Fiscal and Monetary Policy with Heterogeneous Agents

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Abstract

In the past decade, a new paradigm for fiscal and monetary policy analysis has emerged, combining the canonical macro model of income and wealth inequality with the New Keynesian model. These Heterogeneous-Agent New Keynesian ("HANK") models feature new transmission channels and allow for the joint study of aggregate and distributional effects. We review key developments in this literature through the lens of a unified "canonical HANK model". Monetary and balanced-budget fiscal policy have similar aggregate effects as in the standard new Keynesian model, while deficit-financed fiscal policy is much more expansionary. We discuss the split between direct and indirect effects of policy, and also the implications of cyclical income risk, maturity structure, nominal assets, behavioral frictions, and many other extensions to the model. Throughout, we highlight the benefits of using sequence-space methods to solve and analyze this class of models.

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1 Introduction

In the past decade, a rapidly growing body of research has combined heterogeneous-agent (HA) models of income and wealth inequality with the New Keynesian (NK) framework often used to study fiscal and monetary policy. In these "HANK" models, households face uninsurable risk and borrowing constraints, limiting their ability to smooth consumption over long horizons, and making consumption more sensitive to current income. This changes the transmission mechanism of policy: for instance, relative to the standard NK model, monetary policy works less through substitution and more through indirect income effects (Kaplan, Moll and Violante 2018), and deficit-financed fiscal policy has larger effects on output (Auclert, Rognlie and Straub 2024a). These conclusions build on an earlier two-agent ("TANK") literature (Galí, López-Salido and Vallés 2007, Bilbiie 2008), but the HANK framework can speak to additional phenomena, such as the persistent effects of excess savings following a fiscal shock (Aggarwal, Auclert, Rognlie and Straub 2023), the amplification or attenuation of forward guidance (McKay, Nakamura and Steinsson 2016, Bilbiie 2020), and the distributional effects of aggregate shocks (Bayer, Born and Luetticke 2024).

In this paper, we take stock of this literature.[1] Since the seminal work of Oh and Reis (2012), McKay and Reis (2016), and Guerrieri and Lorenzoni (2017), the literature has progressed rapidly. Early HANK models models often merged the HA and NK frameworks by assuming sticky prices and flexible wages, as in the textbook version of the NK model (e.g. McKay et al. 2016, Kaplan et al. 2018, Auclert 2019). This approach leads to implausibly countercyclical profits in response to demand shocks, and these interact with heterogeneity to drive macro outcomes (Bilbiie 2008, Broer, Hansen, Krusell and Öberg 2020). It also requires modifying the standard incomplete market model to incorporate an endogenous labor supply choice, which adds complexity and typically implies marginal propensities to earn that are too large relative to the data (Auclert, Bardóczy and Rognlie 2023a).[2] Here, we follow another approach to integrating HA and NK, assuming sticky wages and flexible prices. This approach preserves the core structure of the standard incomplete market model, with endogenous choice only between consumption and savings. It also features low (zero) marginal propensities to earn, and avoids any endogenous redistribution through profits. Our goal is to introduce a simple model that, while imperfect, can serve as a natural foundation upon which many additional features can be built.

We write down a "canonical HANK model" along these lines, and use the model to discuss the main lessons from the HANK literature regarding fiscal and monetary policy. Monetary and balanced-budget fiscal policy often have similar aggregate effects as in the standard new Keynesian model (Werning 2015), but deficit-financed fiscal policy is much more powerful at boosting output (Auclert et al. 2024a). Redistribution between agents is central: the more that poor agents with high MPCs benefit from a policy, the larger its aggregate effects (Auclert 2019). Finally, the

[1] See Kaplan and Violante (2018) and McKay and Wolf (2023) for earlier reviews of the HANK literature.

[2] We define the marginal propensity to earn (MPE) as the response of earned income to a one-time transfer in the first year, multiplied by -1. Recent work by Golosov, Graber, Mogstad and Novgorodsky (2024) finds a low value for the MPE of 0.023, although they emphasize the cumulative effect over many years, which is larger.

indirect, general equilibrium effects of policies, especially the equilibrium feedback from income to consumption, play a much more important role than in the standard model (Kaplan et al. 2018).

We then turn to important connected issues by making simple modifications of our model. One prominent question is the cyclicality of income risk, which is widely understood to be central in whether incomplete markets amplify or dampen the aggregate effects of policy (McKay et al. 2016, Acharya and Dogra 2020, Bilbiie 2024). We also cover the role of the maturity structure of assets and liabilities (Auclert 2019), nominal redistribution in the monetary transmission mechanism (Doepke and Schneider 2006), fiscal and monetary reaction functions, behavioral frictions with heterogeneous agents (Auclert, Rognlie and Straub 2020), the fiscal theory of the price level (Cochrane 2023), and the self-financing of unfunded deficits (Angeletos, Lian and Wolf 2023).

In addition, we touch on a number of additional topics that require more complex departures from the canonical model. First, we discuss the role an illiquid account can play in generating a more realistic correlation between wealth and MPCs at the individual level through the presence of "wealthy hand-to-mouth" households (Kaplan and Violante 2014, 2022). Second, we discuss the role of other components of aggregate demand in the transmission mechanism, such as that of durable goods (McKay and Wieland 2021), investment (Auclert et al. 2020), and exchange rates (Auclert, Rognlie, Souchier and Straub 2021b). Third, we discuss how endogenous portfolio choice can affect the transmission of monetary and fiscal policy (Auclert, Rognlie, Straub and Tapák 2024c). Finally, we review existing efforts in solving for the optimal monetary and fiscal responses to shocks in these environments (Bhandari, Evans, Golosov and Sargent 2021, McKay and Wolf 2022, Dávila and Schaab 2023).

Throughout the paper, we emphasize the usefulness of the sequence-space approach to writing and solving models of this type (Boppart, Krusell and Mitman 2018, Auclert, Bardóczy, Rognlie and Straub 2021a).[3] In addition to enabling a rapid and accurate solution, this approach allows one to understand and decompose the economic mechanisms underlying the aggregate effects. A GitHub repository[4] provides code that illustrates this methodology and replicates all the results in this paper.

The layout of the article is as follows. Section 2 sets up our canonical HANK model. Section 3 studies fiscal policy, and section 4 studies monetary policy. Section 5 discusses more advanced topics. Section 6 concludes.

2 A canonical HANK model

This section presents a simple merger of a standard incomplete markets model in the Bewley-Huggett-Aiyagari tradition with the New Keynesian paradigm, calibrated to be jointly consistent

[3] Boppart et al. (2018) observed that small perfect-foresight shocks (also known as "MIT" shocks) could be used to solve for the first-order perturbation solution in heterogeneous agent models. Auclert et al. (2021a) showed how to use sequence-space Jacobians to obtain this first-order perfect-foresight solution.

[4] Available at `https://github.com/shade-econ/annual-review`

with marginal propensities to consume (MPCs), aggregate income and wealth, and their distributions.

Model. The economy is inhabited by a mass 1 of agents that are ex-ante identical, but ex-post different due to uninsurable idiosyncratic risk. For convenience, we study first-order "MIT shocks": unexpected shocks at date 0 that perturb the aggregate steady state of the economy, with perfect foresight after date 0. This is equivalent to solving for first-order impulse responses in a stochastic economy.[5]

Agents face idiosyncratic risk with respect to their labor productivity e_{it} and time discount factor β_{it}. The former is standard, and the latter is helpful in matching aggregate wealth and its distribution. There is a Markov chain describing the transitions between any state (e, β) and any other state (e', β'), and the mass of agents in each state is assumed to always equal the mass in the stationary distribution. We assume that the labor productivity and discount factor processes are independent, and normalize the cross-sectional mean of labor productivity to $\mathbb{E}[e_{it}] = 1$.

Households can save in a mutual fund, subject to a borrowing constraint that we assume to be zero, and earn labor income, which is taxed at rate τ_t. They have log preferences over consumption c_{it}, work n_{it} hours, and have separable disutility of labor $v(n_{it})$ from those hours. The problem of household i, starting at $t = 0$ with asset position $a_{i,-1}$ in the mutual fund, idiosyncratic income state e_{i0} and discount factor β_{i0}, is given by:

$$\begin{aligned} \max_{c_{it}} \quad & \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \left(\prod_{s \leq t-1} \beta_{is} \right) \{ \log(c_{it}) - v(n_{it}) \} \right] \\ \text{s.t.} \quad & c_{it} + a_{it} \leq \left(1 + r_t^p\right) a_{it-1} + (1 - \tau_t) w_t e_{it} n_{it} \\ & a_{it} \geq 0 \end{aligned} \tag{1}$$

In (1), r_t^p denotes the ex-post return on mutual fund assets, and w_t the pre-tax real wage per unit of efficient labor. Hours are not chosen by individual agents and instead set by unions according to current labor demand. Thus, the steady-state problem described in (1) is that of a standard incomplete markets model with additive income risk. In particular, agents' consumption and saving decisions are described by a "buffer-stock" rule that is consistent with micro data (Deaton 1991, Carroll 1997), and the model can match realistic average MPCs and a realistic wealth distribution. Discount factor shocks help in hitting these targets simultaneously.

Firms produce out of labor only, using a production function with constant aggregate productivity. The production function is

$$Y_t = N_t$$

where N_t is aggregate effective labor, $N_t = \mathbb{E}[e_{it} n_{it}]$. We assume that firms set their price at a

[5] This is because first-order solutions satisfy certainty equivalence. See, e.g. Fernández-Villaverde, Rubio-Ramírez and Schorfheide (2016), Boppart et al. (2018) and Auclert et al. (2021a).

constant markup μ over their nominal marginal cost, which equals the nominal wage W_t.[6] Hence $P_t = \mu W_t$, and the real wage equals $w_t = \frac{1}{\mu}$ at every date. Firms' dividends are taxed at the same rate τ_t as labor income. Their real post-tax dividends are therefore $d_t = (1-\tau_t)(Y_t - w_t N_t) = (1-\tau_t)\left(1-\frac{1}{\mu}\right)Y_t$. There is a mass 1 of outstanding firm shares with end-of-period price p_t. Firms are assumed to maximize shareholder value $d_t + p_t$.

Nominal wages are assumed to be sticky. As in Erceg, Henderson and Levin (2000), unions set nominal wages to maximize agent utility subject to adjustment costs. We assume, as in Auclert et al. (2024a), that unions allocate all labor hours uniformly across agents, so that $n_{it} = N_t$.[7] Moreover we assume, as in Hagedorn, Manovskii and Mitman (2019a) and Auclert et al. (2021b), that the union's objective is to maximize the utility of an agent with average consumption $C_t \equiv \int c_{it} di$, discounted by the average discount factor $\overline{\beta}$. Assuming either Calvo or Rotemberg adjustment costs, this results in a first-order Phillips curve for wage inflation $\pi_t^w \equiv \frac{W_t - W_{t-1}}{W_{t-1}}$ given by

$$\pi_t^w = \kappa \left(v'(N_t) - \frac{1-\tau_t}{\mu C_t} \right) + \overline{\beta} \pi_{t+1}^w \tag{2}$$

Wage inflation takes place whenever the marginal cost to agents of working an extra hour $v'(N_t)$ exceeds the marginal benefit that an agent with average consumption would get from working that extra hour, equal to the post tax real wage $\frac{1-\tau_t}{\mu}$ times the marginal utility of average consumption $\frac{1}{C_t}$, now or in the future.[8] Since prices are a constant markup over wages at all dates, price inflation $\pi_t \equiv \frac{P_t - P_{t-1}}{P_{t-1}}$ is equal to wage inflation π_t^w at all times. In particular, the Phillips curve (2) also describes the behavior of price inflation π_t.

A government collects labor and corporate taxes, spends G_t, and issues non-contingent real debt with a promised return r_t. Since overall tax revenue is $\tau_t Y_t$, the government budget constraint is given by

$$G_t + B_t = (1 + r_{t-1}) B_{t-1} + \tau_t Y_t \tag{3}$$

The government is assumed to set plans for G_t and τ_t compatible with an intertemporal budget constraint. Equivalently, it sets paths for government debt B_t and spending G_t, with the tax rate τ_t indirectly set to respect the government budget constraint (3).

A mutual fund collects all household savings a_{it} and invests in government bonds and the

[6] This can be microfounded, for instance, by assuming that firms produce a differentiated variety under monopolistic competition, with each household having CES demand with elasticity of substitution $\frac{\mu}{\mu-1}$ over varieties.

[7] Proportional allocation rules where n_{it} depends on e_{it} are equivalent to reparametrizing e_{it}, so we choose $n_{it} = N_t$ as a normalization. Section 4 considers alternative exogenous allocation rules. A theoretically unappealing aspect of such rules is that they create heterogeneity across agents in the wedge between the marginal rate of substitution and the post-tax real wage. One solution is to instead use a rule that equalizes the labor wedge across all agents subject to total labor demand (e.g. Guerrieri and Lorenzoni 2017), although this results in high marginal propensities to earn (Auclert et al. 2023a).

[8] With a union that maximizes average worker welfare instead, the term $\frac{1}{C_t}$ would be replaced by $\int \frac{1}{c_{it}} di$. This formulation makes heterogeneity matter for the Phillips curve, replacing C_t in (2) with the virtual consumption aggregate $C_t^* \equiv \left(\int \frac{1}{c_{it}} di \right)^{-1}$. See Auclert et al. (2024a).

stock market. Profit maximization implies the no-arbitrage condition

$$1 + r_t = \frac{p_{t+1} + d_{t+1}}{p_t} \tag{4}$$

Asset market clearing requires that all household assets $A_t \equiv \int a_{it} di$ be invested in stocks and bonds:

$$A_t = p_t + B_t \tag{5}$$

Perfect competition in the mutual fund industry imposes that the ex-post return on mutual fund assets is $r^p_{t+1} = r_t$ for all $t \geq 0$, while the initial return r^p_0 is set such that the liquidation value of mutual fund liabilities, $\left(1 + r^p_0\right) A$, equals the beginning-of-period value of its stock and bond portfolio:

$$\left(1 + r^p_0\right) A = p_0 + d_0 + (1 + r) B \tag{6}$$

Equation (6) implies that the gross initial ex-post return $1 + r^p_0$ is a weighted average of the initial stock return $\frac{p_0 + d_0}{p}$ and the steady state bond return $1 + r$, weighted by the steady-state portfolio shares in stocks $\frac{p}{A}$ and bonds $\frac{B}{A}$ in the mutual fund portfolio.

Monetary policy sets the real interest rate r_t on government bonds, by means of a monetary policy rule for the nominal interest rate i_t such that $1 + i_t = (1 + r_t)(1 + \pi_{t+1})$.[9]

Given exogenous sequences for monetary policy $\{r_t\}$ and fiscal policy $\{G_t, B_t\}$ respecting the government budget constraint (3), equilibrium is a set of aggregate prices and quantities $\{r^p_t, p_t, d_t, Y_t, C_t, A_t\}$, household policies, and a distribution of households over their state variables (e, β, a), such that households optimize, the distribution evolves consistently with optimal policies, the asset market clears (5), and the goods market clears,

$$C_t + G_t = Y_t \tag{7}$$

By Walras's law, one of (5) or (7) is redundant.

Representative-agent model. A special case of the model just introduced is the representative-agent (RA) model. In this model, there is a single household solving a version of (1) with no idiosyncratic income or discount factor risk ($e_{it} = 1$ and $\beta_{it} = \beta$), and facing no borrowing constraint. Consumption for this agent is then described by the Euler equation $C_t^{-1} = \beta (1 + r_t) C_{t+1}^{-1}$.

Two-agent model. A small variation on the RA model is the two-agent (TA) model (Bilbiie 2008, Ascari, Colciago and Rossi 2017). In this model there are two types of agents: a mass $1 - \lambda$ of unconstrained agents whose behavior is described by the Euler equation $\left(C^u_t\right)^{-1} = \beta (1 + r_t) \left(C^u_{t+1}\right)^{-1}$, and a mass λ of constrained agents with no access to financial markets, so that their consumption is always equal to their post-tax labor income. We assume that both agents

[9]Underpinning this is a market for nominal bonds or bank reserves, which are in zero net supply, on which the central bank sets the nominal interest rate. See Auclert et al. (2024a), appendix A.2, for details.

have the same idiosyncratic productivity $e_{it} = 1$ and that the labor allocation rule is $n_{it} = N_t$. This implies that $C_t^c = (1-\tau_t)\, w_t N_t$, and aggregate consumption is $C_t = (1-\lambda)\, C_t^u + \lambda C_t^c$.

Calibration. We calibrate the heterogeneous-agent model's steady state as follows. The frequency is quarterly. We take the income process for e_{it} from Kaplan et al. (2018). This is a continuous-time income process, which we discretize.

Our goal is to obtain a level and distribution of wealth that is a good fit for the recent U.S. economy. We target a wealth-to-GDP ratio of $A/Y = 500\%$, a government debt to GDP ratio of $B/Y = 100\%$, and a real interest rate of $r = 2\%$ (all annualized). We set government spending to $G/Y = 20\%$. This implies a tax-to-GDP ratio of $\frac{T}{Y} = \frac{G}{Y} + r\frac{B}{Y} = 22\%$. By (5), the stock market value is 400% of GDP. Since $\frac{p}{Y} = \frac{d/Y}{r} = \left(1 - \frac{1}{\mu}\right)\left(\frac{1-T/Y}{r}\right)$, we can back out the markup $\mu = 1.11$.

We assume a two-point Markov chain for the discount factor $\beta \in \{\beta_L, \beta_H\}$, with β_L representing currently impatient agents and $\beta_H > \beta_L$ representing currently patient agents. We assume that each period, agents keep their old β with probability $1-q$; with probability q, they have a new, independent draw of β, equal to β_H with probability ω and β_L with probability $1-\omega$.[10] We set $q = 0.01$, implying that a new draw of β occurs on average every 25 years—which, in the spirit of Krusell and Smith (1998), we interpret as representing generational turnover.[11] We then pick β_L, β_H, and ω to hit three calibration targets: asset market clearing, an income-weighted MPC of $M_{00} = 0.2$, and a zero average gap between the Lorenz curves for wealth in the model and in the 2019 Survey of Consumer Finances. The resulting parameters, together with a summary of our rest of the calibration, are reported in table 1. As is evident from figure 1(b), the fit to the overall Lorenz curve is very good, though the model slightly understates the mass of in the middle of the distribution (the "missing middle" problem discussed by Kaplan and Violante 2022) and understates inequality in the far right tail.

The parameters of the Phillips curve are less critical to our calibration, since real outcomes can typically be calculated without reference to inflation. Nevertheless, when we solve for inflation, we calibrate $v(N) = \zeta \frac{N^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}}$, where we set the Frisch elasticity of $\nu = 1$, and set ζ to normalize GDP to $Y = 1$. We set the slope of the Phillips curve to $\kappa = 0.01$ and $\overline{\beta} = \omega\beta^H + (1-\omega)\,\beta^L$.[12]

Intertemporal MPCs. Before proceeding further, we define the model's *intertemporal marginal propensities to consume*, or *iMPCs* (Auclert et al. 2024a). These objects connect microeconomic evidence on marginal propensities to consume with the general equilibrium effects of aggregate shocks.

[10]The Markov transition matrix over types β_L, β_H is therefore $\Pi = \begin{pmatrix} (1-q) + q(1-\omega) & q\omega \\ q(1-\omega) & (1-q) + q\omega \end{pmatrix}$.

[11]Since our estimated ω turns out to be close to 0.5, the average duration of either state is approximately 50 years, the same as the duration of the high and low states in Krusell and Smith (1998).

[12]We calculate $\kappa = 0.01$ following the standard Calvo formula $\kappa = \frac{1}{1+\Gamma}\frac{(1-\theta)(1-\overline{\beta}\theta)}{\theta}$, where we take the quarterly probability $1-\theta = 0.2$ of wage adjustment from Grigsby, Hurst and Yildirmaz (2021) and the real rigidity coefficient Γ to be 5.

	Variable	Value		Variable	Value
r	Real interest rate (annual)	2%	μ	Markups	1.11
A	Assets to GDP (annual)	500%	(β^L, β^H)	Discount factors (quarterly)	(0.91, 1.00)
B	Bonds to GDP (annual)	100%	ω	Share of patient	49%
M_{00}	Income-weighted MPC (quarterly)	0.2	q	Prob of new β draw (quarterly)	1%
G	Government spending to GDP	20%	T	Taxes to GDP	22%

Table 1: Calibration of the baseline HA model

To define these, we first note that there are only two time-varying aggregates that enter the household problem in (1): ex-post returns r_0^p, and, given that $n_{it} = N_t$, also the time-varying sequence of post-tax labor income $Z_t \equiv (1-\tau_t) w_t N_t$. Household policy functions at each date, mapping (β, e, a) to consumption and asset choices, depend only on these sequences. Therefore, given the steady-state distribution coming into date 0, the distribution at every date only depends on these sequences as well, and we can write aggregate consumption as a function of them.

Substituting in $r_{t+1}^p = r_t$ for $t \geq 0$, we also observe that $\{r_0^p, r_1^p, r_2^p, \ldots\} = \{r_0^p, r_0, r_1, \ldots\}$, where real interest rates r_t are controlled by monetary policy, and the initial return r_0^p on assets results from the determination of equilibrium asset prices in (6). Hence, we can write the aggregate consumption function $\mathcal{C}_t$ as

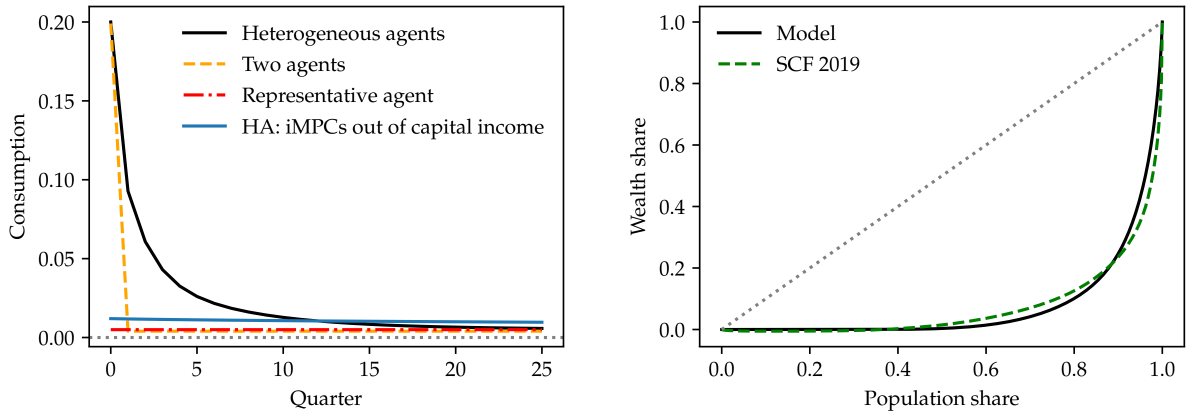
$$C_t = \mathcal{C}_t\left(r_0^p, \{r_t\}, \{Z_t\}\right)$$

Next, we consider the derivatives of this function around the steady state where $r^p = r$ and Z are constant. We call $M_{ts} \equiv \frac{\partial \mathcal{C}_t}{\partial Z_s}$ the iMPCs out of labor income, $m_t \equiv \frac{1}{A}\frac{\partial \mathcal{C}_t}{\partial r_0^p}$ the iMPCs out of capital gains, and $M_{ts}^r \equiv \frac{\partial \mathcal{C}_t}{\partial r_s/(1+r)}$ the consumption responses to real interest rate changes. Given first-order shocks to interest rates $d\mathbf{r} \equiv \frac{1}{1+r}\{dr_0, dr_1, \ldots\}$, after-tax income $d\mathbf{Z} \equiv \{dZ_0, dZ_1, \ldots\}$ and capital gains $d\text{cap} \equiv A dr_0^p$, consumption $d\mathbf{C} \equiv \{dC_0, dC_1, \ldots\}$ evolves according to

$$d\mathbf{C} = \mathbf{M}^r d\mathbf{r} + \mathbf{M} d\mathbf{Z} + \mathbf{m} d\text{cap} \tag{8}$$

Figure 1(a) displays the iMPCs out of labor income M_{t0} and capital gains m_t for the models considered in this paper. M_{t0} describes the aggregate spending response to an innovation in aggregate labor income. As Auclert et al. (2024a) show, this corresponds to a weighted average of individual-level dynamic MPCs that can be estimated empirically. A key empirical finding is that MPCs are large on impact and remain elevated for some time afterwards: see, for instance, Fagereng, Holm and Natvik (2021) and Colarieti, Mei and Stantcheva (2024).[13] Our calibrated HA model is consistent with this pattern. On the other hand, the RA model cannot match the level of the MPC, and

[13]The magnitude of the impact MPC M_{00}, around 0.15 to 0.25 at a quarterly level, is consistent with the general findings of a large literature (e.g. Johnson, Parker and Souleles 2006, Parker, Souleles, Johnson and McClelland 2013, Jappelli and Pistaferri 2014, Kueng 2018, Ganong, Jones, Noel, Greig, Farrell and Wheat 2020, Orchard, Ramey and Wieland 2023). Our target for M_{00} falls in the middle of this range. We note that typical estimates are for the unweighted MPC, rather than the labor-income weighted MPC M_{00}; but since the empirical correlation between income and MPCs tends to be low, the two should be fairly close in the data. The exact magnitude of M_{t0} for $t > 0$ is still subject to empirical debate.



(a) Intertemporal MPCs

(b) Lorenz curve

Figure 1: iMPCs out of income and capital gains (left) and wealth distribution in the HA model (right)

the TA model cannot match the later iMPCs. Figure 1(a) also shows the iMPCs out of capital gains m_t generated by the HA model. They are low and flat, generally consistent with recent evidence (see e.g. Di Maggio, Kermani and Majlesi 2020, Chodorow-Reich, Nenov and Simsek 2021).

Quantitatively, discount factor heterogeneity is important in achieving the HA model's overall fit to iMPCs. Without it, there is a tradeoff between matching MPCs and matching the level and distribution of aggregate wealth: for instance, high impact MPCs M_{00} require low wealth, and vice versa (see, for instance, Kaplan and Violante 2022).[14] In section 5, we discuss illiquid accounts as an alternative to discount factor heterogeneity in resolving this tradeoff.

Other tractable models. We saw that neither RA nor TA models can successfully match iMPCs. There is a literature developing tractable models to improve this fit. The main routes explored in the literature are bond-in-the-utility (BU) models (Kaplan and Violante 2018, Michaillat and Saez 2021, Wolf 2023), portfolio adjustment costs (Cantore and Freund 2021), the zero-liquidity limit of a HA model (Werning 2015, Bilbiie 2024), and perpetual-youth OLG models (Aggarwal et al. 2023, Angeletos et al. 2023). Auclert et al. (2024a) derive in closed form the iMPCs for these classes of models. They argue that these tractable models, sometimes with hand-to-mouth agents added, can approximate M_{t0} well, but there currently does not exist a tractable model that also matches the low marginal propensities to consume out of capital gains m_t documented in the data. This is because existing tractable models generally have MPCs out of capital gains that are equal or similar to MPCs out of labor income. By contrast, our model jointly matches high MPCs out of labor income and low MPCs out of capital gains, because its MPCs are sharply declining in wealth, and capital gains accrue mostly to agents with high wealth while labor income accrues to other agents as well.

[14] The role of discount factor heterogeneity in reconciling the level of wealth, the wealth distribution, and MPCs is explored by Carroll, Slacalek, Tokuoka and White (2017).

Toward general equilibrium. While iMPCs are partial equilibrium objects and can be confronted with cross-sectional estimates, they are also sufficient statistics for household behavior in general equilibrium. To see this, we use a few additional equilibrium relations from the model.

We first note that $Z_t \equiv (1-\tau_t)\, w_t N_t = \frac{1}{\mu}\left(Y_t - \tau_t Y_t\right) = \frac{1}{\mu}\left(Y_t - T_t\right)$, where we define $T_t \equiv \tau_t Y_t$ as total tax revenue. Given our specification of monetary and fiscal policy in terms of r_t, B_t and G_t, (3) shows that T_t is exogenously specified by policy. This implies that that $d\mathbf{Z} = \frac{1}{\mu}\left(d\mathbf{Y} - d\mathbf{T}\right)$.

Next, we note that $d\text{cap} \equiv A dr_0^p = d\left(p_0 + d_0\right)$, where $p_0 + d_0$ is given by the present discounted value of dividends d_t at the sequence of ex-ante interest rates r_t. Given $d_t = \left(1 - \frac{1}{\mu}\right)\left(Y_t - T_t\right)$, differencing the asset pricing condition $p_0 = \sum_{t=0}^{\infty}\left[\prod_{s=0}^{t}\left(1+r_s\right)\right]^{-1} d_t$ around the steady state implies $d\left(p_0 + d_0\right) = -p\mathbf{q}' d\mathbf{r} + \left(1 - \frac{1}{\mu}\right)\mathbf{q}'\left(d\mathbf{Y} - d\mathbf{T}\right)$, where $\mathbf{q}' \equiv \left(1, \frac{1}{1+r}, \left(\frac{1}{1+r}\right)^2, \ldots\right)$ takes the present value of a sequence. Hence, we have that

$$d\mathbf{C} = \underbrace{\left(\mathbf{M}^r - p\mathbf{m}\mathbf{q}'\right)}_{\equiv \overline{\mathbf{M}}^r} d\mathbf{r} + \underbrace{\left(\frac{1}{\mu}\mathbf{M} + \left(1 - \frac{1}{\mu}\right)\mathbf{m}\mathbf{q}'\right)}_{\equiv \overline{\mathbf{M}}}\left(d\mathbf{Y} - d\mathbf{T}\right) \tag{9}$$

Equation (9) shows that perturbations to post-tax income $d\mathbf{Y} - d\mathbf{T}$ map into changes in consumption via the matrix $\overline{\mathbf{M}}$, which is an average of labor income and capital gains iMPCs, weighted by the shares of aggregate income earned as wages and dividends. Similarly, an increase in interest rates affects spending both directly via standard income and substitution effects, and also indirectly by depressing asset values. The combined effect is summarized by the matrix $\overline{\mathbf{M}}^r$.

3 Fiscal policy

We begin by studying fiscal policy holding monetary policy constant, that is, holding r_t at its steady-state level.[15] We consider two types of fiscal policy shocks: a shock to government spending G_t, holding deficits constant, and a shock to deficits, holding government spending constant. We restrict our attention in this section to first-order shocks around the steady state, though some of our results also hold nonlinearly.

Setting $d\mathbf{r} = 0$ in (9), and combining with the linearized version of the goods market clearing condition, $d\mathbf{C} + d\mathbf{G} = d\mathbf{Y}$, we obtain the "intertemporal Keynesian cross" (Auclert et al. 2024a),

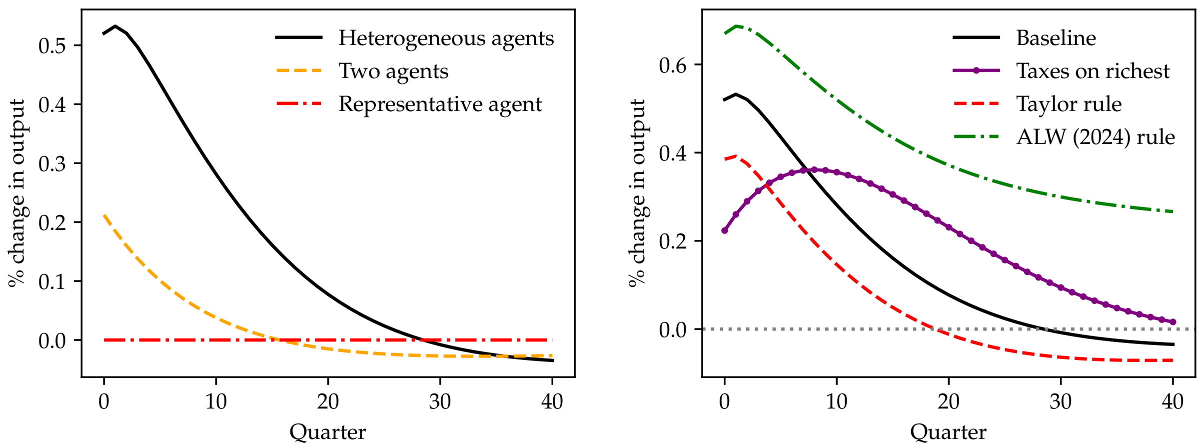
$$d\mathbf{Y} = \overline{\mathbf{M}}\left(d\mathbf{Y} - d\mathbf{T}\right) + d\mathbf{G} \tag{10}$$

Proposition 1. *(Balanced-budget fiscal multiplier.) A shock to government spending $d\mathbf{G}$ with $d\mathbf{B} = d\mathbf{r} = 0$ has a multiplier of 1: $d\mathbf{Y} = d\mathbf{G}$, irrespective of all household heterogeneity.*

The proof follows immediately from the observation that $d\mathbf{B} = 0$ imposes $d\mathbf{T} = d\mathbf{G}$, and then $d\mathbf{Y} = d\mathbf{G}$ solves (10).[16] This result is important because it establishes a benchmark in which the

[15] This can be interpreted as a Taylor rule with a coefficient of 1 on expected inflation.

[16] This assumes that there is a unique solution to (10). Uniqueness can be verified by checking the winding number



(a) Role of heterogeneity

(b) Alternative het.-agent models

Figure 2: Responses to deficit-financed tax cuts in several models

multiplier is identical to that from a representative-agent model with the same monetary policy rule (e.g. Woodford 2011, Bilbiie 2011). It echoes a balanced-budget multiplier result from the old Keynesian literature (e.g. Gelting 1941, Haavelmo 1945).

While RA, TA, and HA models all have the same balanced-budget multipliers, they obviously have different implications for deficit-financed fiscal policy, given that the RA model features Ricardian equivalence while the others do not. We next study the effects of a deficit-financed tax cut, keeping government spending constant ($d\mathbf{G} = 0$). We assume mean-reverting public debt, so that the economy eventually returns to its original steady state. Specifically, we assume a fiscal rule of the form $dB_t = \rho_B dB_{t-1} - dT_t^{shock}$, where $-dT_t^{shock}$ is a deficit-financed tax cut shock, and ρ_B gives the persistence of excess debt that has already been accrued. We calibrate $\rho_B = 0.975$, so that debt is paid off on average within 10 years, and consider a tax cut shock $-dT_t^{shock} = 1\% \cdot Y \cdot 0.9^t$.

Figure 2(a) shows the impulse response of output to this shock in the RA, TA, and HA models. As anticipated, the RA model has no response, due to Ricardian equivalence. The output change in the TA model is proportional to the tax cut in each period—so as the government starts raising taxes to stabilize and then reduce the debt, the output effect becomes negative.[17]

In the HA model, on the other hand, deficit-financed tax cuts have prolonged effects on economic activity. The reason is that an initial tax cut is partially spent, as in the TA model, but also partially saved, strengthening household balance sheets—as is necessary to purchase the additional government debt outstanding. Since households have buffer-stock behavior, households try to spend down these "excess savings", consistent with empirical evidence during the recent Covid pandemic (see e.g. Aggarwal et al. 2023, Bardóczy, Sim and Tischbirek 2024). This results in additional consumption-income feedback in later periods, sustaining economic activity even

of the asset Jacobian. See Auclert, Rognlie and Straub (2023b).

[17] The exact formula in the TA model is $dY_t = -\frac{\lambda}{1-\lambda} dT_t$ (see Bilbiie, Monacelli and Perotti 2013 and Auclert et al. 2024a). Note that the present value of this response is zero, while it is positive in the HA model.

after the government begins to raise taxes. The initial response of output is also larger than in the TA model, because households are able to bring forward some of the anticipated income from the future boom.

Overall, deficit-financed fiscal policy has very long and persistent effects on economic activity in the HA model. This is underpinned by interesting distributional dynamics: since poor households with larger MPCs spend down their excess savings the fastest, the increase in private wealth from government bond issuances becomes increasingly concentrated at the top of the wealth distribution, a "trickling up" phenomenon (Auclert, Rognlie and Straub 2023c).

While we just analyzed the effects of deficit-financed tax cuts, similar conclusions apply to deficit-financed government spending, which is the sum of a deficit-financed tax cut and a balanced-budget government spending shock.

Alternative tax instruments and distribution. We have stressed that deficit-financed fiscal policy can have large aggregate effects. The nature of taxation clearly matters for this result. The model is set up so that an aggregate increase in labor income or an aggregate decline in taxes of the same magnitude has the same effect on every agent. A progressive tax system on its own need not alter this result, if a tax hike lowers everyone's after-tax income by the same proportion. However, if a tax change is tilted toward the rich or poor, the multiplier will vary. For instance, in the purple line in figure 2(b), households in the highest income state both receive the tax cut and pay for it later. Importantly, this results in a lower impact multiplier, since the rich households have lower MPCs out of the tax cut—but it also implies a more persistent output effect, since these households also have lower MPCs out of the subsequent tax hikes. Hagedorn et al. (2019a) and Ferriere and Navarro (2024) explore related distributional questions.

Monetary policy response. Our results thus far assume a neutral monetary policy rule, in the sense that r_t neither rises nor falls in response to the shock. A nominal interest rate fixed at the zero lower bound is well-known in the New Keynesian literature to dramatically raise fiscal multipliers (e.g. Christiano, Eichenbaum and Rebelo 2011). Inversely, an active Taylor rule tends to reduce multipliers. For instance, the dashed red line in figure 2(b) shows the response when the Taylor rule is $i_t = r + \phi\pi_t$ with $\phi = 1.5$. This clearly dampens the impulse response to deficits relative to our baseline, but the response nevertheless remains above the TA model with the baseline monetary rule.

Self-financed deficits. An intriguing possibility is that that deficits may be *self-financed* by the increase in tax revenue from the output boom that they create. This possibility was recently studied by Angeletos et al. (2023). Suppose that there is a baseline tax rate τ, relative to which the government cuts by τ_t^X: $\tau_t = \tau - \tau_t^X$. To first order, this implies $dT_t = \tau dY_t - dX_t$ for total tax revenue, where $dX_t = -Yd\tau_t^X$ is the direct effect of the unfunded tax cut on the deficit. Solving (10) with this fiscal rule, we see that there always is a path for output that is consistent with self-financing this unfunded tax cut, given by:

$$d\mathbf{Y} = \left(\mathbf{I} - (1-\tau)\,\overline{\mathbf{M}}\right)^{-1}\overline{\mathbf{M}}d\mathbf{X}$$

Hence, deficits are always self-financing in this model, requiring only that the inverse $\mathbf{I} + (1-\tau)\overline{\mathbf{M}} + (1-\tau)^2\overline{\mathbf{M}} + \ldots$ of $\mathbf{I} - (1-\tau)\,\overline{\mathbf{M}}$ exists. The dash-dot green line in figure 2(b) represents the impulse response to exogenous tax rate cuts $d\tau_t^X = -1\% \cdot Y \cdot 0.9^t$ with this fiscal rule in place. The output boom under this rule is extremely persistent. Intuitively, an unfunded tax cut encourages spending for all agents in the population, since none of them have to bear a future tax increase, as they do in our baseline. This spending generates income and further spending, and so on, with the process only drawing down because the government takes a fraction τ of all new income as tax revenue that it does not distribute further.

4 Monetary policy

We now study monetary policy, and the extent to which heterogeneity alters the lessons from the standard New Keynesian RA model. To do this, we consider monetary policy shocks $\{r_t\}$, keeping fiscal policy as neutral as possible. This is complicated by the fact that a change in r_t alters the government budget constraint: as is clear from (3), whenever there is a positive amount of debt outstanding, a decline in r_t lowers interest payments on the outstanding debt and frees up government resources.

We begin by discussing the case where this effect is absent because the government does not have any debt: $B_t = 0$ at all dates, including in the steady state. This changes the calibration of the model relative to our baseline, requiring a higher μ to hit the same steady-state asset level A. However, in this calibration, we have the following striking result, first obtained by Werning (2015) in an HA model, though an antecedent in a TA model can be found in Bilbiie (2008).

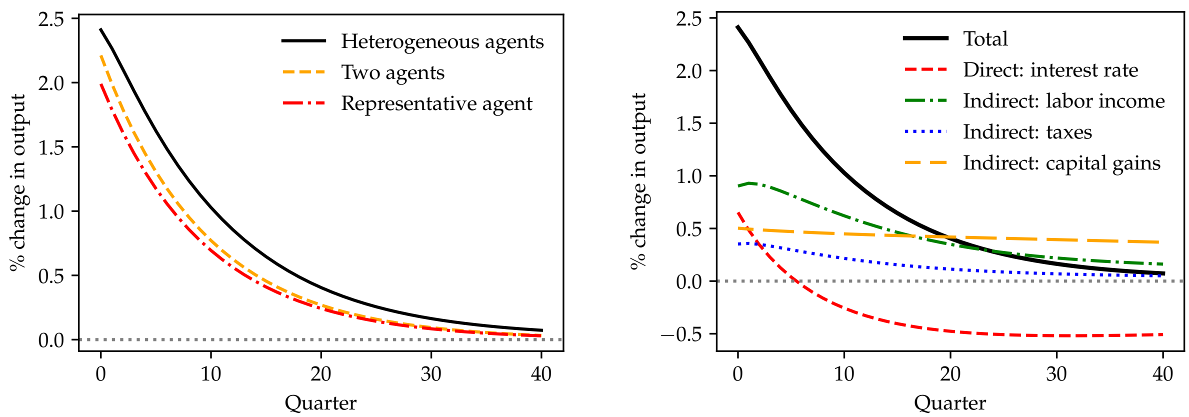
Proposition 2. *(Monetary equivalence.) When $B = 0$ in the steady state, an interest rate shock $d\mathbf{r}$ has identical effect on output in the HA or TA model as in the RA model, that is:*

$$d\mathbf{Y} = -C\mathbf{U}d\mathbf{r} \tag{11}$$

where $\mathbf{U}$ is a matrix with ones on and above the diagonal. More generally, for any given Taylor rule, the responses in RA, HA, TA are identical.

For the aggregate effects of monetary policy, therefore, one should not necessarily expect HA models to deliver different predictions from the standard RA model. After our fiscal policy results in section 3, this result may seem surprising: to the extent that monetary policy moves aggregate demand, the feedback from income to consumption is stronger in the heterogeneous-agent model, so we might expect the aggregate effect on economic activity to be amplified.

It turns out, however, that there is a countervailing effect: when agents have larger MPCs,



(a) Role of heterogeneity

(b) Decomposition

Figure 3: Responses to monetary easing in several models

they are also less sensitive to interest rates. Intuitively, agents with higher MPCs have shorter horizons over which to substitute. Indeed, in our model with log utility, it is possible to derive a relationship between $\mathbf{M}^r$, $\mathbf{M}$ and $\mathbf{m}$ (see Auclert et al. 2024a, Proposition 8) given by:

$$\mathbf{M}^r = -C\left(\mathbf{I} - \left(1 - \frac{rA}{C}\right)\mathbf{M}\right)\mathbf{U} + (1+r)\,A\mathbf{m}\mathbf{1}' \tag{12}$$

Hence larger iMPCs in "$\mathbf{M}$", everything else constant, tend to lower $\mathbf{M}^r$. Plugging this result into (9), and using the facts that $\frac{1+r}{r}\mathbf{1}' - \frac{1}{r}\mathbf{q}' = \mathbf{q}'\mathbf{U}$ and $rp = \left(1 - \frac{1}{\mu}\right)Y$ as well as the market clearing conditions $p = A$ and $d\mathbf{C} = d\mathbf{Y}$, delivers equation (11).[18]

With $B > 0$, as in our baseline calibration, proposition 2 is no longer exactly true. To evaluate this quantitatively, we need to specify a fiscal rule. Here, we will assume that the government adjusts taxes to target a constant $(1 + r_t)B_t$: if r_t falls, the government lowers taxes and raises B_t so that the debt burden heading into $t + 1$ is constant.

Figure 3 shows the impulse response to an AR(1) real interest rate shock, $dr_t = -1\% \cdot 0.9^t$ (expressed in annual percent), in our three models. The HA model responds slightly more than the TA model, which responds slightly more than the RA model. Consistent with the spirit of proposition 2, the responses are close. But here, because there is a fiscal response, the insight from section 3 that tax cuts have larger effects in HA than in TA and RA is visible as well.

Direct vs indirect effects. As is clear from the above discussion, the transmission mechanisms in HANK models can be quite complex: consumption is affected by interest rates, by labor incomes

[18]The expression for $\mathbf{q}'\mathbf{U}$ follow from the fact that $(\mathbf{q}'\mathbf{U})_t = \sum_{s=0}^{t}\left(\frac{1}{1+r}\right)^s = \frac{1+r}{r} - \frac{1}{r}\left(\frac{1}{1+r}\right)^t$. Substituting (12) into (9) then yields $\left(\mathbf{I} - \left(1 - \frac{rA}{C}\right)\mathbf{M} - \frac{rA}{C}\mathbf{m}\mathbf{q}'\right)d\mathbf{C} = -C\left(\mathbf{I} - \left(1 - \frac{rA}{C}\right)\mathbf{M} - \frac{rA}{C}\mathbf{m}\mathbf{q}'\right)\mathbf{U}d\mathbf{r}$, and we obtain equation (11) by cancelling the $\left(\mathbf{I} - \left(1 - \frac{rA}{C}\right)\mathbf{M} - \frac{rA}{C}\mathbf{m}\mathbf{q}'\right)$ terms.

determined in general equilibrium, by the fiscal response, and so on. A popular way of unpacking these mechanisms, proposed by Kaplan et al. (2018) and Auclert (2019), is to decompose the consumption impulse response into the determinants of consumption. A sequence-space approach to the solution makes this straightforward to do. In particular, we can rewrite (8) as

$$d\mathbf{C} = \underbrace{\mathbf{M}^r d\mathbf{r}}_{\text{Direct interest rate effect}} + \underbrace{\frac{\mathbf{M}}{\mu} d\mathbf{Y}}_{\text{Labor income effect}} + \underbrace{-\frac{\mathbf{M}}{\mu} d\mathbf{T}}_{\text{Govt transfer effect}} + \underbrace{\mathbf{m} dcap}_{\text{Capital gain effect}}$$

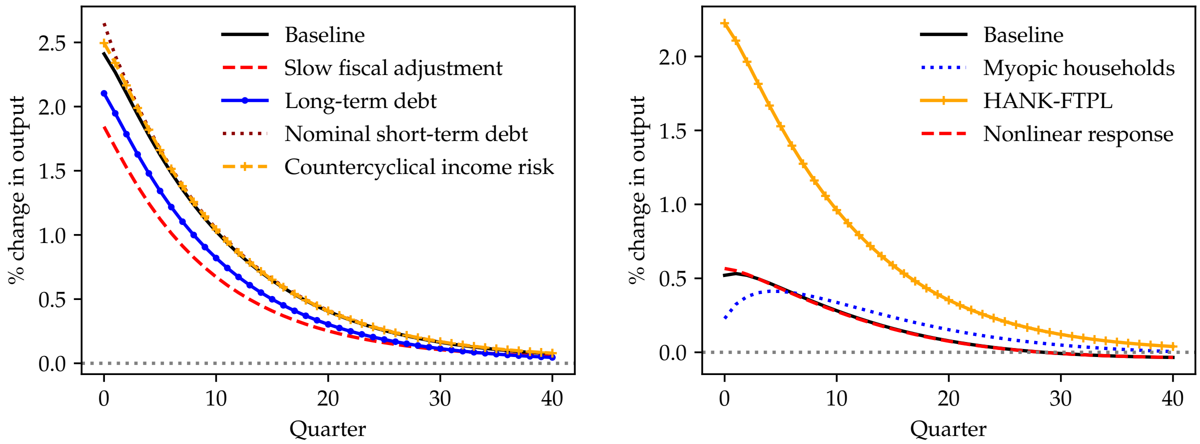
and then calculate each term on the right-hand side of this decomposition using the equilibrium values for $d\mathbf{r}$, $d\mathbf{Y}$, $d\mathbf{T}$, and $dcap$. Figure 3(b) shows the outcome of this decomposition. The interest rate effect is positive early and negative later, reflecting intertemporal substitution in response to lower rates, in addition to a negative income effect. By contrast, the capital gains effect is positive throughout: lower interest rates generate a substantial stock market boom, and agents have a relatively low but persistent marginal propensity to consume $\mathbf{m}$ out of this stock market wealth. The labor income effect is large on impact and then declines relatively slowly, as the increased employment income feeds into consumption according to the pattern of labor iMPCs $\mathbf{M}$. Government tax cuts from the lower interest burden have a meaningful effect too.

Overall, the "direct" effects of the monetary shock are substantially smaller than the combined "indirect" effects from labor income, taxes, and capital gains. This is one of the key messages from the HANK literature, first established by Kaplan et al. (2018), and it is very robust. Hence, rather than affecting the overall effect of monetary policy—which Proposition 2 shows it does not necessarily do—heterogeneity changes the transmission mechanism.

Slow fiscal adjustment. A fiscal rule that targets constant $(1 + r_t)B_t$ implies a large and immediate tax cut as interest rates fall. In practice, fiscal policy seems unlikely to respond so quickly. As an alternative, the red dashed line in figure 4(a) implements a slow-moving policy, where tax revenue adjusts according to $dT_t = 0.02 dB_{t-1}$ each period. This policy naturally implies a softer output response, as taxes are now only reduced slowly over time, illustrating how the nature of the fiscal rule matters for monetary transmission (see also Kaplan et al. 2018, Auclert et al. 2020).

Maturity structure of assets and liabilities. An important and counterfactual assumption underpinning the experiments in figure 3 is that debt is short-term, maturing every quarter. In practice, government debt is of much longer maturity, so that less of it needs to be rolled over every quarter, making the effect of a monetary shock on the government budget much smaller. This suggests a smaller tax cut than in figure 3, and perhaps a smaller consumption response. On the other hand, holders of government bonds make a capital gain, which boosts consumption.

The net effect of longer maturities is typically that they make monetary policy less effective (Auclert 2019, Auclert et al. 2020). To investigate this, we extend the model assuming each government bond purchased at date t pays off coupons $1, \delta, \delta^2, \ldots$ at dates $t + 1, t + 2, \ldots$ and



(a) Monetary easing

(b) Deficit-financed fiscal stimulus

Figure 4: Impulse responses in alternative parameterizations

so on. The price of this bond is then $q_t = \frac{1+\delta q_{t+1}}{1+r_t}$ and the government budget constraint is $G_t + \tilde{B}_{t-1} = q_t\left(\tilde{B}_t - \delta\tilde{B}_{t-1}\right) + T_t$ with $\tilde{B}_t$ denoting the date $t+1$ coupon payment. With a fiscal rule in the same spirit as before—adjusting T_t to ensure a constant coupon $\tilde{B}_t$ owed in the next period—the blue line in figure 4(a) shows that longer-duration debt indeed leads to weaker effects of monetary policy (here, $\delta = 0.95$). This aligns well with empirical evidence that countries with longer-duration debt tend to have weaker effects of monetary policy (Calza, Monacelli and Stracca 2013). A connected literature discusses the implications of mortgage market structure, and in particular mortgage refinancing, on the transmission mechanism of monetary policy (Greenwald 2018, Wong 2019, Cloyne, Ferreira and Surico 2020, Berger, Milbradt, Tourre and Vavra 2021, Eichenbaum, Rebelo and Wong 2022, Cumming and Hubert 2023).

Nominal asset redistribution. Another important and counterfactual assumption in figure 3 is that all government debt is real. In practice, government debt is typically denominated in nominal terms, and so are many household liabilities, including mortgages. This matters for monetary transmission, since any impulse to aggregate demand generates inflation through the Phillips curve, and therefore generates redistribution between nominal debtors and nominal creditors. Because nominal debtors tend to have higher marginal propensities to consume than nominal creditors, this effect—usually referred to as the "Fisher channel"—tends to go in the direction of amplifying the effects of monetary policy (Fisher 1933, Doepke and Schneider 2006, Auclert 2019, Pallotti 2024), and allows deficits to self-finance party by eroding government debt (Cochrane 2023, Angeletos et al. 2023). This effect can be seen for a version of our model with nominal (short-term) debt in figure 4(a). The exact empirical magnitude of this effect, however, remains open to debate.

Cyclical income risk. We have assumed that the labor market benefits of increases in aggregate demand are proportionally distributed across the population. There is much empirical evidence suggesting that this is not true in practice: for instance, Guvenen, Schulhofer-Wohl, Song and Yogo (2017) document U-shaped sensitivities of individual income to aggregate income, or "worker betas", across the income distribution in the United States. Similar conclusions are reached conditional on monetary policy shocks: see Coibion, Gorodnichenko, Kueng and Silvia (2017) for the U.S., Holm, Paul and Tischbirek (2021) for Norway, Amberg, Jansson, Klein and Picco (2022) in Sweden, Andersen, Johannesen, Jørgensen and Peydró (2023) in Denmark and Hubert and Savignac (2024) for France.

Our $n_{it} = N_t$ labor allocation rule can be relaxed to allow for these richer distributional effects. A simple approach is to assume a functional form for $n_{it} = \gamma(N_{it}, e_{it})$, with the "incidence function" γ chosen to appropriately match empirical evidence. For instance, Auclert and Rognlie (2018) propose $\gamma(N_{it}, e_{it}) = N_t \frac{e_{it}^{\zeta \log N_t}}{E\left[e_{it}^{1+\zeta \log N_t}\right]}$, so that the standard deviation of cross-sectional log earnings rises in an employment boom (procyclical inequality) when $\zeta > 0$, and falls in a boom (countercyclical inequality) when $\zeta < 0$. Importantly, this assumption modifies not just the cyclicality of income inequality, but also that of *income risk*: for instance, anticipation of future recessions makes forward-looking households perceive more income risk when $\zeta < 0$, leading them to increase precautionary savings. Similar effects from countercyclical risk obtain when the Markov transition matrix is affected by the level of economic activity, as with a search and matching microfoundation for labor market risk (e.g. Gornemann, Kuester and Nakajima 2016, Ravn and Sterk 2021, Alves and Violante 2023, Bardóczy et al. 2024), with on-the-job-search (Birinci, Karahan, Mercan and See 2024), or with endogenous occupation and participation choices (Faia and Shabalina 2024, Faia, Shabalina and Wiczer 2024).

Under nominal rigidities, countercyclical income risk amplifies demand shocks. We illustrate this for our monetary policy shock in figure 4(a), where we set $\zeta = -0.15$. The expectation of a future recession raises income risk and lowers spending today, amplifying the recession. Analytical models that feature a precautionary savings channel, such as zero-liquidity or CARA models, are especially useful to tractably illustrate this mechanism (see e.g. Ravn and Sterk 2017, Acharya and Dogra 2020, Bilbiie 2020 and Bilbiie 2024). In addition, the recession redistributes away from low-income, high-MPC agents towards high-income, low MPC agents, so the cyclicality of inequality has an additional amplifying role (Patterson, 2023). Overall, while this effect is plausible, its magnitude is sometimes too powerful, creating challenges for macroeconomic dynamics such as indeterminacy of equilibria, or a very strong "forward guidance puzzle".[19]

Forward guidance. The forward guidance puzzle is the proposition, initially from Del Negro, Giannoni and Patterson (2023), that in the standard New Keynesian model, given an already accommodative monetary policy rule (such as at the zero lower bound for nominal interest rates), the announcement of a future monetary accommodation has very—and perhaps implausibly—powerful

[19]For instance, in this model, we have found that a mildly more negative $\zeta = -0.25$ leads to indeterminacy.

effects on economic activity. Under a rule that holds the real interest rate constant, this is easy to see in equation (11): a future cut to r_s, no matter how far s is in the future, has the same effect on consumption at date 0, and that effect persists all the way to date s. At the zero lower bound, this generates inflation which further lowers real interest rates, boosts demand even more, and so on.

McKay et al. (2016) proposed that HA models might fix the forward guidance puzzle. They observed that agents in HA models have shorter effective horizons and respond less to interest rates far in the future. In our notation, the partial equilibrium effect M^r_{0s} is decreasing in the horizon s. However, what is true in partial equilibrium need not be true in general equilibrium: as equation (11) shows, the equilibrium effect on consumption can be independent of the horizon s. Indeed, the McKay et al. (2016) model ultimately solves the forward guidance puzzle in general equilibrium only because it has procyclical income risk (see e.g. Werning 2015, Hagedorn, Luo, Manovskii and Mitman 2019b, Acharya and Dogra 2020, Bilbiie 2024).

5 Additional topics

This section covers additional topics that are active areas of research in the HANK literature.

Illiquid accounts. We showed that the canonical HANK model with discount factor heterogeneity was able to simultaneously capture an empirically realistic MPC and an empirically realistic wealth distribution, including a large amount of total wealth. Hence, β heterogeneity can in principle solve a key tradeoff in the literature that uses standard incomplete market models: forces that increase the level of aggregate wealth, such as patience, also tend to push households away from borrowing constraints and therefore lower their MPCs (e.g. Krueger, Mitman and Perri 2016, Kaplan and Violante 2022).

A popular alternative approach to resolving this tradeoff is to model households as having two accounts, one liquid and one illiquid (Kaplan and Violante 2014, Kaplan et al. 2018, Kaplan and Violante 2022, Luetticke 2021, Bayer, Luetticke, Pham-Dao and Tjaden 2019). Agents face a choice between investing in a low-liquidity, high-return account and a high-liquidity, low-return account. When these models are calibrated to a large return spread, agents tend to have most of their wealth in illiquid accounts, with relatively little in liquid accounts. Kaplan, Violante and Weidner (2014) document these "wealthy hand-to-mouth" agents in the data, and Kaplan and Violante (2022) show that this helps resolve the "missing middle" problem discussed in section 2.

Models with illiquid accounts yield additional benefits. First, they generate an empirically more realistic correlation between MPCs and income than in the canonical model (Kaplan and Violante 2014). Second, to the extent that stocks are held in illiquid accounts, the iMPCs out of stock market gains $\mathbf{m}$ are small—even smaller than in the canonical HANK model, and potentially more empirically realistic (Auclert et al. 2024a). A downside of two-account models, however, is that they are substantially more complex to work with than one-account models.

Behavioral frictions. Our canonical HANK model is written under the assumption of full information rational expectations (FIRE). While this is a useful benchmark, a large empirical literature documents meaningful departures from this assumption (e.g. Coibion and Gorodnichenko 2012, Coibion and Gorodnichenko 2015). In addition, it is known from the behavioral New Keynesian literature that information frictions can help to solve some prominent puzzles, such as the forward guidance puzzle (e.g. Angeletos and Lian 2018, Gabaix 2020).

Recent research has pointed out interesting interactions between heterogeneity and behavioral frictions: for instance, Farhi and Werning (2019) show that a model with level-k agents and incomplete markets can explain weak effects of forward guidance, while individually these assumptions cannot (see also Pfäuti and Seyrich 2022). As Auclert et al. (2020) have shown, many of these behavioral frictions, as long as they do not change the aggregate steady state of the model, can be implemented naturally with sequence-space methods, so that it is straightforward to incorporate them into our model (see also Guerreiro 2023 and Bardóczy and Guerreiro 2023).[20]

Suppose, for instance, that households never anticipate future labor income or taxes: they are always fully surprised by the realization of either. At the same time, they are aware of their current levels of assets and income, and perfectly rational with respect to individual income risk. Then, the iMPC matrix out of labor income becomes $\mathbf{M}^b$, a lower triangular matrix with elements below the diagonal equal to the first column of the rational $\mathbf{M}$ matrix. The model can then be solved using equation (10), but replacing $\overline{\mathbf{M}}$ with $\overline{\mathbf{M}}^b \equiv \frac{1}{\mu}\mathbf{M}^b + \left(1 - \frac{1}{\mu}\right)\mathbf{mq}'$. The dotted blue line in figure 4(b) performs this exercise, showing that the impulse response of output to a deficit-financed fiscal shock can become hump-shaped, as households do not immediately realize that their income will be persistently higher.

Fiscal Theory of the Price Level. An emerging literature discusses the interaction between household heterogeneity and the fiscal theory of the price level (FTPL) (Kaplan, Nikolakoudis and Violante 2023, Angeletos, Lian and Wolf 2024; see Cochrane 2023 for a review of the FTPL). In the canonical model introduced above, we have worked with a combination of what Leeper (1991) calls an active monetary policy and a passive fiscal policy. An alternative is to assume passive monetary policy and active fiscal policy: for instance, a fixed nominal interest rate combined with an exogenous path of tax revenue T_t. We analyze a negative shock to T_t in figure 4(b), showing that such a HANK-FTPL model generally implies far larger fiscal multipliers than we found earlier. This amplification arises because fiscal stimulus causes inflation, which here reduces the real interest rate and drives additional spending, echoing a well-known effect in the New Keynesian zero lower bound literature (e.g. Christiano et al. 2011).

Nonlinearities. So far we have considered small shocks, but an interesting question is whether monetary and fiscal policy responses depend on the size and sign of the shock. Empirically,

[20] A separate and growing line of work considers behavioral frictions that affect household behavior even in the absence of aggregate shocks: see, for instance, Maxted, Laibson and Moll (2024) and Fernandes and Rigato (2024).

size and sign asymmetries remain open to debate (e.g. Barnichon, Debortoli and Matthes 2022, Ben Zeev, Ramey and Zubairy 2023 for fiscal policy). We investigate nonlinearities in fiscal multipliers in our model with the dashed red line in figure 4(b), where we feed in our 1% tax cut as an unanticipated nonlinear shock. We find effects that are convex in size, but very modestly so, in line with the literature, which has generally not found much nonlinearity (Auclert et al. 2024a, Faria-E-Castro, Nóbrega, Holter, Ferreira and Brinca 2024).

Investment, durable goods, and net exports. The model in this paper has only nondurable consumption and government spending as components of aggregate demand. In practice, investment and durable goods are highly responsive to monetary and fiscal policy shocks; adding these elements to the model brings forth interesting new mechanisms. One important result is the complementarity between investment and high MPCs: now that there is another component of aggregate demand that responds to monetary policy, the effect of monetary policy on consumption gets amplified via the general equilibrium effect of aggregate demand on income (Auclert et al. 2020, Bilbiie, Känzig and Surico 2022). With durable goods, there is also more scope for the intertemporal substitution channel of monetary policy, as rate cuts generate a burst in durable spending followed by a decline in the future. This potentially gives monetary policy less ammunition to boost demand after a recent cut in interest rates (McKay and Wieland 2021).

In open economies, the exchange rate depreciates after rate cuts and net exports can respond, providing another transmission mechanism for monetary policy. Exchange rate depreciations, on their own, also make the economy poorer via a real income effect, and may also adversely affect household balance sheets if those are denominated in foreign currency. A growing open-economy HANK literature studies these and related issues (de Ferra, Mitman and Romei 2020, Auclert et al. 2021b, Guo, Ottonello and Perez 2023, Bellifemine, Couturier and Jamilov 2023, Druedahl, Ravn, Sunder-Plassmann, Sundram and Waldstrøm 2024).

Aggregate risk, risk premia, and endogenous portfolio choice. We wrote down the canonical HANK model by assuming away aggregate risk and appealing to certainty equivalence to say that its first-order impulse responses were the same as in a model with aggregate risk. An issue with this approach is that it does not allow one to study agents' optimal portfolio choices or risk premia, and the impact that policy might have on these. One literature tackles this challenge by writing down models with more limited heterogeneity and solving them with global solution methods (Kekre and Lenel 2022). This literature shows that redistribution can be a mechanism through which accommodative monetary policy lowers risk premia. However, only a handful of papers solve rich HANK models globally without simplifications (Schaab 2020, Fernández-Villaverde, Marbet, Nuño and Rachedi 2024, Lin and Peruffo 2024, Kase, Melosi and Rottner 2024).[21]

A separate approach explores the perturbation solution to higher order. Recent work points out that second-order objects such as steady-state risk premia, as well as optimal portfolio choices

[21] A recent literature is exploring alternatives to risk-based asset pricing in HANK, e.g. Chiang and Zoch (2024), Auclert, Rognlie, Straub and Wu (2024b), and Ilut, Luetticke and Schneider (2024).

at the level of individual agents, can actually be obtained as the byproduct of a first-order solution (Bhandari, Bourany, Evans and Golosov 2023, Auclert et al. 2024c). In particular, when households can invest in stocks and bonds directly, rather than through the mutual fund, solving the canonical HANK model still involves equation (10), but with a modified $\overline{\mathbf{M}}$ that reflects a correction for the presence of locally complete markets with respect to aggregate risk. These solution methods open the door to models with both risk premia and realistic heterogeneity.

Optimal policy. A major success of the New Keynesian literature has been its ability to derive optimal policy from microfoundations. In particular, around an efficient steady state, a quadratic loss function in inflation and the output gap characterizes optimal policy, providing clear principles for the optimal response to shocks (Clarida, Galí and Gertler 1999, Woodford 2003, Galí 2008). The HANK literature has not yet reached a comparable level of maturity. The computation of optimal policy—defined as the optimal response to shocks under either commitment or discretion—remains very difficult in quantitative HANK models.

One approach has been to study simpler models: two-agent models (Bilbiie 2008), zero liquidity models (Challe 2020, Bilbiie 2024), models with CARA preferences (Acharya, Challe and Dogra 2023), or models with flexible prices (Nuño and Thomas 2022). Another approach has been to assume an exogenous objective function, such as the standard quadratic loss function in the output gap and inflation. The sequence-space solution is then a typical quadratic programing problem of minimizing the loss function subject to the linear sequence-space equations characterizing equilibrium to first order (e.g. McKay and Wolf 2022, Barnichon and Mesters 2023). A downside of this approach is that it sidesteps the equity-efficiency tradeoff that is at the core of a heterogenous-agent model.[22]

Recent research has pushed forward using both state-space methods (Bhandari et al. 2021, LeGrand and Ragot 2023) and sequence-space methods (Dávila and Schaab 2023). These papers illustrate the distributional tradeoffs faced by optimal policy: for instance, Bhandari et al. (2021) show that, a central bank may want to lower interest rates in the fact of cost-push shocks if those come from increasing markups which redistribute from workers to capitalists; under sticky prices, this can be undone with a demand-driven boom because this lowers markups.

A lingering difficulty is that an unrestricted HA model, with standard preferences and both monetary and fiscal instruments, typically lacks a well-defined Ramsey steady state (RSS) to which the economy without shocks will converge (Chien and Wen 2022, Auclert, Cai, Rognlie and Straub 2024d). Such an RSS is generally the starting point for optimal policy in response to shocks, and a better understanding of long-run optimal policy will be needed for work in this area to continue.

[22] McKay and Wolf (2022) make progress on this front by also deriving an augmented loss function with a distributional term; this requires assuming preferences for the planner such that the incomplete markets equilibrium is first-best.

6 Conclusion

Adding heterogenous agents to an otherwise standard New Keynesian model introduces powerful new forces, and allows macro models to speak more directly to mechanisms documented in micro data. The canonical model presented in this paper can provide a useful entry point, since it is versatile and easy to build upon. While much progress has been made over the past decade, the HANK literature remains active and open to research.

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