard et al., 2023). We identify a parsimonious combination of the features these papers have explored and embed them in a HANK model to study aggregate dynamics and their distributional consequences. We think this is novel and useful. It is novel because extant New Keynesian models have featured only self-insurance motives, only life-cycle motives, or neither. It is useful because the combination makes progress on challenges that existing HANK models have faced, like generating enough aggregate wealth while preserving high MPCs (Kaplan & Violante, 2022) or reproducing the behavior of "hand-to-mouth" households (Aguiar et al., 2024). Modeling age differences also turns out to be a useful empirical anchor for important cross-sectional relationships that influence aggregate dynamics (see Auclert, 2019), like the main correlates of MPCs (Fagereng et al., 2021), the covariance between MPCs and income exposures to aggregate fluctuations (Patterson, 2023), and differences in portfolios.

Our estimates of the uneven incidence of income fluctuations follow Guvenen et al. (2017) and Amberg et al. (2022) and our results are similar to theirs. These estimates pin down the cyclical behavior of income inequality, which is a crucial determinant of demand shock amplification in HANK (Auclert, 2019; Bilbiie, 2020, 2025). We follow Alves et al. (2020) and Broer et al. (2022) in using administrative records to calibrate our incidence function across the distribution of earnings and add to their results by including unequal incidence

[3] We do not model medical expenses, which are an important source of old-age saving (De Nardi et al., 2010; Kopecky & Koreshkova, 2014). To adequately capture the quantitative effects of health risks, studies have modeled their persistence, their effect on the utility of consumption, and their interaction with government programs, among others (see, for example, Braun et al., 2017; Ameriks et al., 2020; Hosseini et al., 2025); these considerations are outside the scope of our paper.

across age groups. These age differences are large, as would be expected from the long literature that demonstrates younger workers have more volatile earnings and hours (Clark & Summers, 1981; Gomme et al., 2004; Sabelhaus & Song, 2010; Jaimovich et al., 2013; Guvenen et al., 2017).

Our comparison of RANK, OLG-NK, and OLG-HANK relates to several papers. The OLG-NK model is closest to Bielecki et al. (2022) and Braun and Ikeda (2025); it has important simplifications relative to those papers,[4] but those simplifications allow its embedding in a sequence of nested models that delivers useful insights. For example, Beaudry et al. (2024) show that the need to save for retirement can dampen the effects of monetary policy by strengthening interest income effects that work in the opposite direction of usual intertemporal substitution. In our comparison of RANK and OLG-NK we find this to be the case, but show that introducing young, low-wealth households also amplifies labor income effects that push in the usual direction, mostly offsetting that dampening. Similar to Kaplan et al.'s (2018) results in infinite horizon, introducing within-cohort inequality further strengthens labor income effects. Additionally, in the context of retirement savings, it further weakens interest income effects because most households retire with little financial wealth.

Our general equilibrium transmission results combine insights from two main papers. Auclert et al. (2020) devise the decomposition that we use and also find that firms' investment response to the lower user cost of capital is the main mechanism that kick-starts transmission to output and consumption. Patterson (2023) quantifies the covariance between individuals' MPCs and their earnings' exposure to aggregate fluctuations and shows it leads to demand shock amplification. Our age and income-rank incidence function brings the relevant covariance in OLG-HANK close to Patterson's (2023) estimate and greatly amplifies the role of firm investment highlighted by Auclert et al. (2020).

Our results on life-cycle differences in the transmission channels and welfare effects of monetary policy contribute to a group of recent papers that have studied these issues. Bielecki et al. (2022), Bullard et al. (2023), Braun and Ikeda (2025), and Del Canto et al. (2025) are in this group. While these studies incorporate representations of life-cycle changes in the income and assets of households, they abstract away from within-cohort heterogeneity or aggregate it into a few ex-ante types. Our analysis is complementary, as aggregation allows these papers to confront aspects of the problem that our richer heterogeneity forces us to simplify. We contribute to this literature by finding large within-cohort differences in the effects of monetary policy on consumption and welfare, and in the mechanisms behind those effects. We also show, comparing OLG-NK and OLG-HANK, that these differences matter for aggregate conclusions. For example, heterogeneity makes aggregate consumption and average welfare less wealth-centric, because most households own much less than the average wealth. The finding that expansionary shocks tend to benefit lower-wealth households through labor markets and hurt higher-wealth households through asset returns echoes results from HANK economies without detailed representations of the life cycle (Gornemann et al., 2021; Acharya et al., 2023; Dávila & Schaab, 2023).

Finally, our paper relates to studies of the distributional consequences of changes in inflation, real interest rates, and asset prices. Doepke and Schneider (2006), Adam and Zhu (2016), Greenwald et al. (2022), Pallotti et al. (2023), and Fagereng et al. (2025) are in this

[4] For example, it does not have assets with different liquidity or endogenous portfolio decisions.

category and all find that age is a prominent dimension of redistribution. We add to this literature by studying simultaneous changes in these and other conditions (labor markets, for example) that are caused by a monetary policy shock, tying the conditions together with a general equilibrium model.

The rest of the paper is organized as follows. Section 2 presents our baseline OLG-HANK model. Section 3 discusses its calibration and fit of non-targeted moments. Section 4 studies the real effects and transmission of a monetary policy shock in OLG-HANK, comparing it with the nested OLG-NK and RANK models. Section 5 examines the welfare implications of the shock for households of different ages and levels of wealth. Section 6 concludes.

2 Model

Time is discrete and each period corresponds to a year. The economy is inhabited by J overlapping generations of households, a continuum of labor agencies, a representative final goods firm, a unit mass of intermediate goods firms, a representative financial intermediary, a fiscal authority, and a central bank. We focus on a stationary equilibrium with no technological or population growth. This section provides an overview of the economic environment, while Appendix A presents the formal derivation of all equilibrium conditions.

2.1 Households

Households are heterogeneous in age, income, and financial assets. Every period, they decide how much to consume out of their income and accumulated assets. They use savings to partially insure against income shocks, to raise consumption during retirement, and to leave bequests. In this section, we describe the elements of the households' problem, culminating in micro and macro representations of the household sector.[5]

We write household-level objects as sequences of functions. For example, $c_{j,t}(z, a)$ denotes the time-t consumption of a household with age j, labor productivity z, and assets a. The reason is that age and time are discrete states that evolve in steps of one, whereas productivity and assets are continuous states that evolve stochastically.

Demographics. Age is indexed by $j = 1, \dots, J$. Households face age-specific mortality risk captured by ψ_j, the probability that a household lives to age $j+1$ conditional on living to age j. Accordingly, the terminal-age survival probability is $\psi_J = 0$. Every household that dies is replaced with a new household of age $j = 1$, keeping the total population constant.

Labor earnings. All households work until age $j = J_{\text{ret}}$ and retire exogenously afterwards. A working-age household with labor productivity z earns pre-tax labor income $w_t h_{j,t}(z) z$, where w_t is the common real wage per efficiency unit of labor and $h_{j,t}(z)$ is the number of hours worked by households of age j and productivity z. Hours $h_{j,t}(z)$ are not chosen by

[5] By micro representation, we mean the Bellman equations that summarize the dynamics of individual consumption and savings. By macro representation, we mean the sequence-space block that summarizes the dynamics of aggregate consumption and savings.

individual households, but are determined by labor demand at the common wage set by labor agencies.[6] Let L_t denote the total labor efficiency units that the firm sector demands from households and $W_t \equiv w_t L_t$ denote aggregate labor income. We assume that fluctuations in W_t are distributed according to an incidence function $\Gamma_j(z, W_t)$ that allows heterogeneity by age and productivity. The pre-tax labor income of working-age households is then

$$y_{j,t}(z) = w_t \cdot h_{j,t}(z) \cdot z = \Gamma_j(z, W_t) \cdot z.$$

Labor productivity follows

$$\ln(z) = \alpha + f_j + \eta_j$$

where $\alpha \sim \mathcal{N}(0, \sigma_\alpha^2)$ is an individual-specific fixed effect that is drawn when the household enters the economy and remains fixed, f_j is an age-specific fixed effect that evolves deterministically over the life cycle, and η_j is a persistent idiosyncratic shock that follows an age-specific Markov process.

Pensions. Given that our focus is on monetary policy, we do not model Social Security explicitly. Instead, we assume that retired households ($j > J_{\text{ret}}$) receive pension income $y_{j,t}(z) = z$, with productivity given by

$$\ln(z) = \alpha + f_j + \eta_{J_{\text{ret}}}$$

where the persistent component $\eta_{J_{\text{ret}}}$ stays constant at its value in the last working year, and the age-specific fixed effect f_j keeps evolving to capture average income during retirement flexibly.

Assets. Net financial wealth a may be positive or negative. Households with positive wealth invest in stocks and nominal bonds. The two assets offer the same benefits in terms of liquidity and warm-glow bequests and thus, in an environment without aggregate risk, households are indifferent between them. This implies that, in equilibrium, holding both assets requires that they offer the same expected return, $\mathbb{E}_t[R^s_{t+1}] = \mathbb{E}_t[R^b_{t+1}]$. Nevertheless, the realized return on bonds R^b_t may differ from the realized return on stocks R^s_t due to unanticipated aggregate shocks. Portfolios therefore matter even though they are not pinned down by optimizing behavior, and we specify the equity share as a flexible exogenous function of age and wealth, $\zeta_j(a)$.

Households can borrow, with all debt nominal and maturing in one period. The borrowing limit $\underline{a}_{j,t}(z)$ is a constant fraction ω of the present value of expected lifetime earnings up to a given age and zero thereafter.[7] Thus, young, high-income households can borrow more than old, low-income households. Household debt carries the same interest rate as government debt plus an exogenous spread $\chi > 0$.

[6]Demand-determined labor helps the model avoid the trilemma described by Auclert et al. (2023). It is also a common assumption in quantitative New Keynesian models.

[7]We prevent households from borrowing after a certain age because we do not adjust interest rates for mortality risk. Without this assumption, very old households with high mortality rates would find it profitable to borrow and die with debt. The interest rate used to discount future income for calculating the constraint is $R^b_t + \chi$.

To summarize, the realized return on financial wealth is

$$R_{j,t}(a) = \begin{cases} R_t^b + \zeta_j(a)\left(R_t^s - R_t^b\right) & \text{for } a \geq 0 \\ R_t^b + \chi & \text{for } a < 0 \end{cases}$$

Dynamic program. We present the Bellman equations for the household in two stages. The first stage captures the realization of idiosyncratic and aggregate shocks. The second stage captures the consumption-saving decision of surviving households.

The first stage evolves as follows. A household enters period t with states $(j-1, z_{-1}, a_{-1})$ inherited from last period. Next, its age increases by one and becomes j; it draws a new level of idiosyncratic productivity z from a distribution $\Pi_j(z \mid z_{-1})$; and it receives the return on its financial assets. The only risk that remains is mortality. With probability $1-\psi_j$, the household dies and receives utility $\phi(a)$ from bequeathing its assets. With probability ψ_j, it survives and proceeds to the consumption-saving stage. In sum, its value function in the first stage, after reaching age j and drawing a new productivity z, is

$$\begin{aligned} V_{j,t}^{(1)}(z, a_{-1}) &= (1-\psi_j)\phi(a) + \psi_j V_{j,t}^{(2)}(z, a) \\ \text{s.t. } a &= R_{j,t}(a_{-1}) \cdot a_{-1} \end{aligned} \tag{1}$$

In the second stage, the household decides how much to consume and how much to save, taking hours $h_{j,t}(z)$ and income $y_{j,t}(z)$ as given. Preferences over consumption and hours are separable. The value function in the second stage is

$$\begin{aligned} V_{j,t}^{(2)}(z, a) &= \max_{c,a'} \; u(c) - v\big(h_{j,t}(z)\big) + \beta \mathbb{E}_t\big[V_{j+1,t+1}^{(1)}(z', a')\big] \\ \text{s.t. } c + a' &= a + y_{j,t}(z) - \mathcal{T}\big(y_{j,t}(z), \tau_t\big) \\ a' &\geq \underline{a}_{j,t}(z) \end{aligned} \tag{2}$$

where β is the discount factor, $u(c) - v(h)$ is a separable utility function over consumption and labor, and $\mathcal{T}(y, \tau_t)$ is an increasing and convex tax function, where τ_t is a tax shifter. Savings a' become the state a_{-1} of the next period. Solving the Bellman equations yields policy functions for consumption $c_{j,t}(z, a)$ and savings $a'_{j,t}(z, a)$.

Block representation. From a macroeconomic perspective, the household sector is a mapping from aggregate sequences $\{w_t, L_t, R_t^b, R_t^s, \tau_t\}_{t=0}^\infty$ to aggregate sequences $\{C_t, A_t^s, A_t^b, A_t^-, T_t, \Lambda_t, v'(L_t^*), u'(C_t^*)\}_{t=0}^\infty$. The inputs are the wage rate w_t, labor demand L_t, the return on nominal bonds R_t^b, the return on stocks R_t^s, and the tax parameter τ_t. The outputs are consumption C_t, savings in stocks A_t^s, savings in bonds A_t^b, debt A_t^-, taxes net of transfers T_t, bequests Λ_t, and the marginal effects of wage changes on utility through hours and consumption, $v'(L_t^*)$ and $u'(C_t^*)$, expressed in utils and averaged across working-age households.

One output, bequests, is determined at the first stage. Let $D_{j,t}^{(1)}$ denote the time-t measure of age-j households over (z, a_{-1}), using the notation of (1). Then aggregate bequests equal

$$\Lambda_t = \sum_{j=2}^{J} \int (1-\psi_j)\phi\big(R_{j,t}(a_{-1}) \cdot a_{-1}\big)\, dD_{j,t}^{(1)}.$$

All other outputs are defined at the second stage with states (z,a) for all j. The measure of surviving households over (z,a) is $D^{(2)}_{j,t}$.[8] The distribution of newborns is exogenous and denoted by $D^{(2)}_{1,t}$. With these definitions, the remaining aggregate outputs are

$$C_t = \sum_{j=1}^{J} \int c_{j,t}(z,a)\, dD^{(2)}_{j,t}, \qquad T_t = \sum_{j=1}^{J} \int \mathcal{T}\big(y_{j,t}(z), \tau_t\big)\, dD^{(2)}_{j,t},$$

$$A^s_t = \sum_{j=1}^{J} \int_{a'_{j,t}\geq 0} \zeta_j\big(a'_{j,t}(z,a)\big) \cdot a'_{j,t}(z,a)\, dD^{(2)}_{j,t}, \qquad A^-_t = \sum_{j=1}^{J} \int_{a'_{j,t}<0} -a'_{j,t}(z,a)\, dD^{(2)}_{j,t},$$

$$A^b_t = \sum_{j=1}^{J} \int_{a'_{j,t}\geq 0} \big[1-\zeta_j\big(a'_{j,t}(z,a)\big)\big] \cdot a'_{j,t}(z,a)\, dD^{(2)}_{j,t}.$$

We discuss the remaining outputs, $v'(L^*_t)$ and $u'(C^*_t)$, in the labor unions' problem below. We also note that the household block must satisfy firms' labor demand, $L_t = \sum_{j=1}^{J_{\text{ret}}} \int z \cdot h_{j,t}(z)\, dD^{(2)}_{j,t}$.

2.2 Rest of the Model

Labor unions. Nominal wages are set by labor unions whose objective is to maximize the average welfare of working-age households. They take as given the consumption-saving decisions of individual households and the labor incidence function $\Gamma_j(z, W_t)$. We model wage stickiness via a quadratic adjustment cost specified in utils, in the tradition of Rotemberg (1982). In Appendix A, we describe the decision problem of unions in detail and show that it implies a wage Phillips curve

$$\pi^w_t(\pi^w_t - 1) = \kappa_w \left(\frac{v'(L^*_t)}{u'(C^*_t)} - 1\right) + \beta \mathbb{E}_t\big[\pi^w_{t+1}(\pi^w_{t+1}-1)\big]$$

where $\pi^w_t = \pi_t w_t / w_{t-1}$ is nominal wage inflation, π_t is goods inflation, $\kappa_w > 0$ is the slope of the wage Phillips curve, and $v'(L^*_t)/u'(C^*_t)$ is a sufficient statistic that captures labor market power, household heterogeneity, and distortionary taxes on labor supply. Intuitively, $v'(L^*_t)$ is a weighted average of the disutility of labor among working-age households that a marginal change in wages would cause. Similarly, $u'(C^*_t)$ is a weighted average of the utility of consumption that a marginal change in wages would cause. Formally,

$$v'(L^*_t) = \sum_{j=1}^{J_{\text{ret}}} \int v'\big(h_{j,t}(z)\big) h_{j,t}(z) \left[1 + (\epsilon_w - 1)\frac{\partial \Gamma_j(z, W_t)}{\partial W_t} \frac{W_t}{w_t h_{j,t}(z)}\right] dD^{(2)}_{j,t}$$

and

$$u'(C^*_t) = \sum_{j=1}^{J_{\text{ret}}} \int u'\big(c_{j,t}(z,a)\big) \Big[1 - \mathcal{T}'\big(y_{j,t}(z), \tau_t\big)\Big] y_{j,t}(z)(\epsilon_w - 1) \frac{\partial \Gamma_j(z, W_t)}{\partial W_t} \frac{W_t}{w_t h_{j,t}(z)}\, dD^{(2)}_{j,t}$$

where ϵ_w is the elasticity of substitution between the labor varieties that the unions represent.

[8] The transition from $D^{(1)}_{j,t}$ to $D^{(2)}_{j,t}$ captures asset returns and death. The total mass of survivors satisfies $\int d\, D^{(2)}_{j,t} = \psi_j \int d\, D^{(1)}_{j,t}$ for $j > 1$.

Financial intermediary. There is a representative financial intermediary whose balance sheet is given by

$$p_t + B_t = A_t^s + A_t^b - A_t^- + N_t \tag{3}$$

where assets include firm equity valued at p_t and government bonds B_t, and liabilities include the stocks and bonds of the household sector net of debt ($A_t^s + A_t^b - A_t^-$) and the intermediary's own net worth N_t.[9] The equity price reflects the value of physical capital as well as the net present value of monopolistic profits of firms. Net worth evolves according to

$$N_t = R_t^s p_{t-1} + R_t^b B_{t-1} - R_t^s A_{t-1}^s - R_t^b (A_{t-1}^b - A_{t-1}^-) - d_t^{\mathrm{FI}}$$

where d_t^{FI} is a dividend paid to the owner of the intermediary.[10] For simplicity, we assume that the owner is the government and that dividend payout is such that net worth remains constant at its steady-state level.

Absent portfolio adjustment costs and aggregate uncertainty, stocks and bonds must offer the same expected return. The no-arbitrage condition is

$$R_t^e \equiv \mathbb{E}_t[R_{t+1}^b] = \mathbb{E}_t\left[\frac{R_t^n}{\pi_{t+1}}\right] = \mathbb{E}_t[R_{t+1}^s] = \mathbb{E}_t\left[\frac{d_{t+1} + p_{t+1}}{p_t}\right] \tag{4}$$

where R_t^e is the economy-wide ex-ante real interest rate, d_t are firms' dividends, and R_t^n is the nominal interest rate set by the central bank. As we discussed, if an aggregate shock occurs at date t, the ex-post returns

$$R_t^b = \frac{R_{t-1}^n}{\pi_t} \quad \text{and} \quad R_t^s = \frac{d_t + p_t}{p_{t-1}} \tag{5}$$

may differ, as π_t, d_t, and p_t can jump in response to the shock.

Firms. The production block has two types of firms. A competitive final goods firm aggregates intermediate goods with constant elasticity of substitution $\epsilon_p > 1$. Intermediate goods are produced by a unit mass of monopolistically competitive firms. These firms are identical ex ante. They have a Cobb–Douglas production function over capital and effective labor units, $F(k_{t-1}, l_t) = \Theta k_{t-1}^{\alpha} l_t^{1-\alpha}$. There are quadratic adjustment costs on both capital and the intermediate goods price.

In Appendix A, we describe the decision problems of firms in detail and show that they give rise to a symmetric equilibrium in which all firms set the same price and produce with the same amount of labor and capital. The resulting inflation dynamics are characterized by a Phillips curve

$$\pi_t(\pi_t - 1) = \kappa_p (\mu_p mc_t - 1) + \mathbb{E}_t\left[\frac{\pi_{t+1}(\pi_{t+1} - 1)}{R_t^e}\frac{Y_{t+1}}{Y_t}\right]$$

[9] Intermediary net worth bridges the sizable gap between the financial assets of the household sector and a reasonable net supply of assets from physical capital, capitalized profits, and government debt. We discuss this in more detail in the calibration section.

[10] The premium paid by households on their borrowing, χA_{t-1}^-, is wasted.

where $\kappa_p > 0$ is the slope of the Phillips curve, $\mu_p = \epsilon_p/(\epsilon_p - 1)$ is the desired markup of intermediate goods producers, $mc_t = w_t/F_L(K_{t-1}, L_t)$ is the real marginal cost, and Y_t is aggregate output. The dynamics of investment are given by

$$Q_t = 1 + \psi\left(\frac{K_t}{K_{t-1}} - 1\right)$$
$$R^e_t Q_t = \mathbb{E}_t\left[\alpha\frac{Y_{t+1}}{K_t}mc_{t+1} - \frac{I_{t+1}}{K_t} - \frac{\psi}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 + \frac{K_{t+1}}{K_t}Q_{t+1}\right]$$

where Q_t is marginal Q, $\psi > 0$ is the capital adjustment cost, and $I_t = K_t - (1-\delta)K_{t-1}$ is investment Intermediate goods firms make positive profits in equilibrium, on account of their accumulated capital stock and monopoly power. The flow profit is

$$d_t = Y_t - W_t - I_t - \frac{\psi}{2}\left(\frac{K_t}{K_{t-1}} - 1\right)^2 K_{t-1} - \frac{\chi_p}{2}(\pi_t - 1)^2 Y_t.$$

Fiscal and monetary policy. The government pays pensions to retirees, provides endowments $\mathcal{E}$ to newborn households, and consumes an exogenous amount G_t of the final good. It finances these expenditures by issuing one-period nominal bonds B_t, collecting bequests Λ_t from households that die, receiving dividends from its ownership of the financial intermediary, and running a progressive tax and transfer system. In sum, the government's budget constraint is

$$B_t + T_t - G_t + \Lambda_t - \mathcal{E} + N_t = R^b_t B_{t-1}.$$

Following Auclert et al. (2020), we assume that the government adjusts income taxes via the shifter τ_t according to the rule

$$\tau_t = \tau_{ss} + \phi_B \frac{B_{t-1} - B_{ss}}{Y_{ss}}$$

where subscripts ss denote steady-state values and $\phi_B > 0$ governs the speed of debt stabilization. The central bank sets the nominal interest rate R^n_t according to the rule

$$R^n_t = R^n_{ss} + \phi_\pi(\pi_t - \pi_{ss}) + \varepsilon^{MP}_t \tag{6}$$

where $\phi_\pi > 1$ is the coefficient on inflation and ε^{MP}_t is an exogenous monetary policy shock.

Equilibrium. Given a sequence of exogenous variables $\{\varepsilon^{MP}_t, G_t\}_{t\geq 0}$, exogenous distributions of newborns $\{D^{(2)}_{1,t}\}_{t\geq 0}$, and initial conditions $\{D^{(1)}_{j,-1}\}^J_{j=2}$, K_{-1}, and B_{-1}, an equilibrium is a sequence of allocations $\{Y_t, C_t, A^-_t, A^s_t, A^b_t, B_t, \Lambda_t, K_t, I_t, L_t, d_t, d^{\mathrm{FI}}_t\}_{t\geq 0}$ and prices $\{R^e_t, R^b_t, R^s_t, R^n_t, Q_t, w_t, mc_t, p_t\}_{t\geq 0}$ such that: (a) households, labor unions, and firms optimize; (b) the financial intermediary, the government, and the central bank follow their policy rules; (c) the balance sheet (3), no-arbitrage (4), and realized-return (5) conditions hold; and (d) the goods market clears, satisfying

$$Y_t = C_t + G_t + I_t + \frac{\psi}{2}\left(\frac{K_t}{K_{t-1}} - 1\right)^2 K_{t-1} + \frac{\chi_p}{2}(\pi_t - 1)^2 Y_t + \chi A^-_{t-1}. \tag{7}$$

Figure A.1 in Appendix A shows a directed acyclic graph (DAG) representation of this economy, which we use to conceptualize and solve the model via the sequence-space Jacobian (SSJ) method of Auclert et al. (2021). To obtain the sequence-space Jacobians of the household block, we use the method described in Bardóczy and Velásquez-Giraldo (2025), which handles OLG blocks more efficiently.

Alternative models. In Section 4, we compare monetary transmission in our OLG-HANK model with that in two alternative models: a prototypical RANK model and an OLG-NK model with representative cohorts. The alternative models have the same DAG representation as OLG-HANK and differ only in terms of their household blocks. A detailed exposition of these models is provided in Appendix E.

3 Calibration

This section presents the calibration of the model and evaluates its performance in matching a battery of aggregate and cross-sectional moments that the HANK literature has found relevant for monetary policy transmission. The model is meant to represent the U.S. economy, and hence we prioritize using U.S. data. Nevertheless, we use other sources when they are superior in detail, quality, or availability. In particular, we use administrative earnings data from Sweden to refine existing estimates of "worker betas"—which measure heterogeneity in income exposure to aggregate fluctuations—and to validate some of our model's implications for monetary policy.

The calibration proceeds in two steps. First, we calibrate the household block in isolation, choosing steady-state values for its aggregate inputs $\{w, L, R^b, R^s, \tau\}$. Second, we calibrate the rest of the model, ensuring consistency with the household block. Accordingly, we first present the calibration of the household block and discuss its empirical fit before turning to the calibration of the rest of the model.

3.1 Household Parametrization and Functional Forms

Our calibration of the household block relies on two main datasets. We use the 2019 Survey of Consumer Finances (SCF) to calibrate preference and borrowing parameters that govern wealth accumulation, and the Swedish Longitudinal Integrated Database for Health Insurance and Labor Market Studies (LISA) to calibrate the labor income incidence functions.

Demographics. Time and age advance in one-year steps. The initial age is 26 years ($j = 1$) and the maximum age is 100 years ($J = 100 - 26 + 1 = 75$). We set survival probabilities ψ_j based on cross-sectional annual death probabilities for males from the 2004 SSA life tables. Figure B.3 in Appendix B shows that the resulting age distribution in the model approximates the 2020 U.S. Census age distribution well.

Labor earnings and pensions. Households work until age 65 ($J_{\text{ret}} = 65 - 26 + 1 = 40$). Working-age households are exposed to fluctuations in their idiosyncratic productivity, their hours, and the aggregate wage rate. We normalize the steady-state wage rate w_{ss} and the hours of every household $h_{j,ss}(z)$ to 1. Hence, steady-state aggregate labor supply is

$$L_{ss} = \sum_{j=1}^{J_{\text{ret}}} \int z \, dD_{j,ss}^{(2)}.$$

For the stochastic component of idiosyncratic productivity η_j, we use the income shock process of Arellano et al. (2017), optimally discretized into an age-varying Markov chain by Janssens and McCrary (2023).[11] The main feature of this income process is that the age-varying distribution of η_j and its relationship with η_{j+1} is very flexibly specified (without assumptions such as linearity or normality) and estimated to fit data from the Panel Study of Income Dynamics. The resulting process provides a rich representation of earnings growth in the U.S. and of its risk, asymmetries, and persistence; all these features vary over the life cycle and have been extensively validated by Arellano et al. (2017) and Janssens and McCrary (2023).

Age fixed effects $\{f_j\}_{j=1}^{J}$ and the standard deviation of individual fixed effects σ_α control the age profile of earnings (including pensions) and the width of their distribution. We estimate these parameters to reproduce earnings in the SCF, which we define as the sum of wage and salary income (`wageinc`) and Social Security and pension income (`ssretinc`).[12] Age fixed effects come from fitting log earnings to a fifth-degree polynomial in age, considering only households with positive earnings. Then, with $\{f_j\}_{j=1}^{J}$ fixed, we form five-year age bins ($[26, 30]$, $[31, 35]$, ..., $[91, 95]$), calculate the 25th, 50th, and 75th percentiles of earnings within each bin, and choose σ_α to minimize the distance between these moments and their model counterparts. In the model, we discretize the distribution of individual fixed effects with three equiprobable points. The left panel of Figure 1 shows that our model reproduces the age-varying level and dispersion of earnings with great fidelity.

Income taxation. We use the canonical tax function of Heathcote et al. (2017)

$$\mathcal{T}(y, \tau_t) = y - (1 - \tau_t) y^{1-\lambda}$$

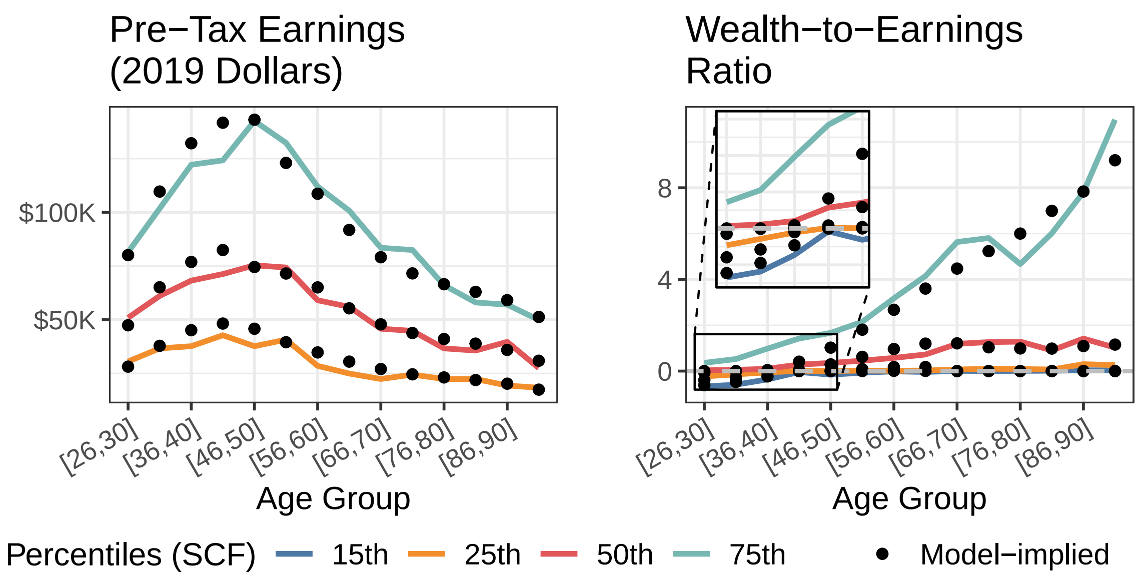
which implies a log-linear relationship between pre-tax income and after-tax income that fits U.S. data very well. We calibrate the tax parameters based on Fleck et al. (2021), who estimate this function considering a comprehensive set of federal and state-level taxes and transfers. Specifically, we set $\lambda = 0.166$ and calibrate τ_{ss} to match a 40 percent average tax rate on an income of \$300,000.[13]

Portfolios. The exogenous equity-share functions for households with positive wealth reproduce the equity allocations of SCF respondents. We specify a feedforward neural network

[11] We thank Eva Janssens for sharing the discretized income process. Arellano et al. (2017) estimate their process up to age 60. We assume these transition matrices and grids remain constant from this age until retirement. We incorporate only the persistent component of productivity and leave out transitory shocks. We found that adding these shocks did not materially change the results of this paper.

[12] We use pre-processed variables from the SCF summary files and write them in `typewriter font`.

[13] These numbers come from Table 2 and Figure 8 of their paper.



The data comes from the 2019 SCF. Income is the sum of wages, salaries, Social Security, and pension income. Wealth-to-income ratios are computed using net financial assets. We restrict the sample to households that report a positive income and have a respondent who is at least 21 years old. We sort households into age bins and calculate income and wealth-to-income ratio percentiles within age bins. In the model, wealth-to-income ratios are end-of-period assets divided by pre-tax income, a'/y.

Figure 1: Age Profiles of Income and Wealth in the Data and the Model.

that takes age and financial assets as inputs and produces a prediction of the equity share of financial assets as its output. We train the network by minimizing its mean absolute error and set the functions $\{\zeta_j(\cdot)\}_{j=1}^J$ using the trained network, which implies that, for $a \geq 0$ and any j,

$$\zeta_j(a) \approx \text{Median}_{\text{SCF}}\big(\text{Equity Share} \mid \text{Age} = j, \text{Fin. Assets} = a\big).$$

Appendix B describes this procedure in greater detail.

Figure B.1 in Appendix B depicts the estimated functions for various ages. They capture several empirical features of equity shares. We highlight two that matter for our quantitative results. First, a large fraction of the population, particularly among those with low financial assets, does not invest in equities at all. Second, above some moderate age-varying level of financial assets, the equity share becomes positive and steeply increasing in wealth: for every age, it is the wealthiest households who tend to have the greatest share of their wealth in equities.

Preferences and borrowing constraint. At every age, the utility from consuming c is $u(c) = c^{1-\rho}/(1-\rho)$ and the utility from bequeathing assets a is $\phi(a) = b(a+\kappa)^{1-\rho}/(1-\rho)$. This bequest specification comes from Carroll (2002) and De Nardi (2004). The parameter κ controls the degree to which bequests are a luxury good. It lowers the marginal value of leaving bequests—especially at lower levels of wealth—thereby making saving rates increase with wealth and shaping the skewness of the wealth distribution at older ages. The overall intensity of the bequest motive is controlled by b. Since labor is determined by demand and the disutility of work is additively separable, the specification of labor disutility does not

Table 1: Household Parameter Estimates

Parameter	Symbol	Estimate
Preferences and Borrowing (SMM)		
Relative-Risk Aversion	ρ	1.78
Discount Factor	β	0.92
Bequest Intensity	b	286.85
Bequest Shifter	κ	$628k
Borrow. Limit Multiplier	ω	0.13
Borrow. Rate Premium	χ	0.13
Income Process		
Productivity F.E. Std. Dev.	σ_α	0.62

Table summarizes the parameters that we calibrate via SMM to fit moments of the income and wealth-to-income distribution over the life cycle.

affect households' choices directly. We discuss the disutility of labor when calibrating the union block.

We estimate the preference parameters $\{\beta, \rho, b, \kappa\}$, the multiple of lifetime earnings that households are allowed to borrow ω, and the interest premium paid on borrowing χ to reproduce the distribution of wealth across the life cycle using the simulated method of moments (SMM). We set the maximum age at which households can borrow to 75. The measure of wealth that we target is net financial wealth. This is the sum of all financial assets (including, for example, bank accounts and retirement accounts, but not cars, houses, or businesses) minus debt that is not secured by real assets (including, for example, credit card balances and student loans, but not mortgages or car loans).[14] This concept is narrower than net worth but broader than the liquid-wealth measures that HANK models typically require to produce plausible MPCs (see Kaplan & Violante, 2022).

We target the distribution of wealth-to-income ratios both within and across cohorts. We use the same five-year age bins as for earnings and, for each bin, compute the 15th, 25th, 50th, and 75th percentiles of the individual-level ratio between our measure of wealth and our measure of annual earnings in the SCF, considering only households with positive earnings.[15] To convey the range of the wealth-to-income ratios we encounter, the 15th percentile of the $[26, 30]$ group is -0.67, and the 75th percentile of the $[91, 95]$ group is 10.97. We estimate our six parameters by minimizing the distance between these 56 moments and their model-implied counterparts.[16]

[14] Specifically, using the definitions in the SCF summary files, our measure of individual wealth is (`asset` − `nfin`) − (`debt` − `mrthel` − `resdbt` − `veh_inst`). See the SCF Networth Flowchart for variable definitions and a depiction of the different components of net worth.

[15] We added the 15th percentile to our targeted moments to improve the identification of borrowing parameters, since the 25th percentile barely dips into negative territory.

[16] The model analog of the wealth-to-earnings ratio that we use is $a'_{j,t}/y_{j,t}$. In our simulated-method-of-moments distance metric, we use a diagonal weighting matrix that roughly rescales absolute differences to relative differences from the SCF.

The estimated parameters are reported in the first panel of Table 1. The values are typical for similar exercises in the labor and macroeconomics literatures: a coefficient of relative risk aversion of 1.8, which implies an intertemporal elasticity of substitution close to 0.6; an annual discount factor above 0.9; and a strong bequest motive with a large shifter that makes the distributions of old-age wealth and bequests skewed. The borrowing parameters imply that households can borrow up to 13 percent of the expected present value of their future earnings and that the interest rate they pay on debt is 13 percentage points higher than that on nominal government bonds. This estimated premium is within the range of premia on the types of debt we consider: it is high for student loans, low for credit cards, and not far from typical premia on unsecured personal loans.

The right panel of Figure 1 depicts the targeted and model-implied wealth moments at the estimated parameters. The model successfully reproduces wealth-to-earnings ratios across the life cycle. It captures the wealth and borrowing levels of young households at and below the median and closely fits all percentiles of the wealth ratios of households around retirement age. It also matches the very skewed distribution of wealth in retirement, with most households at or below one year of earnings saved and a small group of households with very high levels of wealth that they do not consume as they age. The main discrepancy comes from the wealth-to-income ratios of richer young households (those in the fourth quartile), who hold moderate amounts of wealth that the model undershoots.

Incidence of aggregate fluctuations. Our framework allows aggregate labor income fluctuations to be distributed unequally across households through the incidence functions $\{\Gamma_j(z, W_t)\}_{j=1}^{J_{\text{ret}}}$. Such heterogeneous exposure is both an empirical fact and a key determinant of propagation in incomplete markets models (see Werning, 2015; Bilbiie, 2025). We calibrate these functions by estimating regressions of the form

$$\Delta \ln y_{i,t} = \alpha_g + \beta_g \Delta \ln W_t + \epsilon_{i,t} \tag{8}$$

for six age groups and, within each age group, ten earnings deciles, yielding sixty combinations indexed by g. In (8), $\Delta \ln y_{i,t}$ is the log real labor earnings growth of worker i in group g from year $t-1$ to t and $\Delta \ln W_t$ is log real aggregate labor earnings growth over the same period. The dataset we use is the Swedish Longitudinal Integrated Database for Health Insurance and Labor Market Studies (LISA), an annual panel encompassing all legal residents of Sweden aged 16 and above. Appendix B describes our empirical strategy in detail and Appendix F provides a deeper description of the data and variable definitions.[17] We concentrate on prime-age men with positive earnings, giving us 38.67 million individual-year observations from 3.19 million unique individuals in the years 1997-2018. Figure 2 reports the estimated elasticities β_g for men in the 60 age–earnings groups. Elasticities decline with both age and income, with particularly steep gradients among workers below the median: a 26-year-old in the lowest income decile has an elasticity of 6.0, making him about 15 times more exposed to aggregate labor income fluctuations than a 55-year-old in the middle deciles, who has an elasticity below 0.4. These findings are qualitatively similar to the worker betas

[17] This exercise builds on Amberg et al. (2022), and we are grateful to Niklas Amberg for sharing materials and information that facilitated our analysis.

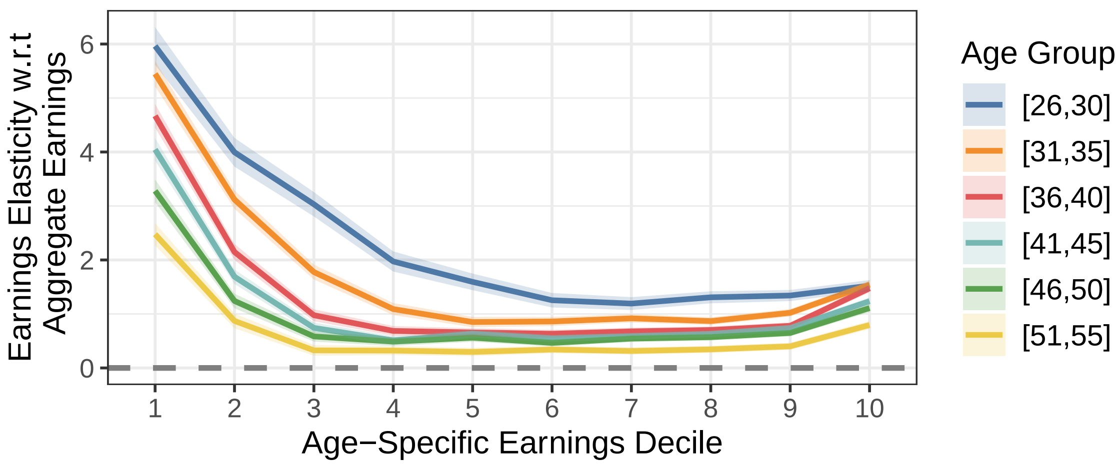


Figure shows the estimated labor earnings elasticities with respect to aggregate labor earnings by age group and earnings decile. Estimates are based on Swedish data for male employees and use wage income only. Earnings percentiles are computed within each age–year cell using a five-year moving average of individual wages. Shaded areas denote 95 percent confidence intervals, computed using heteroskedasticity-robust standard errors.

Figure 2: Earnings Betas by Age and Earnings Decile

estimated by Guvenen et al. (2017) using U.S. data.[18]

We map these estimated elasticities as directly as we can to our incidence functions $\{\Gamma_j(z, W_t)\}_{j=1}^{J_{\text{ret}}}$. We impose, for example, the constraint that individual earnings fluctuations must add up to the given change in aggregate earnings. Appendix B provides a detailed description of how we map the elasticities into the model.

3.2 Non-Targeted Moments of the Household Block

This subsection examines various non-targeted features of the household sector. Throughout, we hold its aggregate inputs $\{w, L, R^b, R^s, \tau\}$ at their steady-state values.

Life cycle profile of consumption. Our calibration procedure explicitly targets quantiles of pre-tax earnings and of wealth-to-earnings ratios by age. This does not guarantee that the model also matches the corresponding moments for consumption. Therefore, Appendix B compares the age-varying distribution of consumption implied by our model to that in the U.S. according to the 2019 Consumer Expenditure Survey. Figure B.2 in Appendix B shows that the model accurately reproduces the life cycle profile and age-specific dispersion of consumption both before and after retirement.[19]

[18]Guvenen et al. (2017) and Amberg et al. (2022) document U-shaped exposures of earnings to GDP that sharply increase in the right tail of the earnings distribution. We find the same patterns in exposures to aggregate earnings but, just as in those studies, most of the right-tail increase occurs above the 99th percentile and is not as pronounced in our coarser grouping.

[19]This holds up to scaling the consumption of every household by a common multiplicative factor, which is close to existing estimates of the share of consumption expenditures measured in the Consumer Expenditure Survey. See Appendix B.

Inequality of consumption, income, and wealth. The distributions of consumption, labor income, and wealth exhibit increasing inequality in that order (Gaillard et al., 2023). An extensive literature has shown that canonical heterogeneous agent models struggle to generate this empirical ordering (see, for example, De Nardi, 2015; Stachurski & Toda, 2019; Benhabib & Bisin, 2018).[20] A related shortcoming is that these models do not generate enough wealth inequality: their implied Gini coefficients are far below those measured in U.S. data (Krusell & Smith, 1998; Auclert et al., 2025).

Our model reproduces the empirical inequality ordering of consumption, earnings, and wealth, as well as the measured Gini coefficient of net financial wealth. In steady state, the Gini coefficient of pre-tax earnings is 0.61; this comes from the Arellano et al. (2017) shock process, which features the possibility of very high-earning states, and from our calibration of individual and age fixed effects. The Gini coefficient of consumption is 0.44, and that of wealth is 0.93, much lower and much greater than that of earnings, respectively. The main contributor to the separation between these three Gini coefficients in our model is the non-homothetic bequest motive: it makes saving rates increase with wealth and hence compresses the consumption distribution while amplifying wealth differences. Their magnitudes are also not far from empirical counterparts. For example, the Gini coefficient of the net financial wealth measure that we use is 0.91 in the 2019 SCF. Figure B.4 in Appendix B compares the empirical and model-implied Lorenz curves of wealth, demonstrating their similarity.

The model also generates plausible dynamics of intragenerational wealth mobility. In Figure B.5 of Appendix B, we evaluate the persistence of households' wealth ranks within their cohorts over their lives. Most wealth mobility occurs before age 40, as Audoly et al. (2024) find in Norwegian tax records. In the U.S., Shiro et al. (2022) find that a ten-percentage-point increase in an individual's percentile in their cohort's early-thirties wealth distribution leads to a 5.9-percentage-point increase in their predicted percentile in their late fifties. In our model, the analogous number between ages 30 and 55 is 5.2.

Hand-to-mouth behavior. Our model also approximates several facts about hand-to-mouth households—that is, those that would immediately consume most of a cash transfer if they received one. Estimates for the share of hand-to-mouth households in the U.S. economy based on their wealth holdings range from 25 to 40 percent (see Kaplan et al., 2014; McKay & Wolf, 2023; Aguiar et al., 2024). In our model, we define hand-to-mouth households as those with an MPC above 0.75. We use this classification because wealth-based criteria depend on small wealth-to-income ratios (for example, having two months or two weeks of income saved) that are sensitive to timing assumptions in models like ours, where income is received in yearly increments. Under this definition, 24 percent of households are hand-to-mouth in our model's steady state.

Aguiar et al. (2024) document several facts about the hand-to-mouth that are at odds with standard precautionary savings models with homogeneous preferences.[21] For example, households classified as hand-to-mouth in year t are more than ten times likelier to be hand-to-mouth in year $t+2$ than those who are not hand-to-mouth in year t. In our model, this

[20] Specifically, models with homogeneous and homothetic preferences, infinite lives, and homogeneous returns to wealth that rely mainly on the precautionary motive for wealth accumulation.

[21] Aguiar et al. (2024) study households below age 65, so we apply the same sample restriction for the statistics reported in this paragraph.

ratio is close to eight: 66 percent of hand-to-mouth households remain so in year $t+2$, and 8 percent of households that were not hand-to-mouth become so in year $t+2$. A second fact is that hand-to-mouth households do not expect greater consumption growth. This is also true in our model: the expected two-year annualized consumption growth of hand-to-mouth households is, after subtracting age fixed effects, roughly 0.7 percentage points lower than that of non-hand-to-mouth households, close to Aguiar et al.'s (2024) estimates.[22]

Marginal propensities to consume. Intertemporal MPCs modulate the strength and transmission mechanisms of monetary and fiscal policy. The average annual MPC out of cash transfers in the steady state of our model is 0.33. This falls within the range of estimates for the U.S. in the literature.[23] Estimates for the effect of transfers on consumption after more than a year has passed (intertemporal MPCs, or iMPCs) are scarcer. In Figure B.6 of Appendix B, we compare our model's iMPCs with Fagereng et al.'s (2021) estimates from Norwegian lottery winners and find qualitative similarities, such as a distinctively high on-impact response followed by smaller, decaying responses after the first year.

Delivering aggregate MPCs of this order has been a challenge for canonical heterogeneous agent models. Kaplan and Violante (2022) show that to have plausible MPCs, these models need to be calibrated to match very narrow measures of wealth, assume that households have heterogeneous preferences, or feature illiquid assets with high rates of return. Our model features none of these ingredients and is calibrated to match a fairly broad measure of financial wealth—the ratio of aggregate household wealth to aggregate household earnings is 3.46.[24] Kaplan and Violante (2022) also find that some models achieve high MPCs through excessively polarized wealth distributions that severely understate median wealth. Our model does well on this "missing middle" problem. The unconditional median of net financial wealth in the SCF is \$21,000. In our annual model, it depends on when it is measured. Taking the budget constraint of (2), we find the median at three different points. Right after receiving their earnings, $a+y-\mathcal{T}$, it is \$59,000. After households consume half of their annual consumption, $a+y-\mathcal{T}-c/2$, it is \$33,000. After they consume all of their annual consumption, a', it is \$4,000. All in all, when the life cycle dynamics and luxurious bequest motive of the model match plausible levels of wealth inequality, plausible MPCs follow.

How MPCs vary across households with different characteristics can amplify or dampen aggregate responses to shocks, shape their incidence, and summarize the value of immediate additional resources to different households (Auclert, 2019). Fagereng et al. (2021) find that age and liquid wealth are the two strongest correlates of MPCs. Figure 3 presents the average MPCs of households of different ages and age-specific wealth quintiles in our model, showing that they decrease with age and with wealth on average.[25] Linearly regressing

[22]We calculate $\ln(\mathbb{E}_t[c_{t+2}]/c_t)/2$ at each gridpoint of our model in steady state and subtract age-specific averages. We then average the result over gridpoints that qualify as hand-to-mouth at time t and over those that do not. The difference is -0.0066, which we compare to the -0.009 and 0.003 estimates in column 1 of Table 4 in Aguiar et al. (2024).

[23]For example, Sahm et al. (2010) estimate a one-year average MPC of 1/3, Commault (2022) 0.32, and Colarieti et al. (2024) 0.42. See Carroll et al. (2017) and Crawley and Theloudis (2024) for reviews.

[24]For this ratio, wealth aggregates the net end-of-period assets of surviving households, and earnings are the labor earnings of working households plus the pensions of retirees, both post-tax.

[25]The relationships are not monotonic. Along the wealth dimension, the ability to borrow at a premium

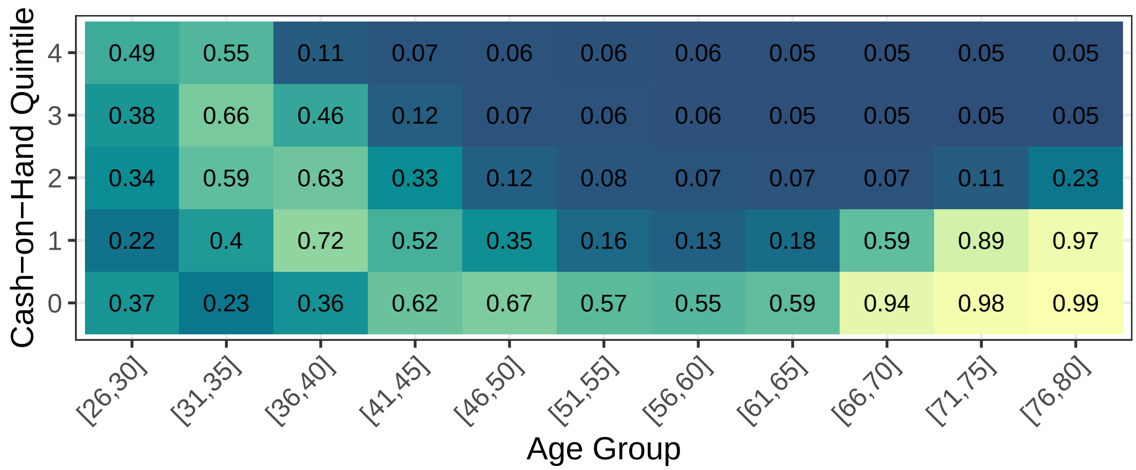


Figure shows annual MPCs from a one-time, unanticipated transfer across in the steady state of OLG-HANK. For each age bin, we group agents into quintiles of their cash-on-hand, $a + y_{j,t}(z) - \mathcal{T}\big(y_{j,t}(z), \tau_t\big)$. The MPC is the derivative of the consumption policy function, $\partial c_{j,t}(z, a)/\partial a$, averaged over agents in each bin using the steady-state distribution.

Figure 3: MPCs Across the Life Cycle and the Wealth Distribution.

MPCs on age and cash-on-hand simultaneously suggests that, in our model, a one-standard-deviation increase in age or in liquid wealth is associated with a decrease in the MPC of about four percentage points. These estimates, which are of the same order of magnitude as those in Fagereng et al. (2021), are reported in Table B.1 of Appendix B. Furthermore, the covariance between workers' MPCs and the elasticity of their earnings with respect to aggregate earnings—a key determinant of multipliers in HANK models—is 0.12 in our model, close to the 0.10 estimated by Patterson (2023) for the U.S.

Finally, we examine the aggregate MPC out of equity returns. In our model, a shock that increases the aggregate value of household equity holdings by $1 leads to a contemporaneous consumption increase of $0.05. This is close to empirical estimates in Chodorow-Reich et al. (2021) and to a stock-wealth-weighted average of those in Di Maggio et al. (2020). This success reflects our matching of portfolios by age and wealth: equities are mostly owned by wealthier households with low MPCs.

3.3 Rest of the Model

We calibrate the rest of the model taking the household block as given and using additional targets from the literature and national statistics. Table B.2 in Appendix B summarizes the calibration of macroeconomic aggregates and selected parameters of our main model, OLG-HANK. Our calibration strategy for OLG-HANK, OLG-NK, and RANK is the same, except where explicitly noted. Recall that one period corresponds to one year.

generates MPCs that are high near the borrowing limit, lower as people pay down their debt, high again for people with zero wealth who are unwilling to borrow, and lower for unconstrained positive wealth. Along the age dimension, MPCs increase after retirement for households that exhaust their retirement savings and live hand-to-mouth.

Labor unions. The disutility from working h hours is $v(h) = \varphi h^{1+\nu}/(1+\nu)$. We set the Frisch elasticity to $1/\nu = 0.5$ and calibrate the scaling parameter φ to ensure that $v'(L^*_{ss}) = u'(C^*_{ss})$ holds given the stationary distribution of households. Calibrating the slope of the wage Phillips curve is non-trivial because the marginal rate of substitution $v'(L^*_t)/u'(C^*_t)$ is much more procyclical in our OLG-HANK model than in most New Keynesian models, including our own alternative models. The reason is that the estimated worker betas, shown in Figure 2, induce countercyclical inequality in income and consumption. Hence, imposing the same κ_w across the three models would imply substantially different dynamics for wages, hours, and inflation. We view this difference as spurious, because the average marginal rate of substitution is an unobservable object and estimating these models on the same aggregate time series data would simply lead to different estimates of κ_w.

Therefore, we proceed as follows. We calibrate κ_w in RANK—our most standard model without countercyclical inequality—to a typical value from the literature. Specifically, we consider the equivalent Calvo model, which implies that the slope equals

$$\kappa_w = \frac{\left[1-\beta(1-\xi_w)\right]\xi_w}{1-\xi_w}$$

where β is the discount factor inherited from the household block and $\xi_w = 0.33$ is the annual frequency of wage adjustment from Grigsby et al. (2021). Then, we calibrate κ_w in OLG-HANK and OLG-NK to match the peak response of real wages to an expansionary monetary policy shock in RANK. This procedure yields $\kappa_w^{\text{RANK}} = 0.188$, $\kappa_w^{\text{OLG-NK}} = 0.085$, and $\kappa_w^{\text{OLG-HANK}} = 0.021$. Conditional on the slope parameter, the elasticity of substitution plays no role. We take $\epsilon_w \to \infty$ to shut down labor unions' monopoly profits.

Firms. In calibrating the household block, we normalized the steady-state wage rate and hours. This pins down total effective hours worked L_{ss} and the aggregate wage bill W_{ss} in steady state. We calibrate TFP Θ and the depreciation rate δ_k so that these values are consistent with a labor share of $1-\alpha_k = 0.706$ and a capital-to-output ratio of $K_{ss}/Y_{ss} = 2.26$. These calibration targets are the same as in Auclert et al. (2024). We calibrate the investment adjustment cost ψ to target a partial-equilibrium semi-elasticity of investment $d\ln(I_t)/dR^e_t = -5$, in line with the findings of Koby and Wolf (2020) and He et al. (2022). We normalize gross inflation to $\pi = 1$. Following Auclert et al. (2024), we set the slope of the Phillips curve to $\kappa_p = 0.23$ and take the limit $\mu_p \to 1$ to shut down profits from monopoly power. Given this choice, the equity price equals the value of capital in steady state, $p_{ss} = K_{ss}$.

Government. The household block pins down households' savings in stocks A^s_{ss} and bonds A^b_{ss}. The firm block pins down the total value of stocks, p_{ss}. We set government bonds to 70 percent of GDP. Together, these choices pin down the financial intermediary's net worth N_{ss}. Government spending $G_{ss} = 0.23$ is pinned down as the residual of the government budget. Following Auclert et al. (2020), we set the tax-smoothing parameter to $\phi_B = 0.1$.

Turning to monetary policy, we set $\phi_\pi = 1.5$, a conventional value. In our main experiments, we assume that the monetary policy shock follows an AR(1) process with an annual autocorrelation of 0.4, which yields an interest rate path that is representative of typical estimates in U.S. data (see, e.g., Auclert et al., 2020).

4 Monetary Policy Transmission

This section uses the calibrated models to study the transmission of monetary policy. First, in Section 4.1, we study the responses of macroeconomic aggregates and the sources of changes in aggregate consumption. We compare RANK, OLG-NK, and OLG-HANK to illustrate the roles of life-cycle dynamics and within-cohort inequality. Then, in Section 4.2, we examine the income changes of different households, compare them with empirical counterparts, and explore the drivers of their consumption responses.

4.1 Aggregate Effects

We start by inspecting the responses of macroeconomic aggregates to a 25-basis-point expansionary monetary policy shock. We compare the predictions of our OLG-HANK model with those of the RANK and OLG-NK models described in Appendix E. These alternative models are nested within OLG-HANK, and we calibrate them using the same strategy, insofar as their restrictions on household heterogeneity permit. We also present decompositions that shed light on the mechanisms driving these responses and their differences across models. Finally, we introduce an extension to OLG-HANK that refines the behavior of asset returns, which are consequential in our setting.

Monetary policy shock. Each economy starts in steady state, with every agent assuming that macroeconomic aggregates will remain constant. At time $t = 0$, a negative 25-basis-point shock to the Taylor rule (6) is announced. The shock decays at a rate of 60 percent per year and its path, $\{\varepsilon_t^{MP}\}_{t\geq 0} = \{-25 \times 10^{-4} \times 0.4^t\}_{t\geq 0}$, is known to all agents.

Impulse responses. Figure 4 displays the monetary policy shock and the dynamic responses of key macroeconomic aggregates across the three models.

In the RANK model, the responses follow a textbook pattern.[26] The real interest rate falls on impact and returns to its steady-state level at roughly the same pace as the shock. The persistent decline in the real rate stimulates consumption and investment, raising output. Labor income increases primarily because hours worked rise. Real wages increase only modestly, as nominal wages are stickier than prices. Consequently, real marginal cost, which is the real wage divided by the marginal product of labor, eventually declines. Inflation, which depends on the present value of future marginal costs, falls below steady state about three years after the shock and then converges back slowly. Asset returns follow the real rate for all $t > 0$. On impact, however, returns diverge due to the unanticipated monetary policy shock. The real return on nominal bonds falls with the surprise inflation, whereas the return on equity rises slightly because lower real rates raise the present value of future profits. Wage stickiness is essential: by limiting the decline in future profits, it prevents stock prices from falling—a typical outcome in New Keynesian models with flexible wages (Broer et al., 2020).

[26] There are subtle differences between our RANK model and the canonical RANK model in which the government adjusts lump-sum transfers. In our model, monetary easing triggers a persistent decline in the marginal labor income tax, which stimulates labor supply and moderates wage inflation. Ultimately, this results in a more persistent responses of the real rate and consumption.

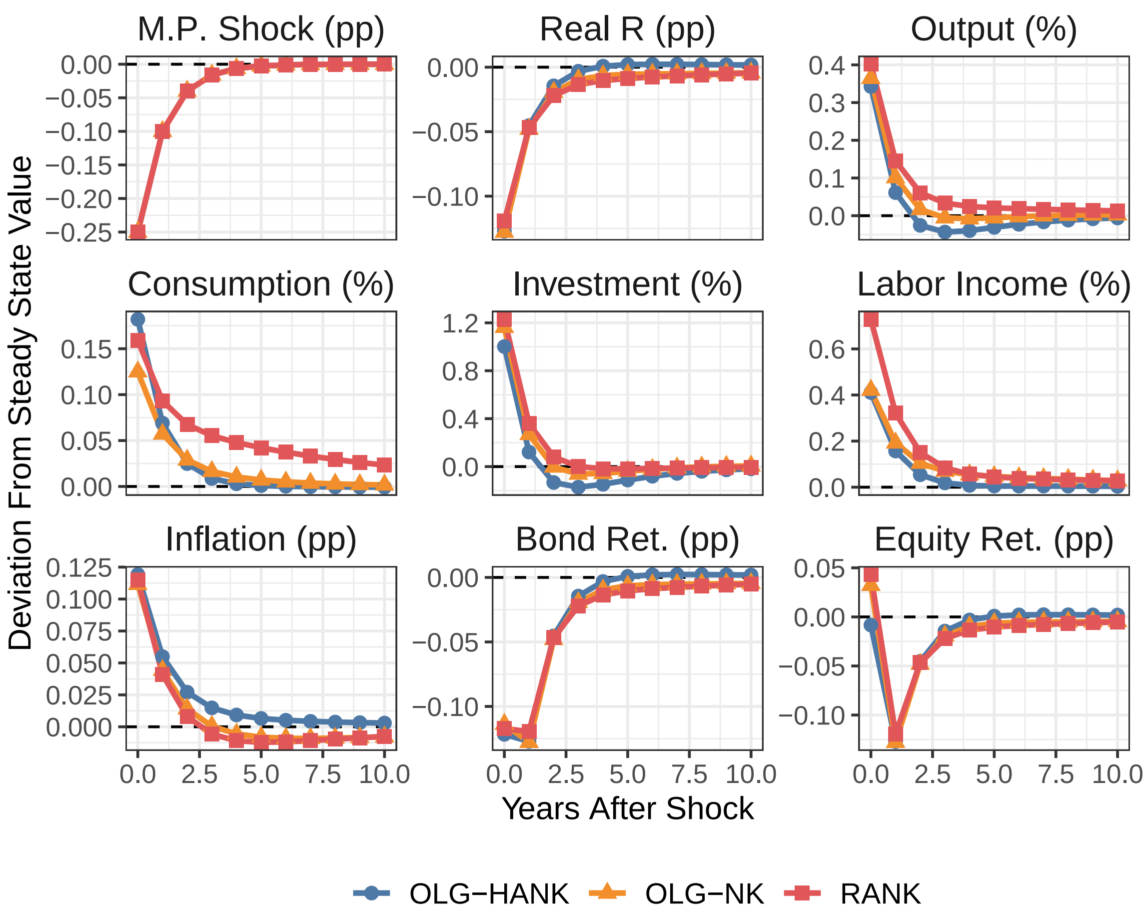


Figure presents impulse responses of different models to the same expansionary monetary policy shock. "Real R" is R_t^e, the ex-ante real interest rate used to discount future payments. "Inflation" is goods inflation. See the main text for model definitions.

Figure 4: Aggregate Responses to an Expansionary Monetary Policy Shock.

The heterogeneous agent models produce impulse responses that are similar to those of the RANK model. The OLG-NK model delivers nearly identical dynamics for most variables, except for a less persistent consumption response and a slightly more muted rise in aggregate labor income. The OLG-HANK model has a somewhat stronger consumption response, which reduces the persistence of the decline in the real rate, crowds out investment, and lowers the return on equity relative to both OLG-NK and RANK. Overall, however, these differences remain modest. That the three models generate similar aggregate impulse responses could be taken as a reason to favor the most parsimonious specification. We take a different view. All macroeconomic models are judged against the same aggregate data. For a new model to be credible, spanning the same range of impulse responses as the incumbent workhorse is a requirement, not a shortcoming. For example, we calibrate the slope of the wage Phillips curve separately for each model to avoid large but spurious differences in outcomes that would disappear if the models were estimated on the same data.[27] Furthermore, as we will demonstrate, agreement on aggregate impulse responses does not imply agreement on the underlying mechanisms or welfare implications.

Partial equilibrium decomposition. As a first step toward understanding the differences across the models, we conduct a partial equilibrium decomposition of their consumption responses following Kaplan et al. (2018). This decomposition reveals the channels through which monetary policy reaches households. The block representation of the household sector implies an aggregate consumption function $\{C_t\}_{t\geq 0} = \mathcal{C}(\{w_t, L_t, R_t^b, R_t^s, \tau_t\}_{t\geq 0})$. It is instructive to refine this function by distinguishing the substitution and income effects of interest rate movements. The intertemporal substitution channel can be isolated by feeding $\{R_t^b, R_t^s\}_{t\geq 0}$ into the Euler equation of every household while holding their budget and borrowing constraints fixed; the asset income channel can be captured by doing the reverse. We refer to the combined effects of the wage rate, hours, and taxes as the labor income channel. Feeding in the general equilibrium paths of inputs one by one yields an additive decomposition of the aggregate consumption response that is exact to first order.

Table 2 reports decompositions of the impact response of aggregate consumption dC_0/C_{ss} into the contributions of intertemporal substitution, labor income, and asset returns. In the RANK model, labor and asset income effects must exactly offset, otherwise a transitory monetary shock would shift consumption permanently. This offset arises through a fall in financial income and a modest rise in labor income, both of which have limited influence on consumption because the representative household's annual MPC is only 0.02. All in all, intertemporal substitution accounts for all of the consumption response.

The OLG-NK model introduces two features that break the permanent income hypothesis: finite planning horizons due to mortality risk and borrowing constraints that can bind for young households. These raise the average MPC to 0.10 and weaken intertemporal substitution. Labor and asset income effects no longer need to sum to zero, although in practice they nearly do. The labor income channel is sizable because young households have both high MPCs and high exposure to labor demand fluctuations.[28] At the same time, the asset

[27]The proximate driver of wage inflation in this class of models, the marginal rate of substitution between labor and consumption, is an unobservable variable.

[28]OLG-NK features heterogeneous worker betas that depend on age but not on income, averaging the

Table 2: Decomposition of Initial Consumption Response to a Monetary Policy Shock

	RANK	OLG-NK	OLG-HANK	OLG-HANK-plus
Total Response	**0.16%**	**0.12%**	**0.18%**	**0.23%**
Mechanisms				
Substitution	0.16%	0.11%	0.07%	0.05%
Labor Income	0.03%	0.09%	0.15%	0.19%
Asset Returns	-0.03%	-0.08%	-0.04%	-0.01%

The table presents a decomposition of the percent deviation of aggregate consumption from steady state in the first year, dC_0/C_{ss}. "Substitution" captures the effect of $\{dR_t^b, dR_t^s\}$ on consumption via the Euler equation; "labor income" captures the effect of $\{dw_t, dL_t, d\tau_t\}$ via the budget and borrowing constraints; and "asset returns" captures the effect of $\{dR_t^b, dR_t^s\}$ via the budget and borrowing constraints. The decomposition is additive because the model is linearized with respect to aggregates.

return channel is strongly negative: every household is either already wealthy or expects to accumulate wealth in the future, making them sensitive to lower financial returns. A large financial income effect that partly offsets intertemporal substitution is a central theme in OLG-NK environments (see, e.g., Beaudry et al., 2024).

The OLG-HANK model adds idiosyncratic income risk, generating within-cohort wealth inequality and a precautionary saving motive. These forces raise the average MPC further to 0.33, making intertemporal substitution weaker still. The labor income channel becomes substantially larger, reflecting the empirically realistic covariance between MPCs and exposure to labor demand fluctuations: young, low-income households face greater changes in earnings with a greater pass-through to their consumption. In contrast, the asset return channel becomes much less negative, even though financial returns fall by more in OLG-HANK than in the other models (see Figure 4). Persistent wealth inequality is key. Although households accumulate wealth on average as they age, within-cohort inequality also widens with age. Many households never accumulate much wealth, leaving them largely insulated from lower returns. Moreover, net borrowers—17 percent of the population and 51 percent among households under age 40 in the model—benefit from lower interest rates and from inflation eroding their debt. Limited wealth accumulation and redistribution from low-MPC savers to high-MPC borrowers attenuate the negative asset income effect and bring it closer to that in RANK than to that in OLG-NK.

General equilibrium decomposition. Partial equilibrium decompositions reveal households' sensitivity to the variables that directly enter their decision problem and how these sensitivities differ across model variants. However, they do not explain why a monetary policy shock moves these variables in the first place. To address this question, we next perform a general equilibrium decomposition following Auclert et al. (2020). We start from the equilibrium paths of the nominal interest rate and inflation $\{R_t^n, \pi_t\}_{t\geq 0}$ in each model which, together with endogenous dividends, determine the various real interest rates that

estimates in Figure 2 across income deciles. See Appendix E for details.

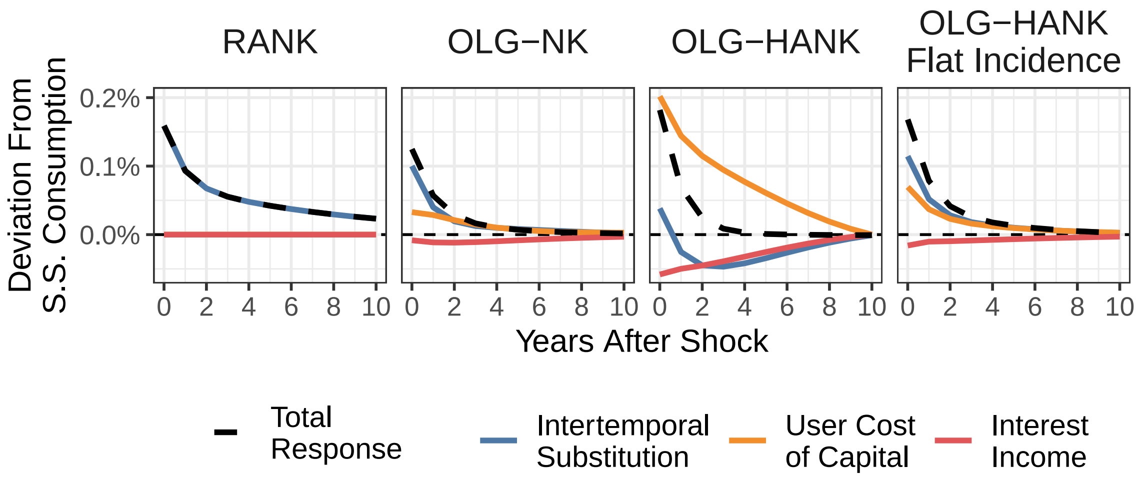


Figure shows the general equilibrium decomposition for a set of models. "OLG-HANK Flat Incidence" corresponds to a model that is identical to OLG-HANK except that it has uniform worker betas. Because the incidence function affects the wage Phillips curve, we recalibrate this version of the model following the procedure in Section 3.3 and targeting the same peak response of real wages as in the other models.

Figure 5: General Equilibrium Decomposition of Consumption Across Models.

affect agents in these economies:

$$R_t^e = \mathbb{E}_t\left[\frac{R_t^n}{\pi_{t+1}}\right], \quad R_t^b = \frac{R_{t-1}^n}{\pi_t}, \quad R_t^s = \frac{p_{t+1}+d_{t+1}}{p_t}$$
$$\text{where } p_t = \mathbb{E}_t\left[\frac{p_{t+1}+d_{t+1}}{R_t^n/\pi_{t+1}}\right].$$

Households care about the expected real interest rate $\{R_t^e\}_{t\geq 0}$ because it governs their intertemporal saving choice, while the realized returns on stocks and bonds $\{R_t^s, R_t^b\}_{t\geq 0}$ enter their budget and borrowing constraints. Firms use $\{R_t^e\}_{t\geq 0}$ to discount future profits, which influences their investment and price setting. The financial intermediary cares about the realized returns on stocks and bonds because they affect its net worth.

Figure 5 presents the general equilibrium decomposition of consumption into three channels: intertemporal substitution (feeding $\{R_t^e\}_{t\geq 0}$ to households), user cost of capital (feeding $\{R_t^e\}_{t\geq 0}$ to firms), and asset returns (feeding $\{R_t^s, R_t^b\}_{t\geq 0}$ to households and the financial intermediary). In each case, every other interest rate is held constant, and labor income (hours, wages, taxes) adjusts so that all equilibrium conditions hold except for the monetary policy rule. In RANK, intertemporal substitution by households is essential for monetary policy to have any effect. In OLG-NK, the user cost channel emerges as an additional, quantitatively relevant transmission mechanism: lower interest rates stimulate investment and labor demand; in equilibrium, households earn higher labor income and consume more even though interest rates are held fixed. Nonetheless, intertemporal substitution remains dominant, as most households are far from being borrowing constrained and increase their consumption when they expect persistently low interest rates.

OLG-HANK shows much larger departures from the RANK benchmark. First, the user cost channel dominates monetary transmission. Second, intertemporal substitution reduces consumption rather than increasing it in most periods. Third, the asset returns channel is greatly amplified. All three differences stem from the much higher sensitivity of consumption to labor income, which creates a strong complementarity between consumption and investment. The user cost effect is analogous to that in OLG-NK, just far stronger. The first-round impact of intertemporal substitution is that unconstrained households pull some consumption forward, but the resulting increase in aggregate demand is not strong enough to create a sustained boom. Firms anticipate weaker future demand and reduce investment accordingly. Similarly, the direct effect of lower asset returns is a small but persistent decline in consumption, which is then amplified by the associated fall in investment and labor demand.

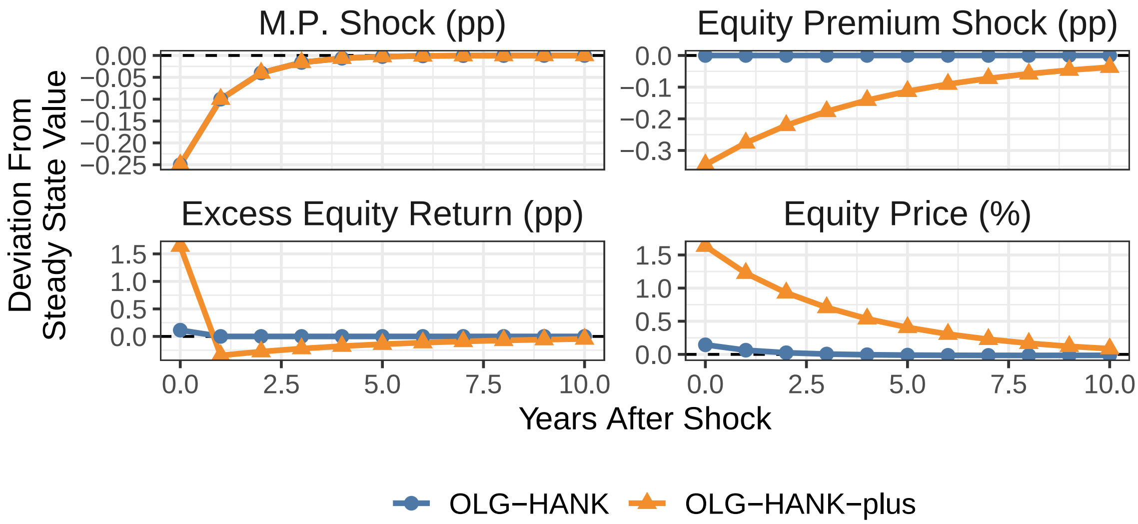
The firm investment transmission channel in OLG-HANK is greatly strengthened by the unequal incidence of labor fluctuations. The fourth panel of Figure 5 demonstrates this by performing the same decomposition in a version of the model where the incomes of all workers have the same elasticity with respect to aggregate earnings. The contribution of the user cost channel falls to less than half of its magnitude in OLG-HANK. Therefore, a crucial gear of monetary transmission in our baseline model is that, when firms invest, they disproportionately increase the incomes of young and low-income workers who are eager to spend these additional earnings. This further increases firms' incentives to invest in a persistent amplification cycle that explains most of the consumption increase at all horizons. Thus, empirically realistic MPCs and worker betas make monetary transmission *firm-centric*: it starts with firms' investment and labor demand decisions rather than with households' intertemporal substitution.

Refining the response of equity prices. In our baseline OLG-HANK model, a 25-basis-point expansionary monetary policy shock raises the price of equities by 14 basis points in the first year. This is far smaller than the 1–2 percentage point effects commonly found in empirical studies (including Rigobon & Sack, 2004; Bernanke & Kuttner, 2005; Gürkaynak et al., 2005; Kekre & Lenel, 2022; Bianchi et al., 2022). New Keynesian models generally struggle to generate substantial stock price responses. Capital adjustment costs and a relatively high degree of wage stickiness help, but are insufficient. This difficulty is unsurprising: empirical evidence indicates that monetary policy raises stock prices primarily by reducing the risk premium, rather than through higher dividends or a lower risk-free rate (see Bernanke & Kuttner, 2005; Kekre & Lenel, 2022). Like most New Keynesian models, ours does not capture this risk premium channel.

Because portfolios are heterogeneous and vary with age and wealth, the repricing of equities can be an important element of the transmission and distributional effects of monetary policy. Therefore, to evaluate the effects of a more vigorous appreciation of equities, we consider an ad hoc extension that allows the model to generate equity returns aligned with the empirical evidence without introducing aggregate risk. We augment the equity pricing equation with an exogenous equity premium term

$$p_t = \mathbb{E}_t \left[\frac{p_{t+1} + d_{t+1}}{R_t^e + \varepsilon_t^{RP}} \right].$$

A decline in ε_t^{RP}, which is zero in steady state, raises the equity price by lowering their



OLG-HANK corresponds to the same model and shock specification as that presented in Figure 4. OLG-HANK-plus is a specification where the monetary policy shock is accompanied by a shock to the equity premium. The excess equity return is $R_t^s - R_t^b$ and the equity price is p_t. The top two panels are exogenous shocks, while the bottom two panels correspond to endogenous equilibrium responses from the model.

Figure 6: Equity Responses in OLG-HANK-Plus.

discount rate, mimicking the effect of reduced macroeconomic uncertainty or a rise in risk appetite in reduced form.

We present an extended experiment where monetary easing lowers both ε_t^{MP} and ε_t^{RP}. The equity premium shock follows an AR(1) process with a persistence that approximates the dynamics of the excess return in Kekre and Lenel (2022).[29] We choose the shock size to produce a 1.5 percentage point jump in the equity return R_t^s, around the midpoint of empirical estimates. Figure 6 shows the calibrated path of ε_t^{RP} and compares the responses of the equity price and the excess return in the extended model ("OLG-HANK-plus") with those in the baseline. As intended, the stock price rises more than ten times as much in OLG-HANK-plus as in OLG-HANK. The initial jump in the excess return is followed by small, negative values, consistent with a persistent—but not permanent—rise in equity prices in response to a transitory monetary expansion.

The last column of Table 2 reports the partial equilibrium consumption decomposition in the extended model.[30] The strong appreciation of equities amplifies the aggregate consumption response by almost 30 percent relative to OLG-HANK. The overall contribution of asset prices to consumption remains negative but is much smaller than in the baseline.[31] The initial rise in the stock price compensates equity-holding households for lower returns

[29]Their Figure 2 shows that, after the initial jump, the excess return becomes negative and declines from roughly 65 basis points to 45 basis points over 20 months, implying an annual discrete decay rate of 0.2.

[30]For this exercise, we input the altered path of equity returns only to the budget constraint of households. We use the ex-ante return on bonds in their Euler equation to calculate the substitution effect.

[31]Table C.1 in Appendix C shows that the asset returns channel is dominated by negative returns on bonds, with equity returns alone providing a small positive contribution.

going forward, allowing them to consume more and boosting labor income for young and low-income households. Intertemporal substitution weakens further, as the central bank must raise the nominal interest rate in the medium run in response to higher inflation generated by the small but persistent increase in consumption financed by stock market gains.[32]

4.2 Distributional Effects

We now turn to the distributional effects of monetary policy across age and income groups. We begin by briefly outlining the empirical procedure used to construct the Swedish income responses that serve as our benchmark. We then compare them with their counterparts in our models. Finally, we examine the model-implied consumption responses.

Empirical specification. Our empirical analysis uses the LISA dataset from Sweden. We build on Amberg et al. (2022), but tailor their approach to our setting by differentiating households by both age and income, and by constructing measures of labor and financial income that map as closely as possible into the model. Specifically, we exclude income from the ownership of businesses and real estate, as well as interest expenses, which in Sweden capture mostly mortgage debt. As a result, our measure of labor income corresponds to pre-tax wages and salaries, while financial income consists of net realized capital gains, dividends, and interest income. A detailed description of the sample and variable definitions can be found in Appendix F.

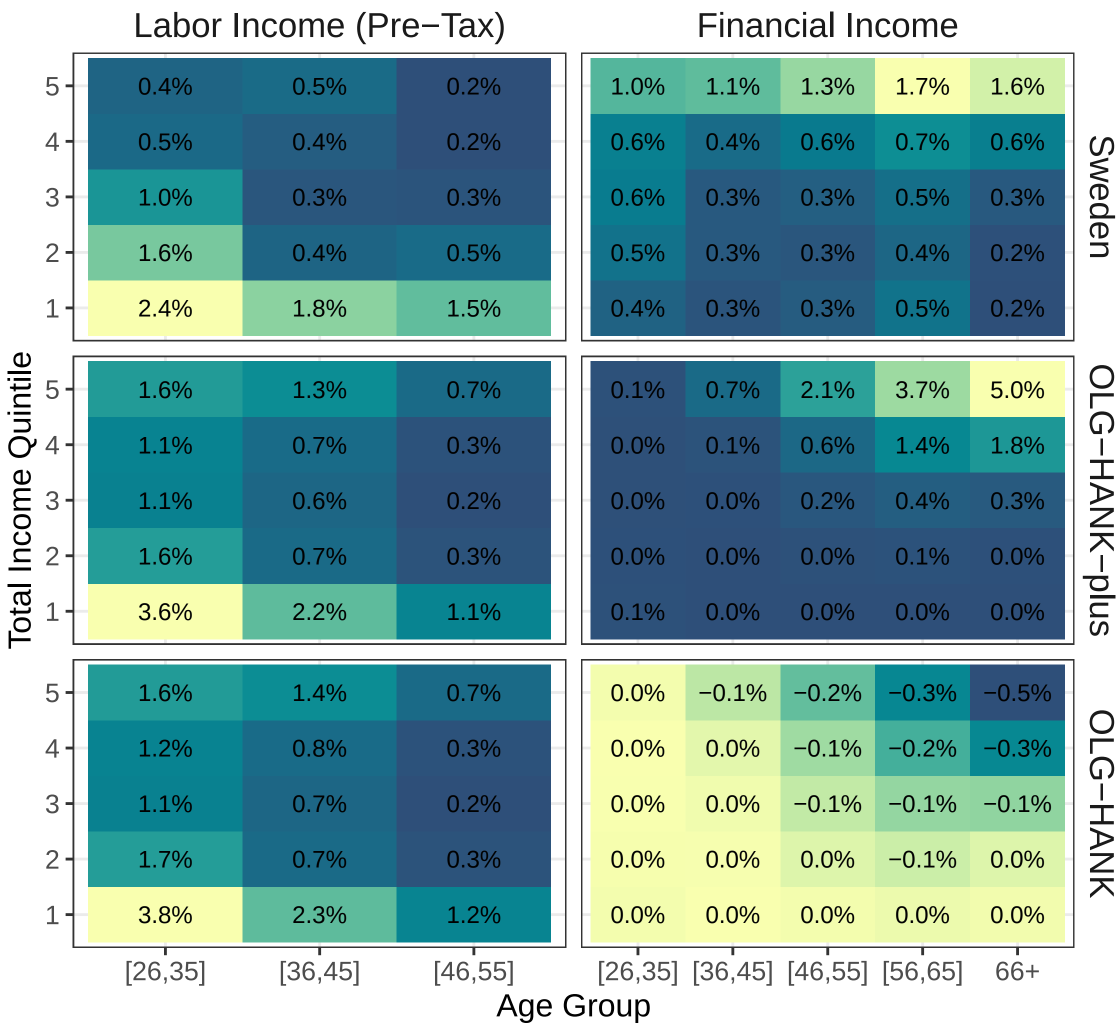
We estimate the response of both income components to an identified monetary policy shock using the following regressions,

$$\frac{x_{i,t+2} - x_{i,t-1}}{y^{AT}_{i,t-1}} = \alpha^x_g + \beta^x_g \cdot \widehat{\Delta i}_t + u_{it}, \tag{9}$$

where $x_{i,t}$ is the labor or financial income of individual i in year t and $y^{AT}_{i,t}$ is his total after-tax income. The shock $\widehat{\Delta i}_t$ comes from Amberg et al. (2022) and captures changes in the Riksbank's policy rate instrumented by high-frequency surprises and purged of the central bank information effect following Jarociński and Karadi (2020). We run these regressions separately for total income quintiles within ten-year age groups indexed by g. We choose the $t + 2$ time horizon to capture the peak responses to monetary policy shocks, as Amberg et al. (2022) do.

Income responses. The top two panels of Figure 7 depict the β^x_g coefficients scaled to represent the effect of a 25-basis-point easing. These values correspond to changes in labor and financial income expressed as percentages of total after-tax income before the shock, which makes them comparable to each other. Labor income responses are positive and decrease with age. They generally decline with income as well, except for the middle age group, for whom we see a U shape. Financial income responses, by contrast, increase with income and are particularly large for the top quintile. The age profile is increasing for the top income quintile and U-shaped for other working-age households before falling off

[32]The full set of impulse responses for OLG-HANK-plus is in Figure C.1 of Appendix C.



Panels show labor and financial income responses to a 25-basis-point monetary expansion across age groups (columns) and income quintiles (rows). Top panels report Sweden's empirical estimates; middle and bottom panels show the OLG-HANK and OLG-HANK-plus results. Labor income responses are shown for prime-age workers, while financial income responses cover all individuals aged 26 and older. Color gradients are specific to each panel to highlight distributional patterns: yellow corresponds to the maximum value of each panel and dark blue to the minimum.

Figure 7: Response to Monetary Policy Shock: OLG-HANK-Plus and Sweden.

in retirement. Notably, labor income rises more than financial income for most working-age households, lending support to the prominent role of labor markets in our narrative of monetary transmission.

The middle and bottom panels of Figure 7 display the corresponding responses in our OLG-HANK-plus and OLG-HANK models. To construct the model analogs of β_g^x, we compute three-year changes in individual incomes ending at the peak response at $t = 0$. We then subtract the change in income under no shock from that under the monetary policy shock. Formally, for each state configuration $s_{-3} = (j, z, a_{-1})$ we compute

$$\beta^x(s_{-3}) = \frac{\mathbb{E}\left[x_0 \mid s_{-3}, \text{shock}\right] - x_{-3}}{y_{-3}^{AT}} - \frac{\mathbb{E}\left[x_0 \mid s_{-3}, \text{no shock}\right] - x_{-3}}{y_{-3}^{AT}}$$

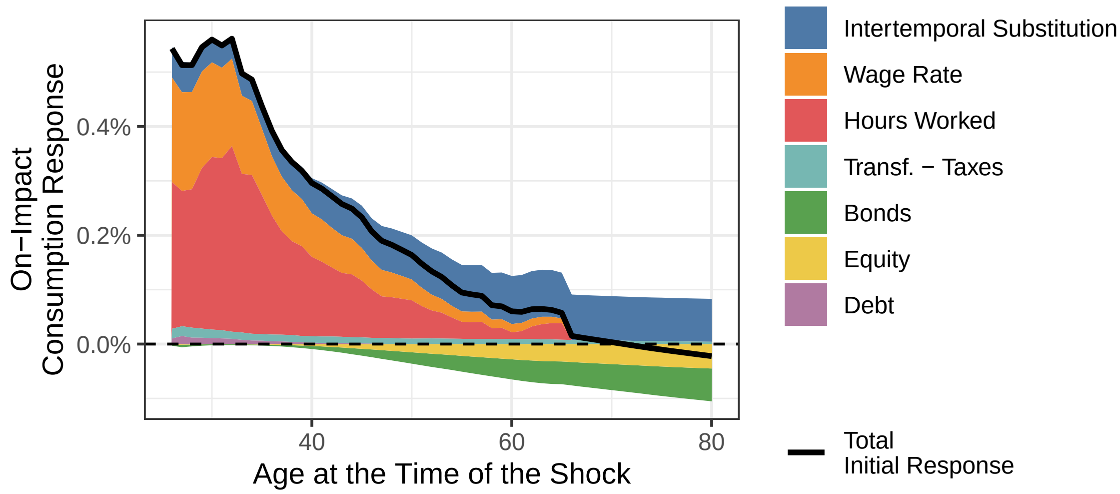
and then average these responses across households within each group g using the steady-state distribution.[33] The resulting responses are comparable to the empirical estimates, subject to two caveats. First, we create income groups based on income in $t = -3$ rather than a three-year moving average as in the data.[34] Second, and more importantly, the model does not distinguish realized and unrealized capital gains: all financial income is realized every year. In the data, however, we only observe realized capital gains. This makes the comparison of financial income responses imperfect, but still informative about qualitative patterns.

The labor income responses fit the distributional pattern of the empirical estimates very well. The two models imply almost identical responses: positive, declining with age, and displaying a U shape by income. The magnitudes are generally larger but not too different, considering that aggregate and household-level responses are both untargeted. We emphasize that while we impose an incidence function for labor income estimated on unconditional business cycle fluctuations, this exercise considers the distributional effects of monetary policy specifically. The model's ability to replicate the distributional patterns of income changes, together with its realistic MPCs, supports its predictions about unobserved outcomes: consumption and welfare effects.

The financial income responses differ markedly between the models. OLG-HANK-plus implies positive responses, while OLG-HANK implies negative responses. In both cases, the magnitude of the response increases with age and income, mirroring the distribution of wealth. The response of equities is crucial: it overturns the negative effects of nominal wealth dilution in OLG-HANK-plus but not in OLG-HANK. As a result, OLG-HANK-plus better captures the empirical estimates, which are also positive and increasing with income. The main discrepancy is that, in Sweden, even young and low-income households enjoy nontrivial gains in financial income. This finding may reflect Sweden's unusually high stock market participation across the wealth distribution. Guiso and Sodini (2012) report that 40 percent of Swedish households own stocks directly, compared with 19 percent in the U.S. The difference is even larger in the bottom quartile of the wealth distribution, with a participation rate of 13 percent versus 1 percent in favor of Sweden. It is also plausible that

[33] In the model, using the notation from Section 2, pre-tax labor income is $y(z)$, financial income is $R(a_{-1}) \cdot \max\{a_{-1}, 0\}$ (excluding interest payments as we do in the data), and total income is pre-tax labor income minus taxes plus financial income.

[34] The model features only persistent income shocks, so this is a good approximation.



We consider an expansionary shock as described in Section 4.1. We index cohorts by their age at the time of the shock. We calculate the on-impact change in the total consumption (dC_0) of each cohort. To decompose the response into its channels, we calculate the responses to the shock-induced changes in subsets of variables, leaving all others at their steady-state values. "Intertemporal substitution" captures the effect of $\{dR_t^b, dR_t^s\}$ on consumption via the Euler equation. "Wage Rate" captures that of $\{dw_t\}$. "Hours Worked" captures that of $\{dL_t\}$. "Transf. - Taxes" captures that of $\{d\tau_t\}$. "Bonds" captures that of $\{dR_t^b\}$ via the budget constraint of households with positive assets. "Equity" captures that of $\{dR_t^s\}$ via the budget constraint. "Debt" captures that of $\{dR_t^b\}$ via the budget constraint of households with negative assets and the borrowing constraint. The decomposition is additive because it is based on the linearized aggregate consumption function of each cohort.

Figure 8: Transmission of an Expansionary Monetary Policy Shock Across the Life Cycle

young households—who tend to have high MPCs—are more likely to realize some of their capital gains when stock prices rise.

All in all, Figures 7 and C.1 in Appendix C show that OLG-HANK and OLG-HANK-plus have very similar implications for both macroeconomic variables and the distribution of labor income. The only substantial difference is in the stock price response itself, which primarily affects older, wealthy households. Therefore, we keep the more conventional OLG-HANK model as our baseline specification for the remainder of the paper. Nevertheless, we discuss the consumption and welfare implications of OLG-HANK-plus and report the corresponding exhibits in the Appendix.

Consumption responses. We now inspect the consumption responses of the cohorts that inhabit our OLG-HANK economy in the period when the monetary policy shock is realized. Using the tools developed in Bardóczy and Velásquez-Giraldo (2025), we calculate age-specific Jacobians that linearize the aggregate consumption function of each cohort and use them to compute additive partial equilibrium decompositions, as we did for total consumption in Tables 2 and C.1. Figure 8 presents the decompositions, showing the change in the aggregate consumption on impact for every cohort and the share of the total response due to each input of the household block.

Our first finding is that cohorts' consumption responses decline steeply with age in OLG-HANK. The total consumption of 30-year-olds increases by 0.56 percent, roughly three times more than aggregate consumption in Table 2. Responses wane for cohorts approaching retirement and turn negative for older cohorts: 55-year-olds' consumption increases by 0.09

percent and that of 80-year-olds decreases by 0.02 percent. More than half of the aggregate response comes from households below age 38, and in net terms its entirety comes from working-age households.[35] A consumption response declining steeply with age is consistent with the empirical evidence from Wong (2019) and Braun and Ikeda (2025).[36]

Our second finding is that households respond to different economic forces over the life cycle. For young cohorts, consumption rises almost entirely because their labor income increases: they have volatile hours and high MPCs. They also hold little wealth, so the asset income channels are muted. While inflation dilutes nominal debt, this channel only gives a small boost to their consumption because indebted households have lower MPCs.[37] Middle-aged cohorts are saving for retirement, have more stable work arrangements, and have lower MPCs. Intertemporal substitution is the largest driver of their response; for example, it accounts for the full response of 55-year-olds, with the other channels offsetting each other. The consumption of older retirees falls, on average, because of lower returns on their accumulated savings. As Figure 1 shows, however, most old households have little wealth, so the negative effects are concentrated in a few wealthy households. For example, the consumption of 80-year-olds falls by 0.02 percent, but this is entirely driven by the wealthiest quartile. The consumption of the bottom three quartiles of 80-year-olds actually increases by 0.01 percent due to slightly lower taxes on their pensions.

How does accounting for within-cohort inequality change our understanding of monetary transmission over the life cycle? First, Section 4.1 showed that within-cohort inequality changes the equilibrium forces to which households ultimately respond. Second, as the example of 80-year-olds above demonstrates, the response to these forces can differ—even in sign—across households within a cohort. Third, within-cohort inequality changes the relative strength of different transmission mechanisms for the aggregate consumption of each cohort: it strengthens disposable income effects and weakens substitution and asset return effects. Table C.2 in Appendix C refines the partial equilibrium decomposition of Table 2, zooming in on the consumption response of different cohorts and comparing the OLG-HANK and OLG-NK models. For cohorts aged 30, 55, and 80, the substitution effect is 100 percent, 33 percent, and 25 percent stronger in OLG-NK than in OLG-HANK, respectively. Negative asset return effects are 40 percent stronger for the 55-year-old cohort and 36 percent stronger for the 80-year-old cohort in OLG-NK; they become positive for the 30-year-olds in OLG-HANK because indebted households benefit from debt erosion. The OLG-NK model is asset-centric because its households are either rich or waiting to be rich. They are born close to their borrowing constraint, but they all know with certainty that the only shock that can prevent them from becoming millionaires is death (see Figure E.1).

Imposing a realistic stock market appreciation mostly affects the consumption of the wealthy old, increasing it and generating a small trickle-down effect on younger and poorer

[35]Figure C.2 of Appendix C plots the share of aggregate consumption response due to each cohort.

[36]Wong (2019) finds that 83 percent of the one-year consumption response to an interest rate shock is due to 25–34-year-olds, 15 percent is due to 35–64-year-olds, and only 2 percent is due to 65–75-year-olds. These are shares out of the total response of 25–75-year-olds. The analogous shares in our model are 39 percent (25 to 34), 60 percent (35 to 64), and 1 percent (65 to 75).

[37]Given the high interest rate on debt, indebted households use some of their additional income to pay down debt. This model prediction finds empirical support in, for example, Colarieti et al. (2024) and Koşar et al. (2025).

households. This additional consumption is reported in the OLG-HANK-plus column of Table 2. Figure C.3 of Appendix C recreates the consumption decomposition across the life cycle in the OLG-HANK-plus experiment in which the monetary policy shock also lowers risk premia. The largest difference between Figures 8 and C.3 is that a large positive contribution from equity returns appears for retirees and makes the age profile of the total response U-shaped: consumption increases most for the youngest and oldest cohorts. The 80-year-old cohort now increases its aggregate consumption by 0.12 percent, 0.14 percentage points more than in our baseline. Those in the top quartile of wealth contribute 0.13 of this 0.14 percentage-point change: they now experience large capital gains. The consumption of 30-year-olds increases by 0.61 percent and that of 55-year-olds by 0.12 percent, 0.05 and 0.03 percentage points more than in our baseline results. The effect of equity returns on middle-aged cohorts remains negative despite the initial appreciation: these households plan to be equity buyers in the handful of years after the shock and, therefore, high current prices with low future returns leave them worse off (Del Canto et al., 2025, document a similar effect).

5 Welfare

We now examine the welfare effects of the expansionary shock. Monetary policy changes the present and future paths of income and asset returns that households face. The magnitude of these changes and their effect on lifetime welfare depend on each household's situation (their age, productivity, and portfolio) when the shock arrives. We use our models to quantify these welfare effects and their causes, and to characterize the groups of households that are most exposed to them. We also compare our conclusions with those arise from a model with homogeneous cohorts.

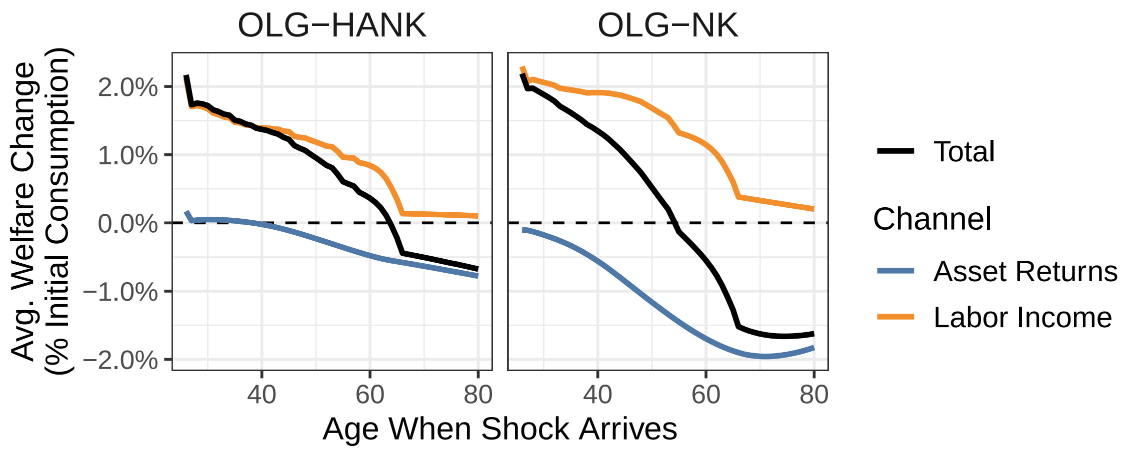
From a household's perspective, a monetary policy shock at time t is a change in the sequence of macroeconomic inputs to its problem $\{w_t, L_t, R_t^b, R_t^s, \tau_t\}_{s\geq 0}$. Using $V_{j,SS}^{(1)}$ to denote the value of a household aged j in the absence of a shock (when aggregates remain at their steady state) and $V_{j,0}^{(1)}$ its value right after the announcement, the welfare effect of the shock is $V_{j,0}^{(1)}(z, a_{-1}) - V_{j,SS}^{(1)}(z, a_{-1})$. We find first order approximations of equivalent variations to these welfare changes and rescale them by the consumption households would have had in steady state:

$$\Delta_j(z, a_{-1}) \equiv \frac{1}{c_{j,SS}(z, a_{-1})} \cdot \frac{V_{j,0}^{(1)}(z, a_{-1}) - V_{j,SS}^{(1)}(z, a_{-1})}{\partial V_{j,SS}^{(1)}(z, a_{-1})/\partial a_{-1}}. \tag{10}$$

The metric $\Delta_j(z, a_{-1})$ is the cash transfer that would take a household of age j, with realized productivity z and assets a_{-1}, to the same level of welfare as the monetary policy shock, expressed as a fraction of the consumption it planned for the year of the shock.[38] A positive Δ_j means the household gains welfare from the shock.

In our baseline OLG-HANK model, a monetary expansion benefits young cohorts on average by raising their labor income and harms old cohorts on average by lowering their asset returns. Figure 9 depicts the average welfare effect for households of different ages.

[38] The true equivalent variation x solves $V_{j,0}^{(1)}(z, a_{-1}) = V_{j,SS}^{(1)}(z, a_{-1} + x)$. We rely on the approximation $V_{j,SS}^{(1)}(z, a_{-1} + x) \approx V_{j,SS}^{(1)}(z, a_{-1}) + x \cdot \partial V_{j,SS}^{(1)}(z, a_{-1})/\partial a_{-1}$.



Average welfare effects for households of different ages in the OLG-HANK and OLG-NK models. The total effect is decomposed into contributions from asset returns and labor income. Welfare changes are expressed as percentage deviations in initial consumption.

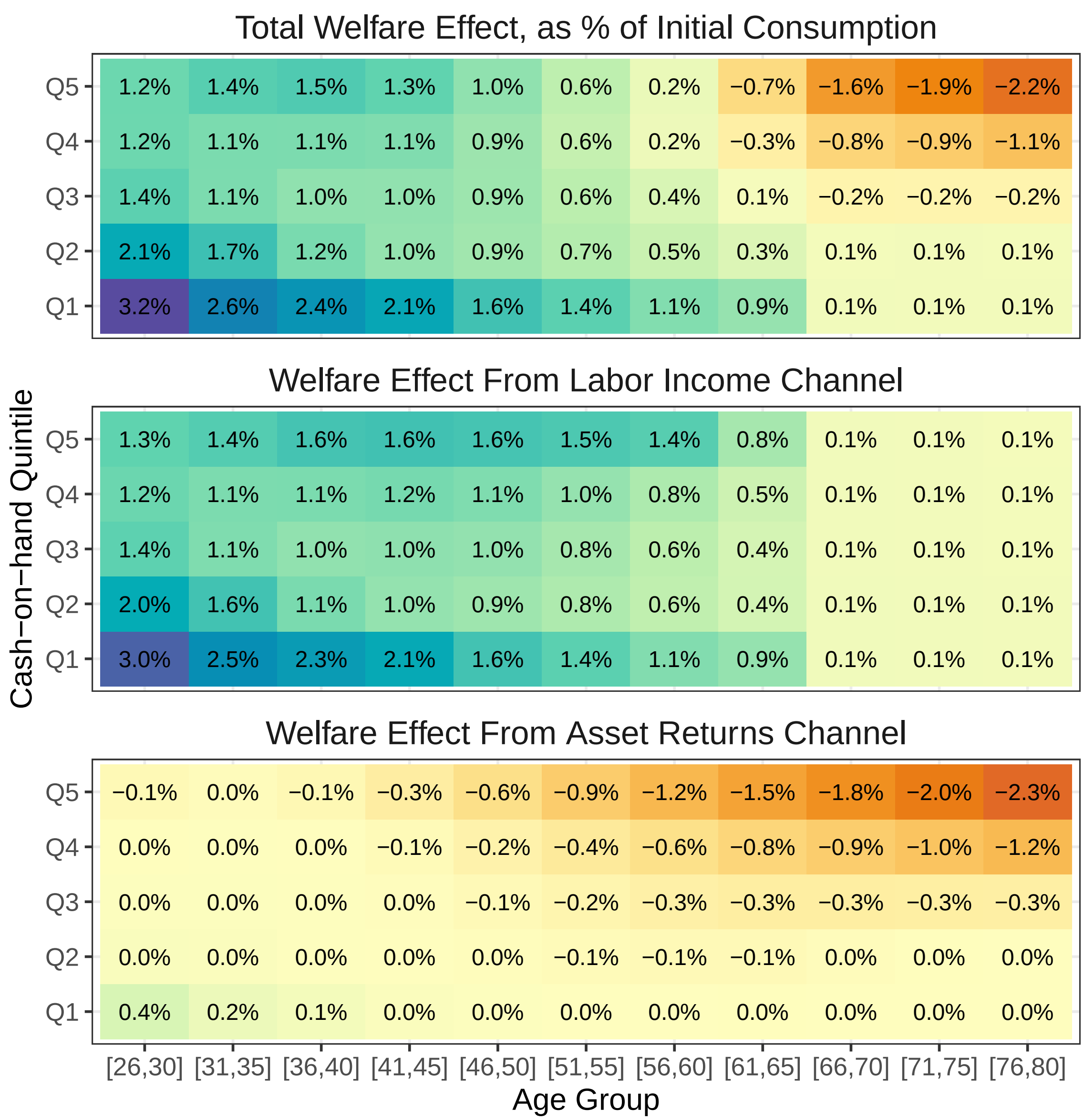
Figure 9: Average Welfare Effects in OLG-HANK and OLG-NK

The left panel uses our baseline OLG-HANK model and shows a clear negative slope in the total effect, with 30-year-olds gaining 1.7 percent of their initial consumption and 80-year-olds losing 0.7 percent of theirs. The figure decomposes the total effect into labor income channels, which only change $\{w_t, L_t, \tau_t\}_{t\geq 0}$, and asset returns channels, which only change $\{R_t^b, R_t^s\}_{t\geq 0}$. The decomposition echoes our findings for consumption in Section 4.2: greater income from buoyant labor markets accounts for most of the welfare gains of young cohorts, and lower sequences of returns on accumulated assets account for most of the welfare losses of old cohorts.

These average effects resemble findings from previous studies of redistribution between overlapping cohorts of homogeneous households, which we represent with the OLG-NK specification in the right panel of Figure 9. This specification also implies that young households gain primarily from rising labor incomes and older households lose primarily from falling asset returns, which is consistent with the findings of Bielecki et al. (2022) and Braun and Ikeda (2025) and with the labor income channel in Del Canto et al. (2025).

The main difference between the average welfare effects in the OLG-HANK and OLG-NK models is the contribution of asset returns. In OLG-HANK, this contribution is positive and small for young cohorts because lower real rates dilute their debt, stays close to zero for those under age 40, and becomes negative and gradually larger for older cohorts, reaching -0.8 percent of consumption for 80-year-olds. In OLG-NK, this effect has a much steeper downward slope: its magnitude is considerable even for 40-year-olds and it reaches -1.8 percent of consumption for 80-year-olds. Due to this steeper slope in the effect of asset returns, estimates of average total welfare losses for retirees in OLG-NK can be more than twice as large as their OLG-HANK counterparts. The forthcoming analysis shows that wealth inequality within retirees is at the core of these differences.

Welfare differences within cohorts can be as large as the differences between cohorts: in OLG-HANK, welfare redistribution runs from the wealthiest old to the poorest young.



Welfare effects are the change in expected discounted utility from period t onwards. We express these changes as an equivalent monetary transfer, rescaled by each household's consumption at time t (see Equation 10). We calculate the welfare metric for every household and group them into bins according to their age. We then split them into age-bin-specific quintiles of cash-on-hand. For each age bin and wealth quintile, we report the average welfare effect. The top panel shows total welfare effects from the monetary policy shock, while the bottom two isolate the labor income and asset returns channels, as defined in the main text.

Figure 10: Welfare Effects of a Monetary Policy Shock by Age and Wealth

In Figure 10, we group households into age bins and quintiles of the age-bin-specific wealth distribution, and present the average welfare effect for each group. The top panel depicts total welfare effects, which range from a 3.2 percent gain for 26–30-year-olds in the lowest wealth quintile to a 2.2 percent loss for 76–80-year-olds in the highest wealth quintile. Wealth shapes a household's exposure to asset return surprises and its valuation of changes in labor income. It is an important driver of heterogeneity that the existing literature on the redistributive effects of monetary policy across generations has not fully accounted for. Indeed, holding an age group fixed in the top panel of Figure 10, we can find welfare effects for the lowest or highest wealth quintiles that are two or even ten times larger than those for the middle quintile.

Both labor income and asset returns, which we isolate in the middle and bottom panels of Figure 10, contribute to the heterogeneity in total welfare effects. The labor income channel declines with age and has a U-shape over wealth, with the lowest and highest wealth households gaining the most. Its shape is governed by our estimated income exposures (see Figure 2) and by households' marginal value of resources. Retirees also perceive a small benefit from lower anticipated taxes. The effect of asset returns is positive for working-age debtors in the lowest wealth quintile, close to zero for most of the population, and negative for older households in the higher wealth quintiles. These households still have a considerable number of years to live (see Figure D.4 in Appendix D), and lower expected returns hurt them mostly by slowing the growth of the wealth they want to hold and bequeath (see Figure D.1 in Appendix D for a decomposition).

The large welfare losses of old cohorts that OLG-NK and previous studies have highlighted are concentrated in a select group of wealthy households; for more than half of retirees, the welfare effects are close to zero. In Figure 9, retirees lose welfare on average due to lower returns on their assets. But the wealth distribution of retirees is skewed: across age groups, their median wealth-to-income ratio is close to 1.0 and the 25th percentile is close to 0.1, while the 75th percentile increases steeply and surpasses 6.0 by age 80. Hence, most retirees in a cohort have far less wealth than the average (or aggregate) wealth-to-income ratio. OLG-HANK reproduces this fact (see Figure 1), whereas OLG-NK does not (see Figure E.1 in Appendix E). The welfare effects of asset returns on the top quintile of retirees in Figure 10 are close to the -2 percent effects of the OLG-NK model in Figure 9 because these are the few households whose wealth is close to average; for most retirees, the effects are much smaller.

In our OLG-HANK-plus specification with a stronger response of equity prices, welfare conclusions about the wealthy old change significantly. Figure D.2 in Appendix D depicts the average welfare effects of a monetary expansion by age and wealth quintiles in our OLG-HANK-plus experiment, and compares them with our baseline results from Figure 10. All age–wealth bins perceive additional welfare gains from strengthened labor markets and weakened fiscal pressures. The main qualitative differences arise for the wealthy old, who own most of the stocks (see Figure B.1 in Appendix B). These households are the biggest losers in the baseline but, with a strong rise in equity prices, they gain welfare in this experiment. For example, the welfare effect on the top wealth quintile of 76–80-year-olds goes from a 2.2 percent loss to a 1.2 percent gain.

In Figure D.3 of Appendix D, we isolate the effects of equity returns in the OLG-HANK-plus experiment. By itself, the jump in equity prices benefits wealthy old households who already own stocks and hurts wealthy working-age households planning to increase their stock holdings: they buy at higher prices and earn lower returns in the future. The magnitude of these effects and their incidence across socioeconomic and age groups are similar to the portfolio channel effects estimated by Del Canto et al. (2025) using a different method based on feasible sets.

In sum, we find that most age and wealth groups benefit from an unexpected monetary expansion, and that the labor income channel accounts for most of the welfare gains.[39] The effects on the wealthiest old depend heavily on changes in financial asset prices that most HANK models (our baseline included) appear to underestimate. However, modeling within-cohort heterogeneity reduces the magnitude of these channels because most households accumulate little financial wealth over their lives.

6 Conclusion

In this paper, we integrate empirically grounded life-cycle dynamics into a HANK environment. Age ties together multiple dimensions of heterogeneity—including wealth, MPCs, and exposure to the business cycle—that shape shock propagation in this class of models. We validate the dynamics of income, wealth, and consumption against the best available evidence. This includes our own analysis of Swedish administrative income records, which shows that monetary easing substantially boosts the labor income of young and low-income households. Interpreted through the lens of our model, this evidence implies that monetary policy operates primarily by stimulating investment and increasing labor demand for this group of workers who consume most of their additional income. While the need to save for retirement exposes households to negative income effects from lower interest rates, this dampening force is secondary to the labor income channel in the aggregate, because most households go through life with little financial wealth.

We consider two specifications for the effect of monetary policy on equity returns. Like most New Keynesian models, our baseline specification implies only a muted increase in equity prices. The second specification matches the robust price response typically found in empirical studies through an exogenous shock to the equity premium. In this second specification, the immediate appreciation of equities followed by lower future returns hurts middle-aged households who are saving for retirement, and benefits older retirees, echoing the results of Del Canto et al. (2025) and Fagereng et al. (2025). Nevertheless, labor income effects remain the dominant driver of the welfare effects of monetary policy shocks, because they are substantial and skewed toward households with the highest marginal value of income.

We highlight two features that may be important but are beyond the scope of our analysis. First, our model features an exogenous equity premium. In a richer model, the equity premium would move endogenously in response to changes in macroeconomic uncertainty and risk appetite. These forces could alter both the aggregate and the distributional effects of monetary policy beyond the mechanical impact on equity prices. Second, we abstract from housing. Housing is the largest item on most households' balance sheets and is a

[39] In interpreting these results, we remind readers that our model takes the anchoring of expectations for granted and does not model the costs of systematically looser monetary policy. See Dávila and Schaab (2023) for a discussion of optimal policy in HANK that confronts expectations under commitment and discretion.

complicated object: a durable consumption good typically purchased with leverage as well as an illiquid asset. We conjecture that properly accounting for housing would have the following implications. Monetary easing raises house prices, which hurts young households who have not yet bought their first home and, more generally, anyone planning to increase their housing stock in the future (Fagereng et al., 2025). Older households planning to downsize may benefit. Monetary easing also lowers mortgage rates and dilutes nominal mortgages, which benefits young homeowners (Wong, 2019; Bielecki et al., 2020; Kinnerud, 2025). We leave a full quantification of these channels in a general equilibrium framework like ours to future research.

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Online Appendix

A Appendix to Section 2

This appendix contains additional details and derivations of our model.

A.1 Production Block

The production block has two types of firms: a representative final goods producer and a unit mass of intermediate goods producers. The role of the final goods firm is to provide a microfoundation for the demand curve faced by the monopolists. The role of the intermediate goods firms is to pin down labor demand, investment, and inflation.

A.1.1 Final Good Producer

Setup. There is a representative firm that buys a continuum of intermediate goods $\{y_{jt}\}$ and turns them into the homogeneous final good Y_t via a constant elasticity of substitution (CES) production function with elasticity $\epsilon_p > 1$. Let the price of the final good be P_t. The profit maximization problem of the firm is

$$\max_{Y_t,\{y_{jt}\}} P_t Y_t - \int_0^1 p_{jt} y_{jt} dj \qquad \text{s.t. } Y_t = \left(\int_0^1 y_{jt}^{\frac{\epsilon_p - 1}{\epsilon_p}} dj\right)^{\frac{\epsilon_p}{\epsilon_p - 1}}.$$

Derivation. Substitute the constraint

$$\max_{\{y_{jt}\}} P_t \left(\int_0^1 y_{jt}^{\frac{\epsilon_p - 1}{\epsilon_p}} dj\right)^{\frac{\epsilon_p}{\epsilon_p - 1}} - \int_0^1 p_{jt} y_{jt} dj.$$

The first order condition (FOC) for y_{jt} is

$$0 = P_t \left(\int_0^1 y_{jt}^{\frac{\epsilon_p - 1}{\epsilon_p}} dj\right)^{\frac{1}{\epsilon_p - 1}} y_{jt}^{\frac{-1}{\epsilon_p}} - p_{jt} = P_t Y_t^{\frac{1}{\epsilon_p}} y_{jt}^{\frac{-1}{\epsilon_p}} - p_{jt},$$

which implies demand curves

$$y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\epsilon_p} Y_t.$$

The final good firm is competitive and makes zero profits. This implies

$$P_t Y_t = \int_0^1 p_{jt} y_{jt} dj = \int_0^1 p_{jt} \left(\frac{p_{jt}}{P_t}\right)^{-\epsilon_p} Y_t dj = P_t^{\epsilon_p} Y_t \int_0^1 p_{jt}^{1-\epsilon_p} dj$$

and, hence, the price index is

$$P_t = \left(\int_0^1 p_{jt}^{1-\epsilon_p} dj\right)^{\frac{1}{1-\epsilon_p}}.$$

A.1.2 Intermediate goods producers

Setup. There is a unit mass of firms indexed by $j \in [0, 1]$ who engage in monopolistic competition. They have Cobb-Douglas production function

$$F(k_{jt-1}, l_{jt}) = \Theta_t k_{jt-1}^{\alpha} l_{jt}^{1-\alpha},$$

face a demand curve

$$y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\epsilon_p} Y_t$$

and set the price of their product subject to a quadratic price adjustment cost

$$\Xi(p_{jt}, p_{jt-1}) = \frac{\chi_p}{2}\left(\frac{p_{jt}}{p_{jt-1}} - 1\right)^2.$$

Firms buy a homogeneous investment good at relative price p_t^I and use it to augment their capital stock subject to a quadratic capital adjustment cost

$$\Psi\left(\frac{k_{jt}}{k_{jt-1}}\right) = \frac{\psi}{2}\left(\frac{k_{jt}}{k_{jt-1}} - 1\right)^2.$$

The profit maximization problem of firm j with states $\Omega_{jt} = \{k_{jt-1}, p_{jt-1}\}$ is

$$\begin{aligned} V_t(\Omega_{jt-1}) = \max_{k_{jt}, i_{jt}, p_{jt}, l_{jt}, y_{jt}} & \frac{p_{jt}}{P_t} y_{jt} - w_t l_{jt} - p_t^I i_{jt} - \Psi\left(\frac{k_{jt}}{k_{jt-1}}\right) k_{jt-1} \\ & - \Xi(p_{jt}, p_{jt-1}) Y_t - fc + \mathbb{E}_t\left[\frac{V_{t+1}(\Omega_{jt})}{R_t^e}\right] \\ \text{s.t. } & k_{jt} = (1-\delta_k) k_{jt-1} + i_{jt} \\ & y_{jt} = \left(\frac{p_{jt}}{P_t}\right)^{-\epsilon_p} Y_t \\ & y_{jt} = F(k_{jt-1}, l_{jt}). \end{aligned}$$

Labor demand derivation. Let's substitute the constraints

$$V_t(\Omega_{jt-1}) = \max_{k_{jt}, p_{jt}, l_{jt}} \frac{p_{jt}}{P_t} F(k_{jt-1}, l_{jt}) - w_t l_{jt} - p_t^I \Big[k_{jt} - (1-\delta_k) k_{jt-1}\Big]$$

$$-\Psi\left(\frac{k_{jt}}{k_{jt-1}}\right) k_{jt-1} - \Xi(p_{jt}, p_{jt-1}) Y_t - fc + \mathbb{E}_t\left[\frac{V_{t+1}(\Omega_{jt})}{R_t^e}\right] - \eta_{jt}\left[F(k_{jt-1}, l_{jt}) - \left(\frac{p_{jt}}{P_t}\right)^{-\epsilon_p} Y_t\right].$$

The FOC for l_{jt} is

$$\eta_{jt} = \frac{p_{jt}}{P_t} - \frac{w_t}{\partial_L F(k_{jt-1}, l_{jt})}.$$

Note that η_{jt} is the marginal profit from producing and selling an additional unit. The marginal profit equals the marginal revenue minus the marginal cost. So we can see from here that the real marginal cost is $mc_{jt} = w_t / \partial_L F(k_{jt-1}, l_{jt})$. In symmetric equilibrium,

$$mc_t = \frac{w_t}{\partial_L F(K_{t-1}, L_t)}.$$

Phillips curve derivation. Note that the partials of price adjustment cost are

$$\partial_{p_{jt}}\Xi(p_{jt},p_{jt-1}) = \chi_p\left(\frac{p_{jt}}{p_{jt-1}}-1\right)\frac{1}{p_{jt-1}}$$
$$\partial_{p_{jt-1}}\Xi(p_{jt},p_{jt-1}) = -\chi_p\left(\frac{p_{jt}}{p_{jt-1}}-1\right)\frac{p_{jt}}{p_{jt-1}^2}.$$

The FOC for p_{jt} is

$$0=\frac{1}{P_t}F(k_{jt-1},l_{jt})-\partial_{p_{jt}}\Xi(p_{jt},p_{jt-1})Y_t+\mathbb{E}_t\left[\frac{\partial_p V_{t+1}(\Omega_{jt})}{R_t^e}\right]-\eta_{jt}\left[\epsilon_p\left(\frac{p_{jt}}{P_t}\right)^{-\epsilon_p-1}\frac{Y_t}{P_t}\right].$$

Let $\pi_t\equiv P_t/P_{t-1}$ denote gross inflation. In symmetric equilibrium, we get

$$\begin{aligned}0&=\frac{Y_t}{P_t}(1-\eta_t\epsilon_p)-\chi_p(\pi_t-1)\frac{Y_t}{P_{t-1}}+\mathbb{E}_t\left[\frac{\partial_p V_{t+1}(\Omega_t)}{R_t^e}\right]\\0&=Y_t(1-\eta_t\epsilon_p)-\chi_p\pi_t(\pi_t-1)Y_t+\mathbb{E}_t\left[\frac{\partial_p V_{t+1}(\Omega_t)}{R_t^e}\right]P_t\\\chi_p\pi_t(\pi_t-1)&=(1-\eta_t\epsilon_p)+\mathbb{E}_t\left[\frac{\partial_p V_{t+1}(\Omega_t)}{R_t^e}\right]\frac{P_t}{Y_t}.\end{aligned}$$

The envelope condition for P_{jt-1} is, using symmetry in the second line,

$$\begin{aligned}\partial_{p_{jt-1}}V_t&=-\partial_{p_{jt-1}}\Xi(p_{jt},p_{jt-1})Y_t=\chi_p\left(\frac{p_{jt}}{p_{jt-1}}-1\right)\frac{p_{jt}}{p_{jt-1}^2}Y_t\\\partial_{p_{t-1}}V_t&=\chi_p\pi_t(\pi_t-1)\frac{Y_t}{P_{t-1}}.\end{aligned}$$

Combining the FOCs yields

$$\begin{aligned}\chi_p\pi_t(\pi_t-1)&=(1-\eta_t\epsilon_p)+\chi_p\mathbb{E}_t\left[\frac{\pi_{t+1}(\pi_{t+1}-1)}{R_t^e}\frac{Y_{t+1}}{P_t}\right]\frac{P_t}{Y_t}\\\pi_t(\pi_t-1)&=\frac{\epsilon_p}{\chi_p}\left(\frac{1}{\epsilon_p}-\eta_t\right)+\mathbb{E}_t\left[\frac{\pi_{t+1}(\pi_{t+1}-1)}{R_t^e}\frac{Y_{t+1}}{Y_t}\right].\end{aligned}$$

Substituting $\eta_t = 1-mc_t$ yields the Phillips curve

$$\pi_t(\pi_t-1)=\frac{\epsilon_p}{\chi_p}\left(mc_t-\frac{\epsilon_p-1}{\epsilon_p}\right)+\mathbb{E}_t\left[\frac{\pi_{t+1}(\pi_{t+1}-1)}{R_t^e}\frac{Y_{t+1}}{Y_t}\right].$$

A slight rearrangement lets us parameterize the slope of the linearized New Keynesian Phillips curve (NKPC), κ_p, directly:

$$\pi_t(\pi_t-1)=\underbrace{\frac{\epsilon_p}{\chi_p}\frac{\epsilon_p-1}{\epsilon_p}}_{\kappa_p}\left(\frac{\epsilon_p}{\epsilon_p-1}mc_t-1\right)+\mathbb{E}_t\left[\frac{\pi_{t+1}(\pi_{t+1}-1)}{R_t^e}\frac{Y_{t+1}}{Y_t}\right].$$

Investment derivation. The FOC for k_{jt} are

$$-p_t^I - \Psi'\left(\frac{k_{jt}}{k_{jt-1}}\right) + \mathbb{E}_t\left[\frac{\partial_{k_{jt}} V_{t+1}(\Omega_{jt})}{R_t^e}\right] = 0$$
$$p_t^I + \Psi'\left(\frac{k_{jt}}{k_{jt-1}}\right) = \mathbb{E}_t\left[\frac{\partial_{k_{jt}} V_{t+1}(\Omega_{jt})}{R_t^e}\right].$$

The right-hand side is Q_t by definition, so we have

$$Q_t = p_t^I + \Psi'\left(\frac{k_{jt}}{k_{jt-1}}\right) = p_t^I + \psi\left(\frac{k_{jt}}{k_{jt-1}} - 1\right).$$

The envelope condition is

$$\partial_{k_{jt-1}} V_t = \frac{p_{jt}}{P_t}\partial_k F(\cdot) + p_t^I(1-\delta_k) - \left[-\Psi'\left(\frac{k_{jt}}{k_{jt-1}}\right)\frac{k_{jt}}{k_{jt-1}} + \Psi\left(\frac{k_{jt}}{k_{jt-1}}\right)\right] - \eta_{jt}\partial_k F(\cdot)$$
$$\partial_{k_{jt-1}} V_t = \left[\frac{p_{jt}}{P_t} - \eta_{jt}\right]\partial_k F(\cdot) + p_t^I(1-\delta_k) + \Psi'\left(\frac{k_{jt}}{k_{jt-1}}\right)\frac{k_{jt}}{k_{jt-1}} - \Psi\left(\frac{k_{jt}}{k_{jt-1}}\right)$$
$$\partial_{k_{jt-1}} V_t = mc_{jt}\partial_k F(\cdot) + p_t^I(1-\delta_k) + \Psi'\left(\frac{k_{jt}}{k_{jt-1}}\right)\frac{k_{jt}}{k_{jt-1}} - \Psi\left(\frac{k_{jt}}{k_{jt-1}}\right).$$

In symmetric equilibrium, we have that

$$\psi\left(\frac{K_t}{K_{t-1}} - 1\right) = Q_t - p_t^I$$
$$R_t^e Q_t = mc_{t+1}\partial_k F_{t+1}(\cdot) + p_{t+1}^I(1-\delta_k) - \Psi\left(\frac{K_{t+1}}{K_t}\right) + \frac{K_{t+1}}{K_t}(Q_{t+1} - p_{t+1}^I).$$

A.1.3 Block representation

The retailers maximize their profit, taking input prices as given. Given the constant-returns-to-scale technology, the level of production is not pinned down by prices alone. So we'll consider aggregate demand as an input to the production block in addition to prices. In sum, given the sequences of inputs $\{Y_t, w_t, R_t^e, p_t^I\}$ and initial condition K_{-1}, the production block returns nine sequences of outputs $\{L_t, K_t, I_t, Q_t, mc_t, \pi_t, p_t, d_t, R_t^s\}$.

- **Production function.** Gives labor:

$$Y_t = F(K_{t-1}, L_t) = \Theta_t K_{t-1}^{\alpha} L_t^{1-\alpha}.$$

- **Labor demand.** Gives marginal cost:

$$mc_t = \frac{w_t}{F_L(K_{t-1}, L_t)} = \frac{1}{1-\alpha}\frac{w_t L_t}{Y_t}.$$

- **Phillips curve.** Gives inflation:

$$\pi_t(\pi_t - 1) = \kappa_p\left(\frac{\epsilon_p}{\epsilon_p - 1}mc_t - 1\right) + \mathbb{E}_t\left[\frac{\pi_{t+1}(\pi_{t+1}-1)}{R_t^e}\frac{Y_{t+1}}{Y_t}\right]. \quad (11)$$

- **Marginal Q.** Gives Q_t:

$$Q_t = \psi \left(\frac{K_t}{K_{t-1}} - 1 \right) + p_t^I. \tag{12}$$

- **Investment Euler.** Gives capital:

$$R_t^e Q_t = \mathbb{E}_t \left[\alpha \frac{Y_{t+1}}{K_t} mc_{t+1} - p_{t+1}^I \frac{I_{t+1}}{K_t} - \frac{\psi}{2} \left(\frac{K_{t+1}}{K_t} - 1 \right)^2 + \frac{K_{t+1}}{K_t} Q_{t+1} \right].$$

- **Capital law of motion.** Gives investment:

$$I_t = K_t - (1 - \delta_k) K_{t-1}$$

- **Profit.** Gives dividends:

$$d_t = Y_t - w_t L_t - p_t^I I_t - \Psi \left(\frac{K_t}{K_{t-1}} \right) K_{t-1} - \frac{\chi_p}{2} (\pi_t - 1)^2 Y_t - fc.$$

- **Equity price.** Gives equity price:

$$p_t = \mathbb{E}_t \left[\frac{d_{t+1} + p_{t+1}}{R_t^e} \right].$$

- **Return on equity.**

$$R_t^s = \frac{p_t + d_t}{p_{t-1}}.$$

A.1.4 Steady state

The calibrated household block pins down $\{R, wL\}$. We must ensure that the firm block is consistent with these values. Nevertheless, there are additional degrees of freedom, which we resolve by choosing three additional targets: the capital-output ratio K/Y, the labor share wL/Y, and the capitalized value of profits to GDP $(p - K)/Y$.

We do not model the production of investment goods separately. The implicit assumption is that investment goods are produced one-to-one from the final good. Therefore, $p_t^I \equiv 1$. Let steady-state inflation be normalized to $\pi = 1$. Then, equations (12) and (11) imply immediately that $Q = 1$ and $mc = (\epsilon_p - 1)/\epsilon_p$. Labor income wL inherited from the household block plus the new targets imply

$$Y = \left(\frac{wL}{Y} \right)^{-1} wL, \qquad K = \left(\frac{K}{Y} \right) Y, \qquad p = \left(\frac{p - K}{Y} + \frac{K}{Y} \right) Y.$$

Next, we can solve for the technology parameters that justify the targeted quantities

$$\alpha = 1 - \frac{wL}{Y} \frac{1}{mc}, \quad \delta_k = 1 + \alpha \frac{Y}{K} mc - R, \quad \Theta = \frac{Y}{K^\alpha L^{1-\alpha}}, \quad fc = Y - wL - I - p(R - 1).$$

Finally, compute investment and flow profits (dividends)

$$I = \delta K, \qquad d = p(R - 1).$$

A.2 Labor Block

The labor block has two types of agents: a representative labor packer and a unit mass of unions. The role of the labor packer is to provide a microfoundation for the demand curves faced by the unions. The role of the unions is to pin down wage inflation via a New Keynesian wage Phillips curve.

A.2.1 Labor packer

Setup. There is a representative firm that buys a continuum of labor services $\{L_{kt}\}$ and turns them into aggregate labor services L_t via a CES production function with elasticity $\epsilon_w > 1$. Let the aggregate nominal wage be w_t^n, and task-specific nominal wages be $\{w_{kt}^n\}$. The profit maximization problem of the labor packer is

$$\max_{L_t, \{L_{kt}\}} w_t^n L_t - \int_0^1 w_{kt}^n L_{kt} dk \qquad \text{s.t. } L_t = \left(\int_0^1 L_{kt}^{\frac{\epsilon_w - 1}{\epsilon_w}} dk \right)^{\frac{\epsilon_w}{\epsilon_w - 1}}.$$

Derivation. Substitute the constraint

$$\max_{\{L_{kt}\}} w_t^n \left(\int_0^1 L_{kt}^{\frac{\epsilon_w - 1}{\epsilon_w}} dk \right)^{\frac{\epsilon_w}{\epsilon_w - 1}} - \int_0^1 w_{kt}^n L_{kt} dk.$$

The FOC for N_{kt} is

$$0 = w_t^n \left(\int_0^1 L_{kt}^{\frac{\epsilon_w - 1}{\epsilon_w}} dk \right)^{\frac{1}{\epsilon_w - 1}} L_{kt}^{\frac{-1}{\epsilon_w}} - w_{kt}^n = w_t^n L_t^{\frac{1}{\epsilon_w}} L_{kt}^{\frac{-1}{\epsilon_w}} - w_{kt}^n,$$

which implies demand curves

$$L_{kt} = \left(\frac{w_{kt}^n}{w_t^n} \right)^{-\epsilon_w} L_t.$$

The labor packer is competitive and makes zero profits. This implies

$$w_t^n L_t = \int_0^1 w_{kt}^n L_{kt} dk = \int_0^1 w_{kt}^n \left(\frac{w_{kt}^n}{w_t^n} \right)^{-\epsilon_w} L_t dk = (w_t^n)^{\epsilon_w} L_t \int_0^1 (w_{kt}^n)^{1-\epsilon_w} dk$$

and, hence, the wage index is

$$w_t^n = \left(\int_0^1 (w_{kt}^n)^{1-\epsilon_w} dk \right)^{\frac{1}{1-\epsilon_w}}.$$

A.2.2 Unions

Setup. There is a union for every labor service $k \in [0, 1]$ that sets the nominal wage w_{kt}^n. To ensure that a symmetric equilibrium exists, we assume that every union represents a representative sample of the working-age population. The objective of the unions is to maximize the welfare of working-age households, taking their consumption-saving decisions and the age-specific labor demand schedule as given. There is a quadratic utility cost of adjusting the nominal wage.

The Bellman equation is

$$V_t(w^n_{k,t-1}) = \frac{1}{\sum_{j=1}^{J_{ret}} D^{(2)}_{j,t}} \sum_{j=1}^{J_{ret}} \int u\big(c_{j,t}(z,a)\big) - v\big(h_{j,t}(z)\big)\, dD^{(2)}_{j,t}$$

$$- \frac{\chi_w}{2}\left(\frac{w^n_{k,t}}{w^n_{k,t-1}} - 1\right)^2 + \beta \mathbb{E}_t\left[V_{t+1}(w^n_{k,t})\right]$$

$$\text{s.t. } L_{k,t} = \left(\frac{w^n_{k,t}}{w^n_t}\right)^{-\epsilon} L_t.$$

Derivation. To ease the exposition, let's write the integral over working-age households indexed by i instead of states (j, z, a) and let μ denote their total mass. Furthermore, let's rewrite the problem in terms of real wages $w_{k,t} = w^n_{k,t}/P_t$ and $w_t = w^n_t/P_t$.

$$V_t(w_{k,t-1}) = \mu^{-1} \int u(c_{i,t}) - v(h_{i,t})\, di - \frac{\chi_w}{2}\left(\pi_t \frac{w_{k,t}}{w_{k,t-1}} - 1\right)^2 + \beta \mathbb{E}_t\left[V_{t+1}(w_{k,t})\right]$$

$$\text{s.t. } L_{k,t} = \left(\frac{w_{k,t}}{w_t}\right)^{-\epsilon} L_t.$$

The FOC is

$$0 = \int \mu^{-1}\left[u'(c_{i,t})\frac{\partial c_{i,t}}{\partial w_{k,t}} - v'(h_{i,t})\frac{\partial h_{i,t}}{\partial w_{k,t}}\right] di - \chi_w\left(\pi_t \frac{w_{k,t}}{w_{k,t-1}} - 1\right)\frac{\pi_t}{w_{k,t-1}} + \beta \mathbb{E}_t\left[V'_{t+1}(w_{k,t})\right].$$

The envelope condition is

$$V'_t(w_{k,t-1}) = \chi_w\left(\pi_t \frac{w_{k,t}}{w_{k,t-1}} - 1\right)\pi_t \frac{w_{k,t}}{w^2_{k,t-1}}.$$

Combining these two yields

$$0 = \int \ldots\, di - \chi_w\left(\pi_t \frac{w_{k,t}}{w_{k,t-1}} - 1\right)\frac{\pi_t}{w_{k,t-1}} + \beta\chi_w\left(\pi_{t+1}\frac{w_{k,t+1}}{w_{k,t}} - 1\right)\pi_{t+1}\frac{w_{k,t+1}}{w^2_{k,t}}.$$

In symmetric equilibrium, all unions set the same wage. Let's define wage inflation $\pi^w_t \equiv \pi_t w_t / w_{t-1}$. Then, we can write

$$\left(\pi^w_t - 1\right)\pi^w_t = \frac{w_t}{\chi_w}\int \ldots\, di + \beta\left(\pi^w_{t+1} - 1\right)\pi^w_{t+1}. \tag{13}$$

Unpacking the integral. Let's start with the disutility of labor. For worker i represented by union k, labor demand is

$$h_{i,t} = \frac{\Gamma_j(z, w_{k,t}L_{k,t})}{w_{k,t}} = \frac{\Gamma_j\left(z, w^{1-\epsilon_w}_{k,t} w^{\epsilon_w}_t L_t\right)}{w_{k,t}}.$$

Thus, the partial is

$$\begin{aligned}\frac{\partial h_{i,t}}{\partial w_{k,t}} &= \frac{\partial \Gamma_j(z, w_{k,t}L_{k,t})}{\partial w_{k,t}L_{k,t}} \frac{\partial w_{k,t}L_{k,t}}{\partial w_{k,t}} \frac{1}{w_{k,t}} - \frac{\Gamma_j(z, w_{k,t}L_{k,t})}{w_{k,t}^2} \\ &= \frac{\partial \Gamma_j(z, w_{k,t}L_{k,t})}{\partial w_{k,t}L_{k,t}} (1-\epsilon_w) \frac{L_{k,t}}{w_{k,t}} - \frac{\Gamma_j(z, w_{k,t}L_{k,t})}{w_{k,t}^2} \\ &= (1-\epsilon_w) \frac{\partial \Gamma_j(z, w_{k,t}L_{k,t})}{\partial w_{k,t}L_{k,t}} \frac{L_{k,t}}{w_{k,t}} - \frac{h_{i,t}}{w_{k,t}}.\end{aligned}$$

Note that the envelope theorem applied to the household problem implies that we can evaluate indirect utility as if marginal changes in income are consumed fully. So, instead of consumption, we can take the partial of real, post-tax income:

$$y_{i,t}^{at}(w_{k,t}) = w_{k,t}h_{i,t}z - \mathcal{T}\left(w_{k,t}h_{i,t}z\right).$$

which, using the symmetry $w_{k,t} = w_t$, is

$$\begin{aligned}\frac{\partial y_{i,t}^{at}}{\partial w_t} &= h_{i,t}z + w_t z \frac{\partial h_{i,t}}{\partial w_t} - \mathcal{T}'\left(w_t h_{i,t} z\right) \left[h_{i,t}z + w_t z \frac{\partial h_{i,t}}{\partial w_t}\right] \\ &= \left[1 - \mathcal{T}'\left(w_t h_{i,t} z\right)\right] \left[h_{i,t}z + w_t z \frac{\partial h_{i,t}}{\partial w_t}\right] \\ &= \left[1 - \mathcal{T}'\left(w_t h_{i,t} z\right)\right] \left[h_{i,t}z + h_{i,t}z \left((1-\epsilon_w) \frac{\partial \Gamma_j(z, w_t L_t)}{\partial w_t L_t} \frac{L_t}{h_{i,t}} - 1\right)\right] \\ &= \left[1 - \mathcal{T}'\left(w_t h_{i,t} z\right)\right] h_{i,t} z (1-\epsilon_w) \frac{\partial \Gamma_j(z, w_t L_t)}{\partial w_t L_t} \frac{L_t}{h_{i,t}}.\end{aligned}$$

Plug these back into (13), using the symmetry between unions, to get

$$\begin{aligned}\left(\pi_t^w - 1\right)\pi_t^w =& \frac{1}{\chi_w}\left[\mu^{-1} \int v'(h_{i,t}) h_{i,t} \left((1-\epsilon_w) \frac{\partial \Gamma_j(z, w_t L_t)}{\partial w_t L_t} \frac{L_t}{w_t h_{i,t}} - 1\right) di \right. \\ & \left. - \mu^{-1} \int u'(c_{i,t}) \left[1 - \mathcal{T}'\left(w_{k,t} h_{i,t} z\right)\right] y_{i,t} (1-\epsilon_w) \frac{\partial \Gamma_j(z, w_t L_t)}{\partial w_t L_t} \frac{L_t}{h_{i,t}} \, di\right] \\ & + \beta\left(\pi_{t+1}^w - 1\right)\pi_{t+1}^w.\end{aligned} \tag{14}$$

Sanity check. If labor demand is uniform $\Gamma_j(z, w_t L_t) = w_t L_t$, the working-age population is $\mu = 1$, and the tax function is linear $\mathcal{T}(Y_t) = \tau_t Y_t$, then (14) reduces to

$$\begin{aligned}\left(\pi_t^w - 1\right)\pi_t^w =& \frac{\epsilon_w}{\chi_w}\left[- v'(L_t) L_t - w_t L_t (1-\tau_t) \left(\frac{1-\epsilon_w}{\epsilon_w}\right) \int u'(c_{i,t}) z_{i,t} \, di\right] \\ & + \beta\left(\pi_{t+1}^w - 1\right)\pi_{t+1}^w,\end{aligned}$$

which is the standard wage Phillips curve with heterogeneous households (see e.g. Auclert et al., 2023).

Scaling the Phillips curve. Let's define aggregates C_t^* and L_t^* implicitly via

$$u'(C_t^*) = \mu^{-1} \int u'(c_{i,t}) \Big[1 - \mathcal{T}'\left(w_t h_{i,t} z\right) \Big] y_{i,t} (1-\epsilon_w) \frac{\partial \Gamma_j(z, w_t L_t)}{\partial w_t L_t} \frac{L_t}{h_{i,t}} \, di,$$
$$v'(L_t^*) = \mu^{-1} \int v'(h_{i,t}) h_{i,t} \left((1-\epsilon_w) \frac{\partial \Gamma_j(z, w_t L_t)}{\partial w_t L_t} \frac{L_t}{h_{i,t}} - 1 \right) di.$$

Then, the nonlinear Phillips curve becomes

$$(\pi_t^w - 1)\, \pi_t^w = \frac{1}{\chi_w} \Big[v'(L_t^*) - u'(C_t^*) \Big] + \beta \left(\pi_{t+1}^w - 1 \right) \pi_{t+1}^w. \tag{15}$$

The New Keynesian literature typically works with loglinearized Phillips curves, and calibrates the slope based on the frequency of price or wage adjustments. To follow that strategy, it is useful to loglinearize (15). Let hatted variables denote log-deviations from steady state. Assuming that gross inflation in steady state is 1, we get

$$\hat{\pi}_t^w = \frac{1}{\chi_w} \left[v''(L_{ss}^*) L_{ss}^* \hat{L}_t^* - u''(C_{ss}^*) C_{ss}^* \hat{C}_t^* \right] + \beta \hat{\pi}_{t+1}^w.$$

Using that $v'(L_{ss}^*) = u'(C_{ss}^*)$, we can write this as

$$\hat{\pi}_t^w = \frac{v'(L_{ss}^*)}{\chi_w} \left[\frac{v''(L_{ss}^*) L_{ss}^*}{v'(L_{ss}^*)} \hat{L}_t^* - \frac{u''(C_{ss}^*) C_{ss}^*}{u'(C_{ss}^*)} \hat{C}_t^* \right] + \beta \hat{\pi}_{t+1}^w \tag{16}$$
$$\hat{\pi}_t^w = \underbrace{\frac{v'(L_{ss}^*)}{\chi_w}}_{\kappa_w} \left[\nu \hat{L}_t^* + \rho \hat{C}_t^* \right] + \beta \hat{\pi}_{t+1}^w, \tag{17}$$

where $\nu > 0$ is the reciprocal of the Frisch elasticity, and $\rho > 0$ is relative risk aversion. Equation (17) has the form of a textbook New Keynesian wage Phillips curve with slope $\kappa_w > 0$. In a Calvo model where unions can adjust wages with probability ξ_w, the slope is

$$\kappa_w = \frac{1}{1+\Gamma_w} \frac{[1-\beta(1-\xi_w)]\xi_w}{1-\xi_w}$$

where $\Gamma_w \geq 0$ captures real rigidities. This formula allows us to calibrate the slope of the Phillips curve based on frequency of wage adjustment in micro data.

As a final step, note that we can rewrite the nonlinear Phillips curve (15) as

$$(\pi_t^w - 1)\, \pi_t^w = \kappa_w \left(\frac{v'(L_t^*)}{u'(C_t^*)} - 1 \right) + \beta \left(\pi_{t+1}^w - 1 \right) \pi_{t+1}^w$$

which is equivalent up to first-order, but is conveniently parameterized with κ_w.

A.3 DAG Representation

In this section, we present the directed acyclic graph (DAG) representation of the full macro model. See Auclert et al. (2021) for a formal introduction of the DAG concept.

- Unknowns: $\{R_t^b, Y_t, \tau_t, w_t\}$. Exogenous: $\{\varepsilon_t^{MP}, G_t\}$.
- Compute the ex-ante rate $\{R_t^b\} \to \{R_t^e\}$ as $R_t^e = \mathbb{E}_t[R_{t+1}^b]$.
- Evaluate production block

$$\{Y_t, w_t, R_t^e\} \to \{L_t, K_t, I_t, Q_t, mc_t, \pi_t, p_t, d_t, R_t^s\}.$$

  Note that $p_t^I \equiv 1$ because investment good is the same as the final good in this model.
- Evaluate monetary block $\{\pi_t, \varepsilon_t^{mp}\} \to \{R_t^n\}$.
- Evaluate household block $\{w_t L_t, R_t^b, R_t^s, \tau_t\} \to \{C_t, A_t^s, A_t^b, A_t^-, T_t, \Lambda_t, v'(L_t^*), u'(C_t^*)\}$.
- Evaluate the labor block $\{v'(L_t^*), u'(C_t^*)\} \to \{\pi_t^w\}$.
- Solve the combined fiscal / intermediary block $\{A_t^s, A_t^b, A_t^-, p_t, R_t^s, R_t^b, T_t, \Lambda_t\} \to \{B_t\}$ as follows.
  - Unknown: $\{B_t\}$.
  - Evaluate intermediary block to get $\{d_t^{FI}, N_t\}$ as

$$d_t^{FI} = R_t^s p_{t-1} + R_t^b B_{t-1} - R_t^s A_{t-1}^s - R_t^b(A_{t-1}^b - A_{t-1}^-) - N_{ss} \tag{18}$$
$$N_t = R_t^s p_{t-1} + R_t^b B_{t-1} - R_t^s A_{t-1}^s - R_t^b(-A_{t-1}^-) - d_t^{FI}. \tag{19}$$

  - Evaluate fiscal block to get $\{S_t\}$ as

$$S_t = T_t - G_t + \Lambda_t - \mathcal{E} + d_t^{FI}. \tag{20}$$

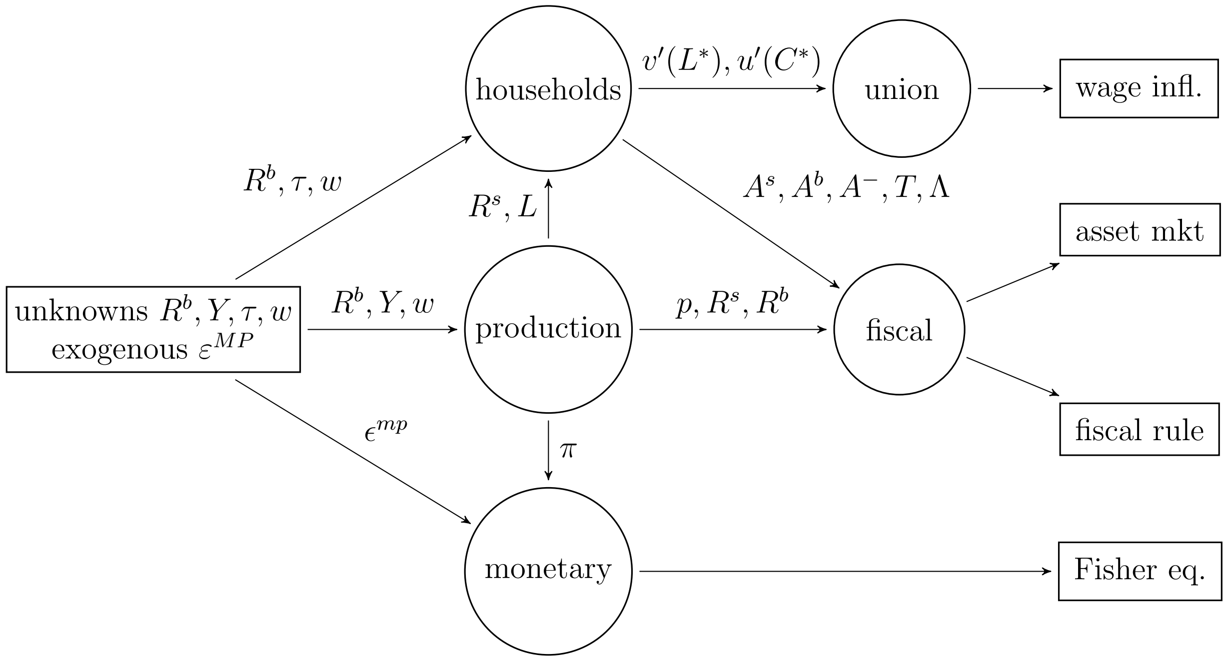
  - Target:

$$0 = B_t + S_t - R_t^b B_{t-1}. \tag{21}$$

- Targets:

$$0 = \frac{R_{t-1}^n}{\pi_t} - R_t^b$$
$$0 = \pi_t^w \frac{w_t}{w_{t-1}} - \pi_t$$
$$0 = \tau_t - \tau_{ss} + \phi \frac{B_{t-1} - B_{ss}}{Y_{ss}}$$
$$0 = p_t + B_t - N_t - A_t^s - (A_t^b - A_t^-).$$

- Validate Walras's law on goods market clearing (7).



The model's blocks can be represented as a directed acyclic graph (DAG). Endogenous sequences that are not produced by any block are treated as "unknowns." By stacking endogenous and exogenous sequences into vectors U and Z, each block of the DAG can be evaluated to generate all endogenous sequences, including those that must equal zero in equilibrium, encoding the mapping $H(U, Z) = 0$.

Figure A.1: Directed Acyclic Graph Representation of the HANK model

B Appendix to Section 3

This appendix contains additional details on the calibration and validation of our model.

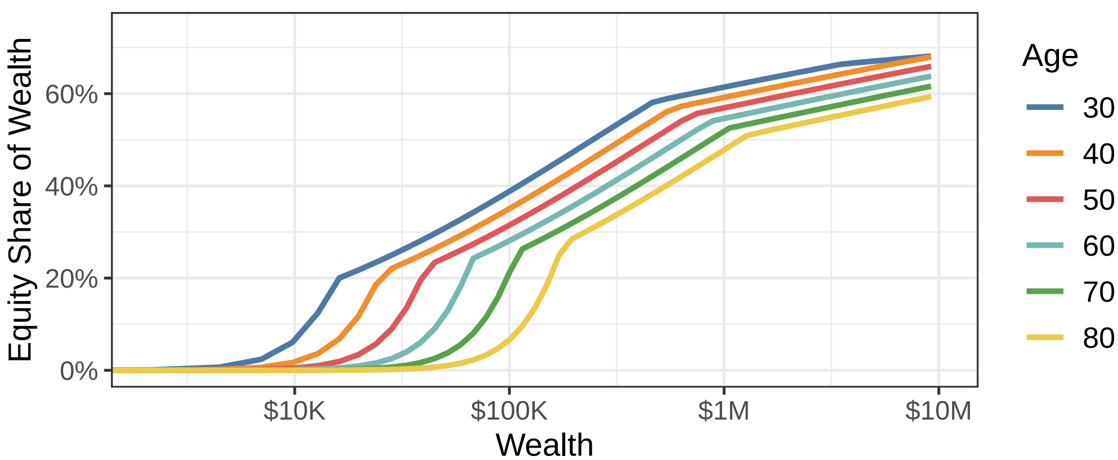
B.1 Calibrating the Exogenous Portfolio Functions

To calibrate our equity share functions, we start by specifying a flexible functional form $\tilde{\zeta}(\cdot, \cdot; \vartheta)$ with auxiliary parameters ϑ. We choose a feed-forward neural network with two inputs (age and assets), a single output (the equity share), and a single hidden layer with eight neurons. We use `ReLu` activations for the input and hidden layers, and a sigmoid activation for the output layer to impose the restriction that shares must be in the unit interval. The simple structure of the network balances our goals of capturing the principal non-linearities in the data and preserving a smooth function.

Then, we estimate this function minimizing its mean absolute error for predicting the equity share of SCF respondents as a function of their age and financial assets,

$$\hat{\vartheta} = \arg\min_{\vartheta} \ \text{average} \left|\left| \tilde{\zeta}(\text{age}_i, \texttt{fin}_i; \vartheta) - (\texttt{eqty}_i / \texttt{fin}_i) \right|\right|,$$

where `eqty` denotes equity holdings (both direct and indirect), `fin` denotes financial assets, and the average is taken over SCF respondents, indexed by i. We use only respondents with positive financial assets.



This figure depicts a non-parametric estimate of the equity portfolio share for different ages and levels of wealth using the 2019 SCF. The estimated function minimizes the mean absolute error of predicted portfolio shares in the SCF micro data.

Figure B.1: Share of Assets in Equity, Estimated Function

The age-specific equity share functions are projections of the estimated flexible function, $\zeta_j(\cdot) \equiv \tilde{\zeta}(j + 26, \cdot; \hat{\vartheta})$. Figure B.1 depicts them for various ages.

B.2 Estimating Worker Betas

This section describes how we estimate the heterogeneous earnings elasticities with respect to aggregate earnings ("worker betas") and how we map them into our model.

Variables and sample selection. We use the Swedish Longitudinal Integrated Database for Health Insurance and Labor Market Studies (LISA), described in detail in Appendix F. Consistently with our model, we focus on labor income from wages and salaries only (labor earnings). For this exercise, we restrict the sample to men of prime-age between 26 and 55 years old with strictly positive labor earnings in years t, $t-1$, and $t-2$. We adjusted all income variables to real terms using the GDP price deflator with 2015 as the base year. Our final sample for this exercise comprises 38.67 million individual-year observations and 3.19 million unique individuals covering the sample period 1997-2018.

Estimation. We group individuals into five-year age bins—26–30, 31–35, 36–40, 41–45, 46–50, 51–55—and ranked into income deciles within each age–year cell. We construct income deciles using a measure of past average labor earnings. Let $y_{i,t-k}$ denote the real annual labor earnings of individual i in year $t-k$. The target measure is the average labor earnings over the years $t-6$ to $t-2$,

$$\bar{y}^{(5)}_{i,t-2} = \frac{1}{5}\sum_{k=2}^{6} y_{i,t-k}.$$

If one or more of these labor earnings observations are missing, we recalculate the average using the longest uninterrupted sequence of available labor earnings ending in $t-2$. Formally,

$$\bar{y}_{i,t-2} = \frac{1}{m_i}\sum_{k=2}^{m_i+1} y_{i,t-k},$$

where $m_i \in \{1,2,3,4,5\}$ is the largest number of consecutive non-missing labor earnings observations available backward from $t-2$. We assign percentiles separately by year and age group. For each group, we then run the regression

$$\Delta \ln y_{i,t} = \alpha_g + \beta_g \Delta \ln W_t + \epsilon_{i,t}, \tag{22}$$

where $\Delta \ln y_{i,t}$ is the log real labor earnings growth of worker i from year $t-1$ to t and $\Delta \ln W_t$ is log real aggregate labor earnings growth from year $t-1$ to t.

Derivation of model counterparts. Our goal is to map worker betas into the model nonparametrically. Recall that pre-tax income is given by $y_{j,t}(z) = z \cdot \Gamma_j(z, W_t)$, where $\Gamma_j(z, W_t)$ is an incidence function that satisfies the following adding-up constraint

$$\sum_{j=1}^{J_{ret}} \int z \cdot \Gamma_j(z, W_t)\, dD^{(2)}_{j,t} = W_t \qquad \text{for any } W_t \tag{23}$$

and is such that, in steady-state, income per efficiency unit is equalized across households

$$\Gamma_j(z, W_{ss}) = \frac{W_{ss}}{\sum_{j=1}^{J_{ret}} \int z\, dD^{(2)}_{j,t}} = \frac{W_{ss}}{\mu_z} \qquad \text{for } j = 1, \ldots, J_{ret} \text{ and any } z.$$

The effect of a marginal change in aggregate log-earnings on the log-earnings of an individual worker is

$$\begin{aligned}\Delta \ln y_{i,t} &= \ln z_{i,t} + \ln \Gamma_{j_{i,t}}(z_{i,t}, W_t) - (\ln z_{i,t} + \ln \Gamma_{j_{i,t}}(z_{i,t}, W_{ss})) \\ &\approx \frac{\Gamma^W_{j_{i,t}}(z_{i,t}, W_{ss})}{\Gamma_{j_{i,t}}(z_{i,t}, W_{ss})}(W_t - W_{ss}) \approx \frac{\Gamma^W_{j_{i,t}}(z_{i,t}, W_{ss}) \cdot W_{ss}}{\Gamma_{j_{i,t}}(z_{i,t}, W_{ss})}(\ln W_t - \ln W_{ss}) \\ &= \underbrace{\Gamma^W_{j_{i,t}}(z_{i,t}, W_{ss}) \cdot \mu_z}_{\equiv \beta_{j_{i,t}}(z_{i,t})} \cdot (\ln W_t - \ln W_{ss}) = \beta_{j_{i,t}}(z_{i,t}) \cdot (\ln W_t - \ln W_{ss}),\end{aligned}$$

where $\Gamma^W(\cdot, \cdot)$ terms denote derivatives of incidence functions with respect to aggregate income. We interpret the β_g estimates from (22) as empirical counterparts of $\beta_{j_{i,t}}(z_{i,t})$.

Normalization. The β_g's we obtain from regressions will generally not satisfy the adding-up constraint (23). That constraint, differentiating and evaluating at W_{ss}, implies that

$$\sum_{j=1}^{J_{ret}} \int z \cdot \Gamma^W_j(z, W_{ss})\, dD^{(2)}_{j,t} = 1,$$

which is equivalent to

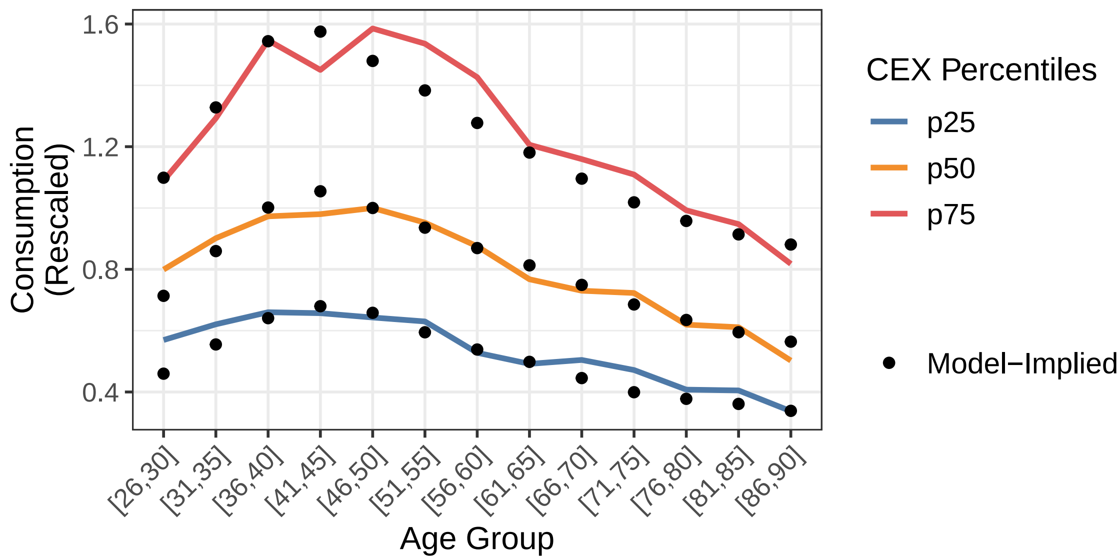
$$\sum_{j=1}^{J_{ret}} \int z \cdot \beta_j(z)\, dD^{(2)}_{j,t} = \mu_z.$$

Thus, we scale the estimated β_g's with a multiplicative factor to ensure that this constraint is satisfied.

Implementation details. We now describe how we transform the β_g empirical estimates into the $\beta_j(z)$ that we use in our model for every age j and productivity level z.

We start from β_g estimates where g indexes combinations of 5-year age bins from $[26, 30]$ to $[51, 55]$ and age-bin-specific labor income deciles. We interpolate linearly over ages to find age-specific β's for each income decile from ages 26 to 65. Specifically, we use the mid-points of each age bracket (28, 33, 38, ...) as the interpolation nodes and use flat extrapolation above age 55. Next, we match each age-specific productivity gridpoint with a β. Note that there are 54 productivity gridpoints for each age: 3 individual fixed effects times 18 persistent-shock values. So, we find the age-specific distributions of productivity (z) implied by our model in steady state, split these distributions into age-specific deciles and find the decile that each productivity gridpoint belongs to. Each age-specific z gridpoint receives the β of its age and decile. Finally, we normalize the β's multiplying them by $\mu_z / \left(\sum_{j=1}^{J_{ret}} \int z \cdot \beta_j(z)\, dD^{(2)}_{j,t}\right)$.

B.3 Life Cycle Profiles of Consumption



Our measure of consumption in the 2019 CEX is annual total expenditures. We divide the consumption percentiles that we obtain from both the CEX and the model by the median consumption of households in the 46-50 age bracket: $49,800 in the CEX data and $56,600 in the model.

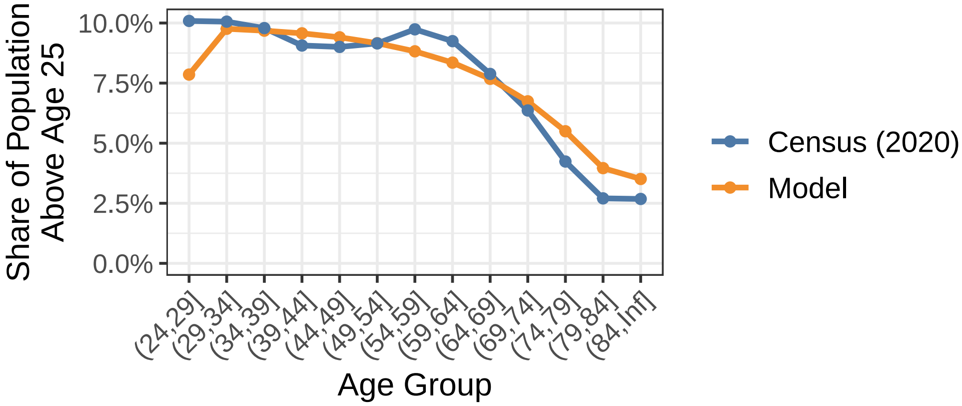
Figure B.2: Age-Profiles of Consumption in the Data and in the Model

We compare the implied path of consumption across the life cycle in our model to the 2019 Consumer Expenditure Survey (CEX). Our measure of consumption in the CEX is "annual expenditures," its broadest aggregate. In both the CEX and the steady-state distribution of our model, we compute the 25th, 50th and 75th percentiles of consumption within 5-year age bins. This gives a sense of consumption heterogeneity across the life cycle as well as within cohorts.

An extensive literature has argued that expenditures in the CEX understate what would be the macroeconomically ideal measure of consumption (see the essays in Carroll et al., 2015, for a summary and quantification of these arguments).[40] Therefore, before comparing our model with the CEX, we scale the age profiles of consumption by the median consumption of the 46-50 age bracket. This scaling factor is $49,800 in the CEX data and $56,600 in our model; their ratio, 0.88, is close to the 0.74 coverage ratio of comparable personal consumption expenditures that Passero et al. (2014) estimate for the CEX in 2010, indicating that our model matches well the average level of consumption. Proceeding with the normalized consumption moments, Figure B.2 shows that our model matches the age profile of consumption and its dispersion very well.

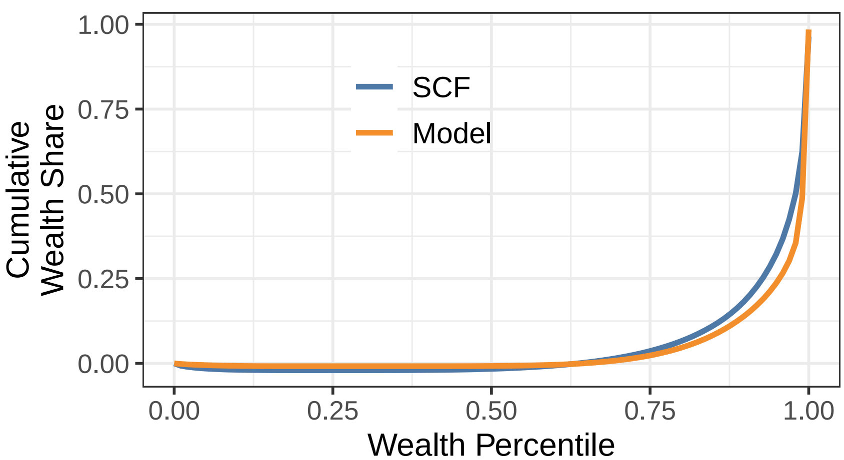
[40]For example, Bee et al. (2013) and Passero et al. (2014). See also Attanasio and Pistaferri (2016).

B.4 Additional Figures and Tables



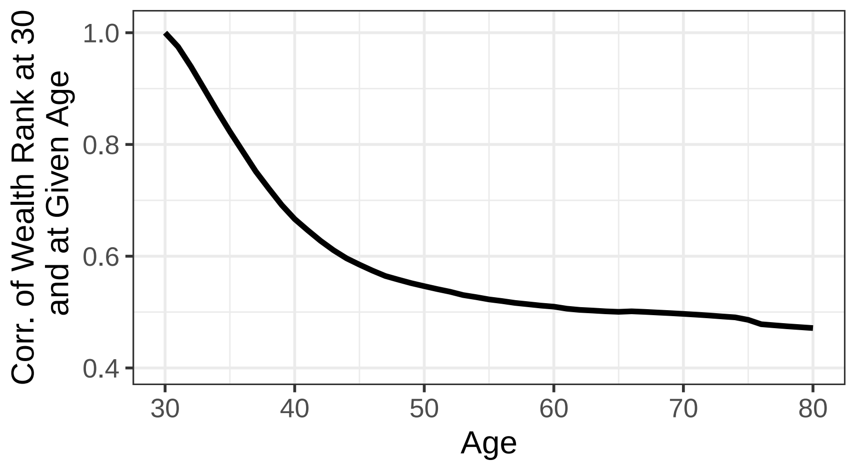
This figure depicts the age distribution of our simulated populations, comparing them with estimates from the 2020 Census. The first bin for the line that corresponds to the model is artificially lower because the model starts at age 26 and the Census bin at age 25; this bin has one less year for the model. Population shares in the model monotonically decrease with age due to survival probabilities and birthrates that are constant over time.

Figure B.3: Age Distribution of Households: Model and 2020 Census



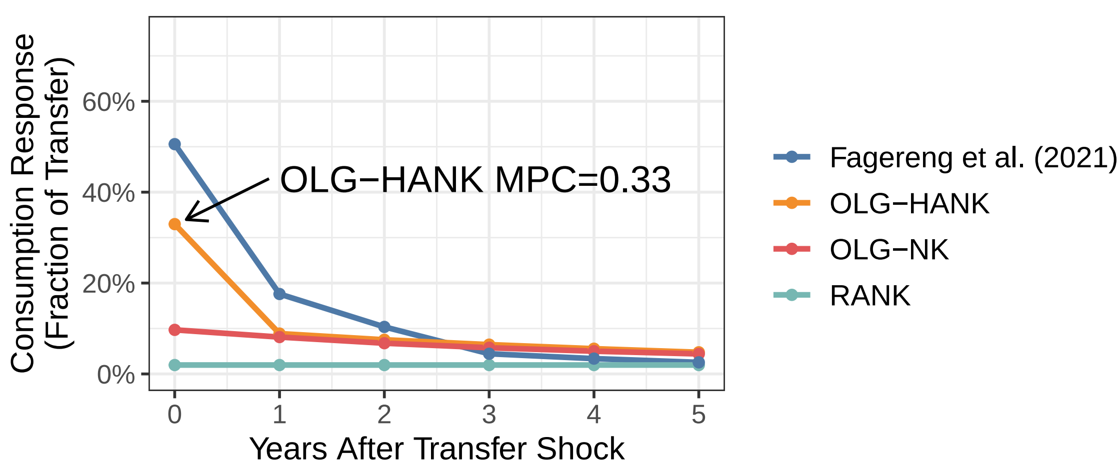
"SCF" corresponds the distribution of our measure of net financial wealth in the 2019 Survey of Consumer Finances; see the main text for a definition. Model-implied corresponds to the distribution of end-of-period assets, a', in the steady state of our OLG HANK model. The curves can dip below 0 because there are observations with negative wealth in both data and model.

Figure B.4: Empirical and Model-Implied Lorenz Curves for Wealth



This figure depicts the correlation of an agent's within-cohort wealth rank at age 30 with its expected within-cohort wealth rank in future ages, conditional on survival, in the aggregate steady state of the OLG-HANK model. We find the expected cash-on-hand rank at every age conditional on being at every cash-on-hand point at age 30. We linearly regress the future expected ranks on the age-30 cash-on-hand rank of every point, weighing by the age-30 steady state distribution. The y-axis values are the slope coefficients of these regressions for every age.

Figure B.5: Wealth Rank Persistence in OLG-HANK



The figure presents intertemporal marginal propensities to consume, which are the aggregate consumption responses at different horizons to a lump-sum transfer received by all agents at time 0. It compares the aggregate iMPC of the household sector in all the models we discuss in the main text to the estimates of Fagereng et al. (2021). For each line, the value at time 0 is the marginal propensity to consume (MPC).

Figure B.6: Intertemporal Marginal Propensities to Consume (iMPCs)

Table B.1: MPCs, Wealth, and Age

	Univariate		Multivariate	
Variable	Coef.	Coef. × Std.Dev.	Coef.	Coef. × Std.Dev.
Age	-0.003	-0.045	-0.003	-0.039
Cash-on-Hand ($100,000s)	-3.528	-0.047	-3.091	-0.041

This table presents estimates from regressions of the form $\text{MPC}_{i,t} = \alpha + \beta X_{i,t} + \varepsilon_{i,t}$ on the steady state distribution of our OLG HANK model. Its purpose is to be compared with Table 8 of Fagereng et al. (2021); thus we restrict our sample to households of age 75 or younger. Columns two and three present estimates from two distinct univariate regressions where age or cash-on-hand are the sole independent variable. Columns three and four present estimates from a regression that includes both simultaneously. Columns titled "Coef." present the $\hat{\beta}$ estimate. Columns titled "Coef.× Std. Dev." scale it by the standard deviation of the independent variable to quantify the effect of a one-standard-deviation increase. "Cash-on-hand" in our model is $R_{j,t}(a_{-1})a_{-1} + y_{j,t}(z) - \mathcal{T}(y_{j,t}(z), \tau_t)$. We do not include income as a control because, in our annual model, its correlation with different measures of wealth can vary significantly depending on timing assumptions and thus make results unstable.

Table B.2: Calibration of Macroeconomic Aggregates

Quantity	Symbol	Value
Macro Aggregates (Steady State)		
Return Factors	$\{R^e, R^b, R^s\}$	1.02
Consumption Ratio	C/Y	0.51
Net HH. Wealth Ratio	A/Y	1.95
Capital Ratio	K/Y	2.26
Investment Ratio	I/Y	0.25
Dividends Ratio	d/Y	0.05
Government Spending Ratio	G/Y	0.24
Government Debt Ratio	B/Y	0.70
Bequest Ratio	Λ/Y	0.09
Parameters		
Frisch Elasticity	$1/\nu$	0.50
Labor Disutility Mult.	φ	1.37
Taylor Rule Coeff. on Inflation	ϕ_π	1.50
Fiscal Coeff. on Debt	ϕ	0.10
Wage P.C. Slope	κ_w	0.02
Goods P.C. Slope	κ_p	0.24
Capital Share	α	0.29
Capital Adjustment Cost	ψ	1.23
Capital Dep. Rate	δ_k	0.11

See the main text for the targets and rationale behind the calibration. For macro aggregates, the table reports steady state-values; Y is steady state output, as defined in Equation 7.

C Appendix to Section 4

This appendix contains additional details and results related to our analysis of the monetary policy transmission mechanisms.

C.1 Estimating Heterogeneous Income Responses

Here we provide details about the empirical procedure used to construct the Swedish income responses. As in Section 3.2, the sample is restricted to male households, and labor income refers exclusively to pre-taxes wages and salaries excluding income from businesses. Our measure of financial income is the sum of net realized capital gains, dividends, and interest income. We exclude real estate income and interest expenses which in Sweden capture mostly mortgage debt. Appendix F provides details on the dataset, variables and sample construction.

For both income variables, we construct two-year forward changes relative to a one-year lag and, to absorb scale differences across individuals, we normalize these changes by initial after-tax income $Y^{AT}_{i,t-1}$. The latter equals labor income plus capital income and transfers, net of taxes imputed using the 2018 Swedish tax schedule, following Amberg et al. (2022).[41] Specifically, for both labor and financial income, we define

$$y^X_{it} = \frac{X_{i,t+2} - X_{i,t-1}}{Y^{AT}_{i,t-1}}.$$

Thus y^W_{it} and y^F_{it} measure two-year changes in wage and financial income, respectively, expressed in units of initial after-tax income. Our goal is to quantify how these two income components respond to a monetary policy shock across the age and permanent-income distributions. The identification strategy exploits time-series variation in the monetary policy shock $\widehat{\Delta i}_t$, taken from Amberg et al. (2022) and interacted with exogenous cross-sectional characteristics (age and income).[42] The shock is common to all individuals each year and is assumed orthogonal to individual-level disturbances, with group composition taken as unaffected by the shock.

To characterize heterogeneity in responses, we organize individuals along 10 year age-groups and permanent income. For every individual i and year t, permanent income is constructed as the moving average of the second to fourth lags of pre-tax total income.[43] Based on this distribution, each individual is assigned to one of five permanent-income quintiles. Hence, for each income component $X \in \{W, F\}$, and estimating the regression separately for total income quintiles within age groups indexed by g, we run:

$$y^X_{it} = \alpha^X_g + \beta^X_g \cdot \widehat{\Delta i}_t + u_{it},$$

[41] See their Online Appendix B for details.

[42] This shock series is identified through a high-frequency strategy based on monetary surprises represented by changes in one-month Treasury bill yields on policy announcement days adjusted for central-bank information effects following Jarociński and Karadi (2020).

[43] Individuals are included in the sample only if they have observed income in $t-1$, $t+h$, and in at least one year between $t-4$ and $t-2$. The construction of past income and income growth relies on non-overlapping periods, ensuring that current income changes do not influence an individual's position in the income distribution.

where y_{it}^X is the labor or financial income of individual i in year t as defined above and $\widehat{\Delta i}_t$ the monetary policy shock. The coefficients β_g^X capture how the response of income component X to a monetary policy shock varies across permanent-income quintiles within each age group. Estimated coefficients are expressed as percentage changes and are rescaled to reflect the effects of a 25 basis point expansionary monetary policy shock over a two-year horizon. We focus on this timeframe, as the impact on Swedish aggregates materializes around two years after the shock (see Amberg et al., 2022).

C.2 Additional Tables and Figures

Table C.1: Detailed Decomposition of Consumption Response to a Monetary Policy Shock

	RANK	OLG-NK	OLG-HANK	OLG-HANK-plus
Total Response	**0.16%**	**0.12%**	**0.18%**	**0.23%**
Mechanisms				
Substitution	0.16%	0.11%	0.07%	0.05%
Labor Income	0.03%	0.09%	0.15%	0.19%
Asset Returns	-0.03%	-0.08%	-0.04%	-0.01%
Labor income sub-components				
Wage	0.01%	0.03%	0.05%	0.05%
Labor Demand	0.01%	0.04%	0.09%	0.09%
Taxes and Transfers	0.01%	0.02%	0.01%	0.06%
Asset returns sub-components				
Bond Returns	-0.02%	-0.05%	-0.03%	-0.02%
Equity Returns	-0.02%	-0.03%	-0.02%	0.01%
Debt Interest	0.00%	0.00%	0.00%	0.00%

The table presents decompositions of the percent deviation from steady state in the first year: dC_0/C_{ss} after a monetary policy shock in different models. The decompositions are additive because they come from linearized aggregate versions of the models.

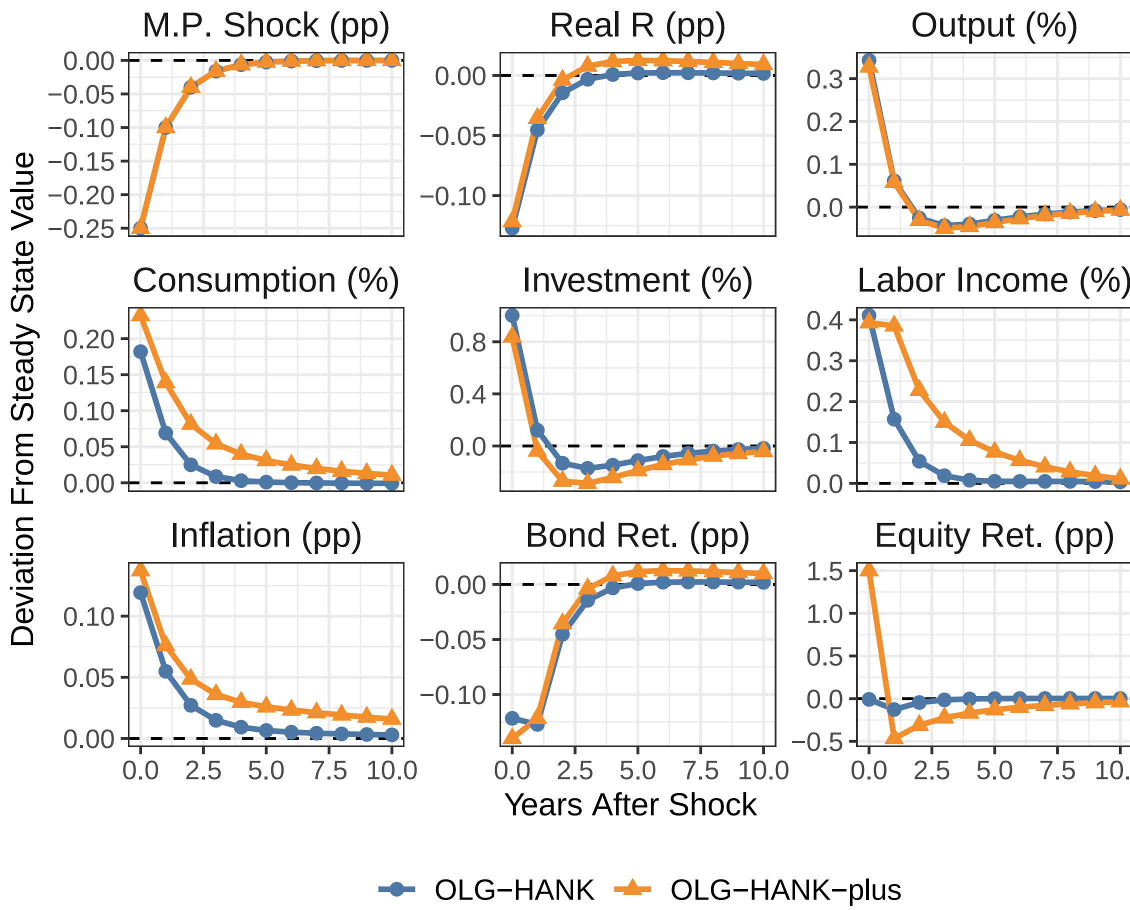
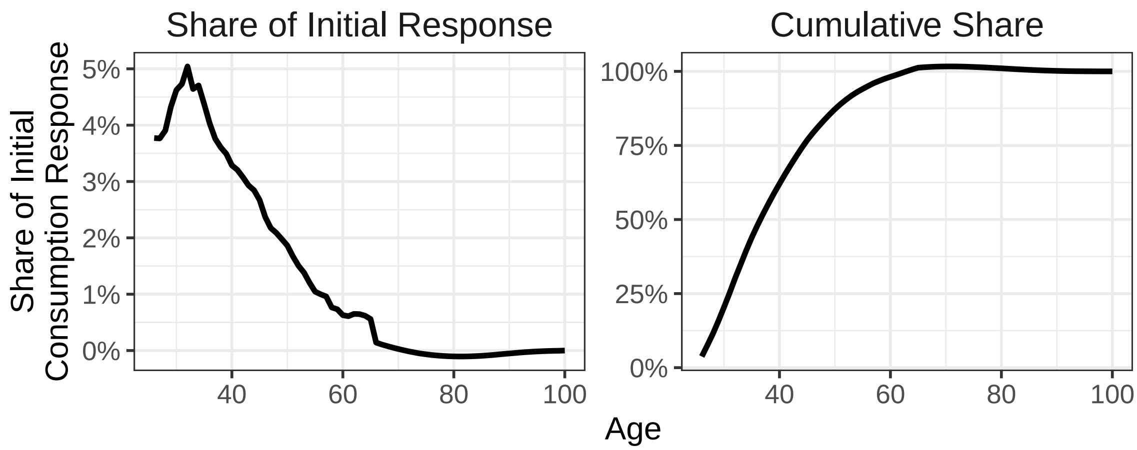


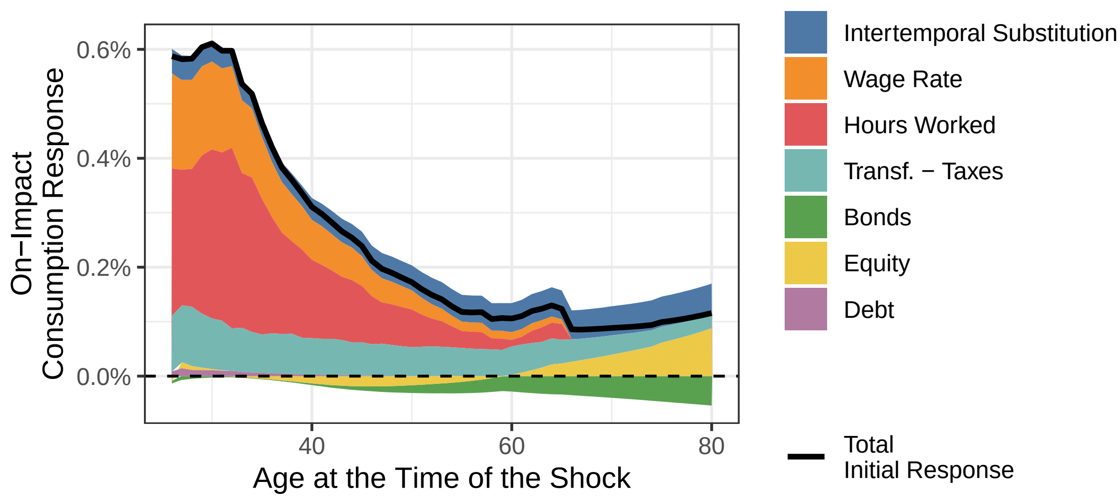
Figure presents impulse responses of different models to the same expansionary monetary policy shock. "Real Interest Rate" is R_t^e, the ex-ante rate used to discount future payments. "Inflation" is goods inflation. See the main text for model definitions.

Figure C.1: Responses to an Expansionary Monetary Policy Shock in OLG-HANK-plus



This figure decomposes the total response in aggregate consumption at the time the monetary policy shock is announced, $C_t - C_{SS}$, into the parts that are due to households of different ages at time t. The left panel displays, for each age, the share of the initial consumption response that comes from the cohort of households of that given age. The right panel presents the cumulative distribution of the shares in the left panel: the share of the response due to households younger than a given age.

Figure C.2: Incidence of the Initial Consumption Response Across Cohorts



We consider an expansionary shock to monetary policy and risk premia as described in Section 4.1 for the "OLG-HANK-plus" specification. We index cohorts by their age at the time of the shock. We calculate the on-impact change in the total consumption (dC_0) of each cohort. To decompose the response into its channels, we calculate the responses to the shock-induced changes in subsets of variables, leaving all others in their steady state-values. "Intertemporal substitution" captures the effect of $\{dR^b_t, dR^s_t\}$ on consumption via the Euler equation."Wage Rate" that of $\{dw_t\}$. "Hours Worked" that of $\{dL_t\}$. "Transf. - Taxes" that of $\{d\tau_t\}$. "Bonds" that of $\{dR^b_t\}$ via the budget constraint of households with positive assets. "Equity" that of $\{dR^s_t\}$ via the budget constraint. "Debt" that of $\{dR^b_t\}$ via the budget constraint of households with negative assets and the borrowing constraint. The decomposition is additive because it is based on the linearized aggregate consumption function of each cohort.

Figure C.3: Monetary Policy Transmission Across the Life Cycle on OLG-HANK-plus

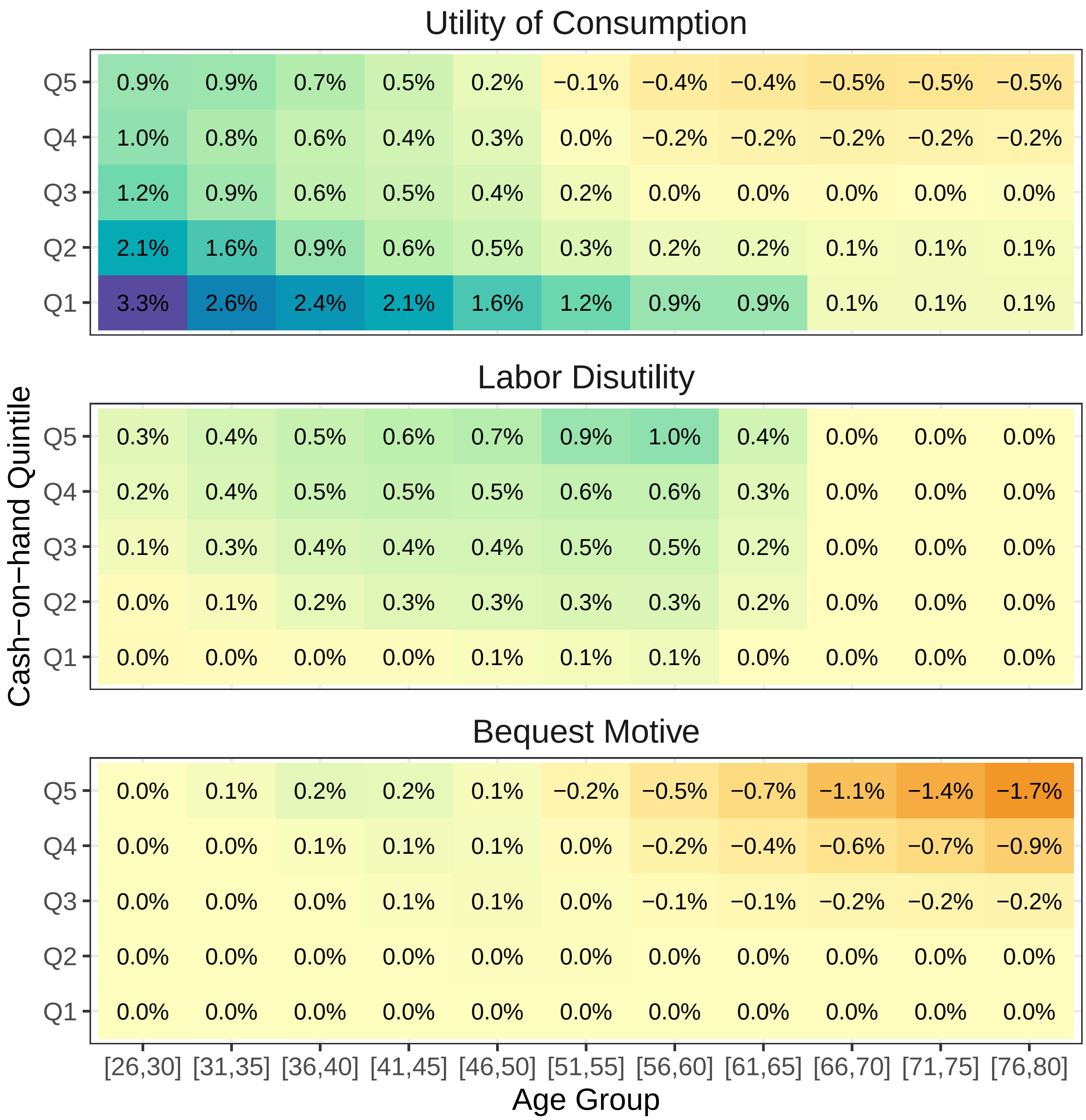
Table C.2: Consumption Response to a Monetary Policy Shock in OLG-HANK and OLG-NK

	OLG-HANK			OLG-NK		
	Age 30	Age 55	Age 80	Age 30	Age 55	Age 80
Total	**0.56%**	**0.09%**	**-0.02%**	**0.46%**	**0.09%**	**-0.03%**
Substitution	0.04%	0.09%	0.08%	0.08%	0.12%	0.10%
Labor Income	0.51%	0.06%	0.00%	0.40%	0.04%	0.01%
Asset Returns	0.01%	-0.05%	-0.11%	-0.02%	-0.07%	-0.15%

This table decomposes the on-impact consumption response of different cohorts to the monetary policy shock in the OLG-HANK and OLG-NK models. Cohorts are indexed by their age at the time that the shock hits. All quantities are expressed as a percentage of a cohort's consumption at time t in absence of the shock, $C^{ss}_{t,\text{Age}}$. To decompose the response into its channels, we calculate the responses to the shock-induced changes in subsets of variables (for example, wages, on-impact asset returns, taxes, and transfers), leaving all others in their steady state-values. "Labor income" includes changes in work hours, the wage rate, and net transfers. "Asset returns" includes changes in the realized and expected future paths of the interest rate paid on debt and the returns to bonds and stocks.

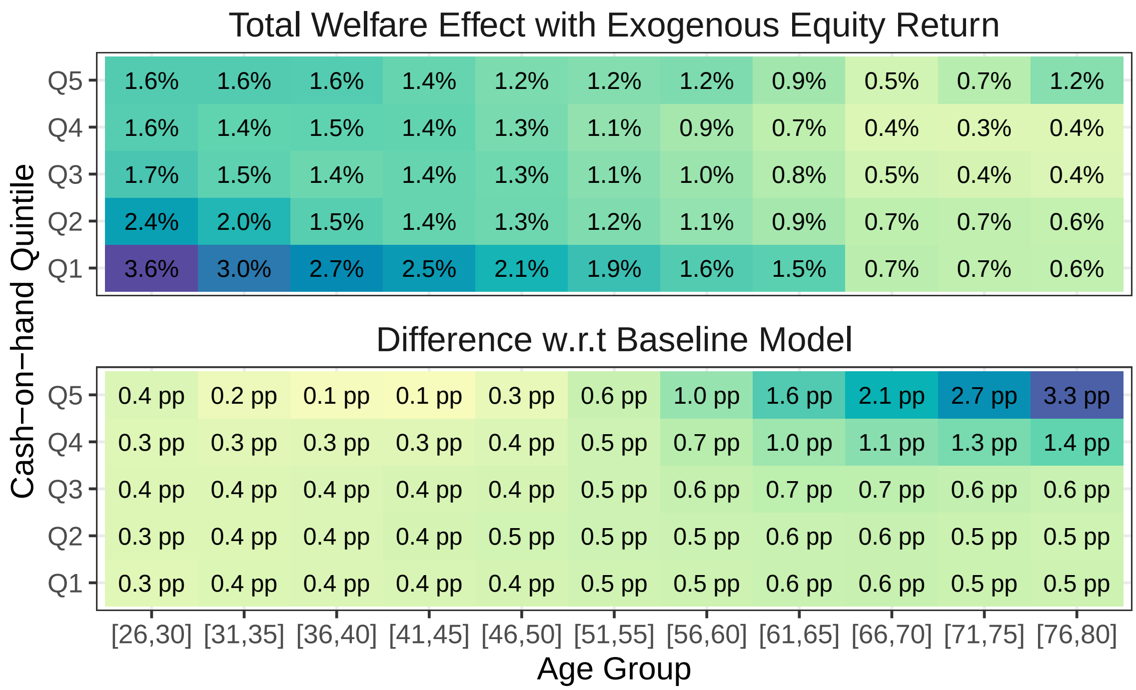
D Appendix to Section 5

This section contains additional results related to our welfare analysis.



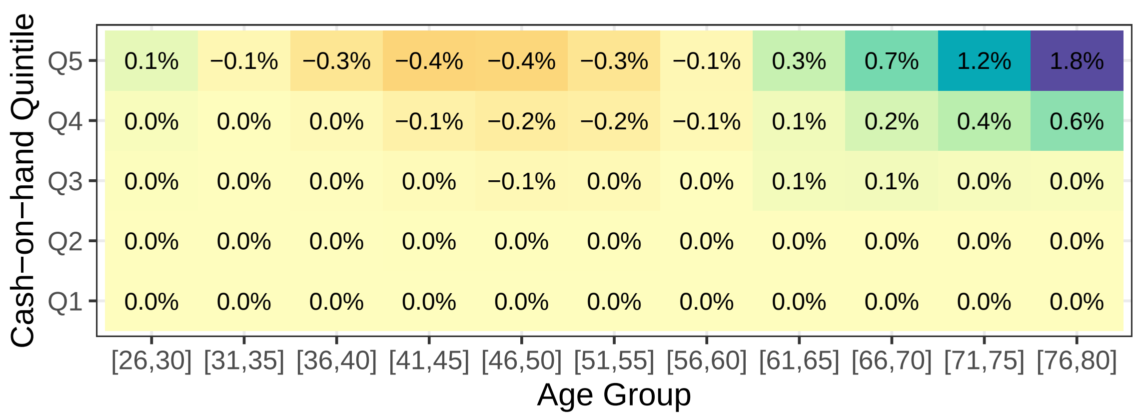
Welfare effects are the change in expected discounted utility from period t onwards. We express these changes as an equivalent monetary transfer, rescaled by the consumption of each household at time t (see Equation 10). This figure decomposes the total change in households' value functions into changes in the expected discounted value of the utility of consumption, the disutility of work, and the utility of leaving bequests.

Figure D.1: Sources of the Welfare Effects of a Monetary Policy Shock



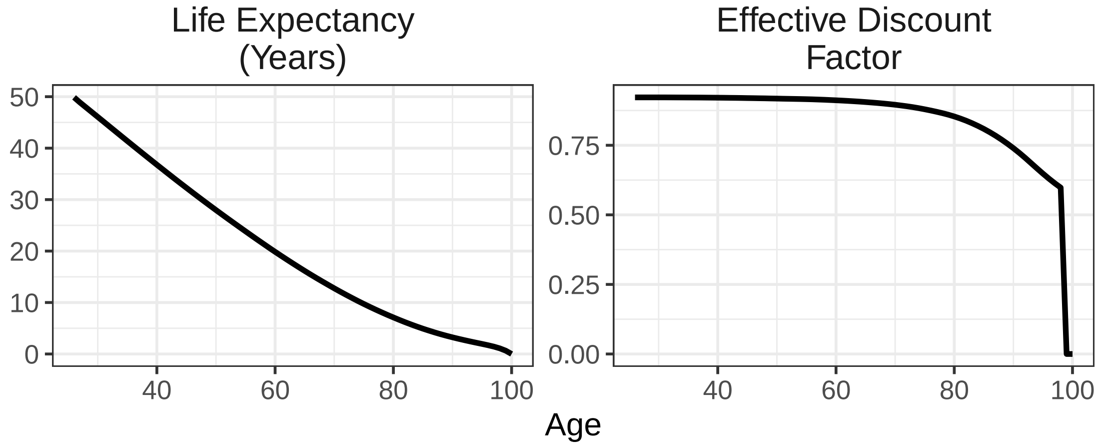
The top panel presents welfare effects in the OLG-HANK-plus experiment (see the main text for a description) expressed as an equivalent monetary transfer, rescaled by the consumption of each household at time t (see Equation 10), and averaged over households in the given age and wealth bin. To facilitate comparisons, the bottom panel presents bin-wise differences between estimates in the top panel and our baseline results for total welfare effects (in the top panel of Figure 10 in the main text).

Figure D.2: Welfare Effects of Monetary Expansion in OLG-HANK-plus.



The figure presents welfare effects in the OLG-HANK-plus experiment when only the path of equity returns $\{R_t^s\}_{t\geq 0}$ changes (to the path in the bottom left panel of Figure 6 in the main text). The other aggregate inputs of the household block are held at their steady state values. The Euler equation ex-ante rate expected by every agent is also held at its steady state, so this exercise approximates only effects that operate through the budget constraint. Welfare effects are expressed as an equivalent monetary transfer, rescaled by the consumption of each household at time t (see Equation 10), and averaged over households in the given age and wealth bin.

Figure D.3: Welfare Effects of Equity Returns in OLG-HANK-plus.



This figure depicts the expected remaining years of life and the effective discount factor ($\beta \times \psi_{j_{t+1}}$) for every age.

Figure D.4: Life Expectancy and Effective Discount Factors of Households

E Description of Alternative Models

In the main text, we compare the implications of our OLG-HANK model with two alternative specifications that represent broad classes of models that have been studied in prior literature: RANK and OLG-NK. This section gives further details on how these two models are calibrated and how they relate to the literature.

E.1 Overlapping Generations New Keynesian Model

OLG-NK represents models that feature nominal rigidities and a household sector in which multiple generations of agents live in any given period, but no within-cohort heterogeneity. In these models, all agents within a cohort are identical and receive no idiosyncratic shocks. Many papers with these characteristics are available in the literature, but they often feature simplified representations of the life cycle with, for example, stochastic transitions between a few states like working life, retirement, and death. We use Bielecki et al. (2022) and Braun and Ikeda (2025) as our references for OLG-NK because, instead, they have full life cycle specifications with age at an annual frequency and stochastic death.

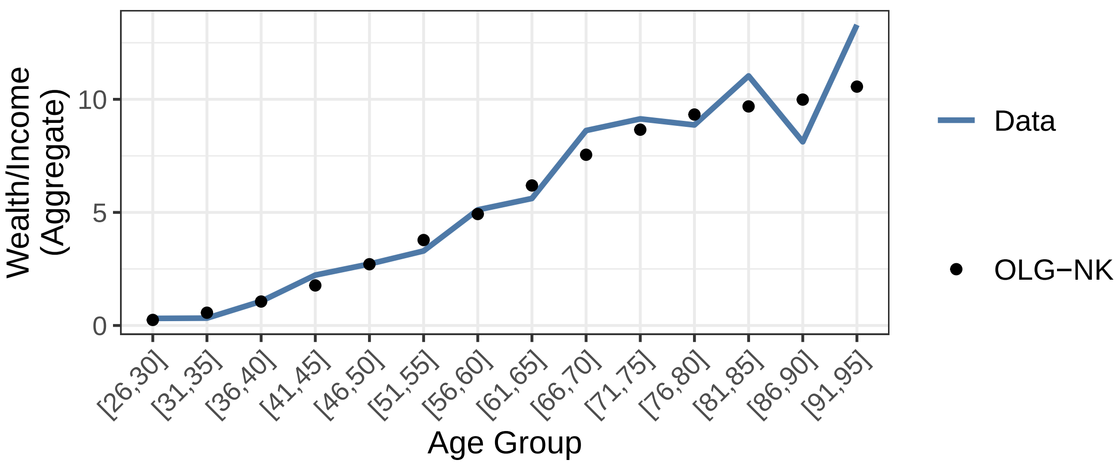
While we calibrate the OLG-NK model to resemble the models in Bielecki et al. (2022) and Braun and Ikeda (2025), it is not a complete replication. These models have elements that we abstract from, such as housing wealth (Bielecki et al., 2022) and endogenous portfolio choices (Braun & Ikeda, 2025). Instead, OLG-NK is the closest we can get to these papers within the class of models nested by our OLG-HANK. We believe this approach provides the cleanest comparisons between the models.

Starting from our OLG-HANK model, we first shut down idiosyncratic productivity shocks (η) and individual income fixed effects (α), and set the age fixed effects (f) to match the age profile of average pre-tax earnings in OLG-HANK. Thus, average salaries and pensions by age are identical in the steady states of OLG-NK and OLG-HANK, but there is no uncertainty or heterogeneity in OLG-NK.

Next, we calibrate preferences and borrowing constraints. Because ρ governs intertemporal substitution and its importance as a transmission channel, we set it to the same value that we use for OLG-HANK, reported in Table 1.[44] We estimate $\{\beta, b, \kappa, \omega, \chi\}$ using the method of moments, targeting the life-cycle profile of wealth-to-income ratios in the 2019 SCF in five-year age bins like we did for OLG-HANK in Section 3. However, since all households of a given age are equal, we target aggregates instead of multiple percentiles, as Bielecki et al. (2022) and Braun and Ikeda (2025) do. For each age bin, we find the total wealth and total income of all households, and then their ratio. Our estimated parameters minimize the distance between the model-implied and empirical age profiles of this aggregate ratios. Figure E.1 shows the close fit that the model achieves and Table E.1 reports the estimated parameters. Estimates are in plausible ranges, with the high discount due to elevated aggregate wealth-to-income ratios targeted.

For portfolio allocations, we use age-specific equity shares that do not depend on wealth (because all agents in a cohort have the same wealth and portfolio). To calibrate these age-specific aggregate equity shares, we first group SCF respondents by their age. Then,

[44] Our goal is to hold this intrinsic characteristic constant as we compare OLG-HANK and OLG-NK.



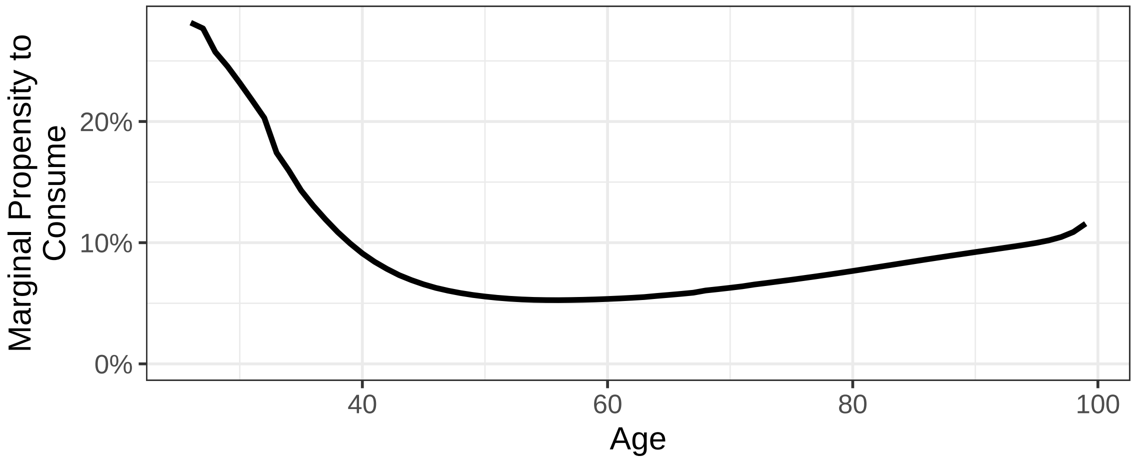
Our measure of income is the sum of wages and salaries, and Social Security and pension income from the 2019 SCF. Aggregate wealth-to-income ratios are the ratio of the sum of all financial assets to the sum of all the income of households in an age bin. Our sample is households that report a strictly positive income and where the respondent is at least 21 years old. In the OLG-NK model, the measure of wealth is end-of-period assets, a'.

Figure E.1: Wealth-to-Income Ratios in the OLG-NK Model

Table E.1: Parameter Estimates in the OLG-NK Model

Parameter	Symbol	Estimate
Discount Factor	β	0.99
Bequest Intensity	b	38.54
Bequest Shifter	κ	\$20k
Borrow. Limit Multiplier	ω	0.01
Borrow. Rate Premium	χ	0
Relative-Risk Aversion	ρ	1.78

Parameters are estimated to match the age profiles of aggregate wealth to income ratios. See the text for details.



The figure presents one-year steady-state marginal propensities to consume in OLG-NK model. Since agents are homogeneous within cohorts, all households of a given age share the reported MPC.

Figure E.2: Marginal Propensities to Consume in the OLG-NK Model

we calculate the total equity holdings and total financial assets of each age group and get the aggregate portfolio share by dividing these two quantities. For smoothness, we use the values of a fifth-degree polynomial of age fitted to the resulting (Age, Equity Share) series.

The incidence of fluctuations in aggregate earnings is a function only of age in this model, because there is no within-cohort heterogeneity in productivity z. To calibrate the incidence functions, we follow the same steps described at the end of Appendix C but average the βs over income percentiles for every age after interpolating. This yields a single β per age, $\{\beta_j\}_{j=1}^{J_{\text{ret}}}$. The earnings response of households of age j to a change in aggregate earnings is then $\Delta \ln y_{j,t} = \beta_j \cdot (\ln W_t - \ln W_{ss})$. Thus, OLG-NK preserves the unequal incidence of aggregate income changes across age groups.

The resulting OLG-NK model reproduces several important properties of the models in this literature. For example, the wealth profile in our model (Figure E.1) resembles that of Braun and Ikeda (2025).[45] Implied marginal propensities to consume by age in the OLG-NK model, presented in Figure E.2, also qualitatively resemble those in Braun and Ikeda (2025, Online Appendix Figure 2): they are high for young households, fall quickly with age, and start to increase slowly again after retirement. Additionally, the one-year aggregate MPC in OLG-NK is 0.10 (see Figure B.6), very close to Braun and Ikeda's (2025) reported 0.11.

E.2 Representative Agent New Keynesian Model

RANK is a canonical New Keynesian model that we obtain by removing age from OLG-NK altogether. There is a single household who lives forever, so bequests, endowments, and borrowing constraints become irrelevant. For maximum comparability, the non-household blocks remain the same and we retain the division of assets between bonds and equities. As

[45] Braun and Ikeda (2025) normalize net worth by the income of 50-59 year-olds and we normalize the wealth of each age bin by the income of the same age bin. The figures, however, share qualitative features like starting close to zero, being positive at all ages, and increasing with age.

a result, the representative household solves

$$\begin{aligned} V_t(A_{t-1}) &= \max_{C_t, A_t} u(C_t) - v(L_t) + \beta V_{t+1}(A_t) \\ \text{s.t. } C_t + A_t &= \left[\zeta R_t^s + (1-\zeta) R_t^b\right] A_{t-1} + (1-\tau_t) w_t L_t + T_t, \end{aligned} \tag{24}$$

where ζ is a fixed equity share equal to the aggregate equity share in the steady state of OLG-HANK. This is without loss of generality: the steady-state value is correct for $t = 0$, and the equity share becomes irrelevant for $t > 0$ due to the equality of returns $R_t^s = R_t^b$.

Block representation. The RA household block maps sequences $\{w_t, L_t, R_t^b, R_t^s, \tau_t\}_{t=0}^{\infty}$ to sequences $\{C_t, A_t^s, A_t^b, T_t, v'(L_t^*), u'(C_t^*)\}_{t=0}^{\infty}$ according to the following equations.

- Euler equation:

$$C_t^{-\rho} = \beta R_t^e C_{t+1}^{-\rho}$$

- Budget constraint:

$$C_t + A_t^s + A_t^b = R_t^s A_{t-1}^s + R_t^b A_{t-1}^b + (1-\tau_t) w_t L_t + T_t$$

- Equity and bond holdings:

$$A_t^s = \zeta A_{t-1}, \quad A_t^b = (1-\zeta) A_{t-1}$$

- Taxes net of transfers:

$$T_t = \tau_t w_t L_t - T_t$$

- Marginal utilities:

$$v'(L_t^*) = \varphi L_t^{1+\nu}, \quad u'(C_t^*) = C_t^{-\rho}(1-\tau_t) w_t L_t$$

Calibration. We use the same $w_{ss}, L_{ss}, \tau_{ss}$ as in OLG-HANK, and calibrate lump-sum transfers T_{ss} to deliver the same total taxes net of transfers as in OLG-HANK. We assume that R_{ss} is the same in RANK as in OLG-HANK, which pins down $\beta = 1/R_{ss}$. Since the representative household is willing to hold any amount of assets at this interest rate, we assign the same aggregate assets A_{ss} as in OLG-HANK. We maintain the same EIS and Frisch elasticity as in OLG-HANK. Finally, we calibrate the labor disutility scale φ to be consistent with the steady-state labor supply L_{ss}.

F Swedish Data

Data. We use the Swedish Longitudinal Integrated Database for Health Insurance and Labour Market Studies (LISA) already used in Amberg et al. (2022). LISA is an annual panel encompassing all legal residents of Sweden aged 16 and above. The database is curated by Statistics Sweden, which integrates information from multiple official registries. The dataset available to us spans from 1995 to 2018 comprising a universe of 129.97 million individual-year observations and 9.1 million unique individuals before sample selection. We observe demographic information together with individuals' total income from different sources described below. The income data is not subject to top coding and has minimal measurement error compared to self-reported survey data.

Sample Selection. We restrict the analysis to individuals with positive total after-tax income between 1995 and 2018. To limit the influence of outliers, we remove observations where after-tax income growth exceeds 500 percent or when the growth of any major subcomponent, measured as a share of after-tax income, is greater than 5 in absolute value. For the monetary policy analysis, the availability of policy series beginning in 1999 yields a final dataset with 102.57 million individual-year observations and 7.99 million unique individuals. Restricting the sample to men reduces this to 49.42 million individual-year observations and 3.92 million unique individuals. For the worker-betas analysis, we cover the sample period 1997-2018 but the further restriction to prime-age men (ages 25–55) results in 38.67 million individual-year observations and 3.19 million unique individuals, as discussed in Section C.

Variables. Throughout our empirical explorations we focus on two income metrics, labor and capital income, both pre-taxes. Consistent with our model, labor income refers exclusively to wages and salaries from all employers within a given year. Therefore, we exclude bonuses, stocks, exercised stock options, bonds and taxable employee benefits, as well as self-employment income. Our measure of financial income is the sum of net realized capital gains, dividends and interest income, and other financial income, net of interest expenses and housing-related incomes. We adjusted all income variables to real terms using the GDP price deflator (World Bank 2020), with 2015 as the base year. In our monetary policy exercises, wage and net capital income, respectively, are expressed in units of initial after-tax income. The latter is given by the sum of labor income, capital income, and transfers, net of taxes.[46] Table F.1 explains the construction of our main variables of interest.

[46] We impute taxes from labor income and capital income separately, following Amberg et al., 2022 (Appendix B).

Table F.1: Original and Derived Variables Based on LISA

Panel A. Original LISA Variables

Variable	**Description (from LISA)**
LoneInk	Wage and salary income (cash wages, bonuses, taxable employment income).
KIRANTA	Taxable interest and dividend income.
KIRFOR	Positive interest allocation.
KARFOR	Deduction from negative interest allocation.
KV	Capital gains.
KF	Capital losses.
SocInk	Social insurance benefits (e.g., sickness, parental, unemployment).
AldPens	Old-age pension income.
SumEftPens	Survivor and disability pension benefits.
LivArbF	Labor-market related transfers (e.g., wage subsidies, Injury Annuity).

Panel B. Constructed Variables

Variable	**Description**	**Derivation**
wageinc	Wages and salaries	$\texttt{LoneInk} \times 100$
rcg_net	Realized net capital gains	$\texttt{KV} - \texttt{KF}$
divint	Dividend and interest income	$\texttt{KIRANTA}$
otherfin	Other financial income	$\texttt{KIRFOR} - \texttt{KARFOR}$
fininc	Total financial income	$(\texttt{rcg\_net}) + (\texttt{divint}) + (\texttt{otherfin})$
transfers	Government transfers	$(\texttt{AldPens} + \texttt{SocInk} + \texttt{SumEftPens} + \texttt{LivArbF}) \times 100$
totinc_pretax	Total pretax income	$\texttt{wageinc} + \texttt{fininc} + \texttt{transfers}$
totinc_aftertax	Total after-tax income	$\texttt{totinc\_pretax} + \texttt{taxes}$

Table A summarizes the derived variables used to construct the measures employed in the empirical analysis reported in Table B. We use *wageinc* as the dependent variable in equation 8 and as the input for computing age-specific earnings deciles in Figure 2. We further use *wageinc* together with *fininc* as the dependent variables in equation 9, which we standardized by *totinc_aftertax*. Permanent-income quintiles, used in equation 9, are constructed from *totinc_pretax*.