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# DOVES FOR THE RICH, HAWKS FOR THE POOR? DISTRIBUTIONAL CONSEQUENCES OF SYSTEMATIC MONETARY POLICY[1]

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We build a New Keynesian business-cycle model with rich household heterogeneity. In the model, systematic monetary stabilization policy affects the distribution of income, income risks, and the demand for funds and supply of assets: the demand, because matching frictions render idiosyncratic labor-market risk endogenous; the supply, because markups, adjustment costs, and the tax system mean that the average profitability of firms is endogenous. Disagreement about systematic monetary stabilization policy is pronounced. The wealth rich or retired tend to favor inflation targeting. The wealth-poor working class, instead, favors unemployment-centric policy. One- and two-agent alternatives can show unanimous disapproval of inflation-centric policy, instead. We highlight how the political support for inflation-centric policy depends on wage setting, the tax system, and the portfolio that households have.

JEL Classification: E12, E21, E24, E32, E52, J64

Keywords: Monetary Policy, Unemployment, Search and Matching, Heterogeneous Agents, General Equilibrium, Dual Mandate

The online appendix is available at keithkuester.eu/gkn_online_appendix.

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## 1. Introduction

Households differ in their wealth and the composition of their sources of income. Different households, thereby, can be exposed to fundamentally different risks and opportunities. Monetary policy, in turn, shapes this profile through its *systematic* response to inflation and unemployment: in the case of the U.S., for example, through the choice of strategies within the confines of the Federal Reserve's dual mandate. We illustrate that accounting for inequality in wealth and sources of income could profoundly affect our view on how much support specific systematic monetary stabilization policies have.[1]

Toward this end, we build a heterogeneous-agent New Keynesian business-cycle model ("HANK," in short) with rich household heterogeneity. The core of the model is "standard" nominal rigidities, search and matching frictions in the labor market, and incomplete financial markets. In this environment, three channels mean that the systematic conduct of monetary stabilization policy can have distributional consequences. First, a more inflation-centric monetary policy raises not only the cyclicality of unemployment but can also raise *average unemployment*, the exposure to which differs across households. Second, since monetary stabilization policy shapes households' idiosyncratic unemployment risk, it affects the aggregate capital stock and thereby wages and the return to capital through *precautionary savings*. Beyond that, third, the systematic conduct of monetary policy could have the potential to affect the *distribution of income* and, thus, the value of financial assets. One example is precautionary pricing, where in the presence of markup shocks firms choose higher average markups when the central bank seeks to stabilize inflation. Depending on the wage's response, employment alone would fall and/or the labor share.

We calibrate the model so as to match key features of the U.S. wealth and income distribution, tax and welfare system, age structure, and the business cycle. We then ask households if they, compared to the baseline, prefer the central bank's policy rate to respond more/less to inflation/unemployment. At the extreme, we look at a natural benchmark: strict inflation targeting. A representative agent ("RANK," henceforth) would disapprove of this policy and would favor a stronger focus on unemployment. In our HANK baseline, instead, 44 percent of households would favor strict inflation targeting. The gains accrue to the wealth rich and to retirees, whereas the wealth-poor working class loses. A two-agent saver-spender analog (that follows Campbell and Mankiw 1989, "TANK," henceforth) would miss the size of the support for hawkish policy.

More in detail, the HANK model features rich household heterogeneity. Households transition over time between working age and retirement. Working-age households draw labor income, income from financial sources, or unemployment

[1]We focus on the welfare consequences of systematic stabilization policy. This sets the paper apart from related work in heterogeneous-household settings with ample heterogeneity, such as McKay and Reis (2016) and Kaplan et al. (2018). Toward the end of the introduction, we provide a detailed overview of how our paper relates to earlier work in the literature.

benefits. Search and matching frictions (as in Krusell et al. 2010) render average and cyclical unemployment endogenous to monetary policy (as in Christiano et al. 2016). Wages adjust gradually to shocks. To adequately capture the consumption risk associated with unemployment, we allow for persistent earnings losses upon job loss (following Couch and Placzek 2010, Altonji et al. 2013, Davis and von Wachter (2011))). Next, differences in education imply different exposures to unemployment risk (Cairó and Cajner 2018). Retired households are not exposed to labor-income risk. They receive pensions and supplement them with retirement savings (De Nardi 2004). So as to match further salient features of the heterogeneity in wealth and income, we allow for transitory idiosyncratic productivity shocks (including temporary transitions to very high income as in Castañeda et al. 2003, Nakajima 2012a) and differences in patience (as in Krusell and Smith 1998, Carroll et al. 2017).[2] Financial markets are incomplete and households save through a mutual fund. This fund exposes households to the effects that systematic monetary policy has on the value of assets.

In our baseline calibration, the strength of the *average unemployment channel* is comparable across the different model environments (HANK/RANK/TANK). What sets the HANK economy apart from its RANK and TANK counterparts, instead, is that households in HANK self-insure against idiosyncratic risk. This gives a role to the interplay of the demand for funds and the supply of assets, a central mechanism of Aiyagari (1994)-type economies.

If hawkish monetary policy raises households' idiosyncratic labor-income risk, households exposed to this should increase *precautionary savings* and, thus, the demand for funds. Consistent with this, we find that a move to inflation-centric policy raises the net worth held by the bottom half of the wealth distribution. Still, upon a move toward inflation-centric policy, the aggregate capital stock falls sharply in the HANK baseline instead of rising, and more so than in RANK/TANK.[3] The key to this, instead, lies with the *supply side* of financial assets.[4] In our baseline, hawkish monetary stabilization policy reduces the labor share. This leads to windfall gains to financial capital and raises the supply of financial assets by value. In RANK/TANK this is of little consequence because the aggregate demand for funds adjusts elastically to supply. In HANK, instead, households save for a reason, making the demand for funds inelastic to changes in returns.[5] With the demand for funds being less elastic than in RANK/TANK,

[2]The literature finds that household savings are only in part driven by precautionary motives, for example, Hurst et al. (2010); and a still smaller share will be driven by cyclical risk. For the quantitative results of the paper, it matters that households have reasons to save beyond business-cycle risk. Necessarily we cannot model these reasons in much detail.

[3]A move toward strict inflation targeting, for example, reduces the HANK capital stock by roughly 2 percent, and only by about 0.4 percent in RANK/TANK.

[4]That a change in business-cycle characteristics can affect the aggregate capital stock and welfare through the demand for funds is well-known and discussed, for example, in Krusell et al. (2009). Our paper adds to this a supply-side channel.

[5]Many of the reasons to save that we entertain are not related to the business cycle in the first place (aging, bequests, fluctuations in residual income risk); see Footnote 2.

and holding government debt constant (we assume a balanced budget throughout), the supply of assets has to fall to clear the asset market. A fall in the capital stock achieves this.

Through the after-tax *income distribution*, the HANK economy can give rise to distributional concerns beyond productive efficiency. The exact trade-offs in turn depend on particular assumptions, most prominently regarding the wage setting protocol and fiscal policy. The search and matching model allows for a wide range of surplus-sharing rules. This matters because wages allocate changes in average activity between labor and financial capital. Our baseline features a wage rule that is consistent with balanced growth in that wages in the long run move one-to-one with economic activity. If monetary stabilization policy is neutral on employment, changes in aggregate income are shared equally among labor and capital. Instead, if average employment falls, the average labor share falls, too. In the model, retirees are exposed to the windfall gains to capital through retirement savings, but are not exposed to labor income. This is shown in their welfare gains from strict inflation targeting (equivalent to 0.3 percent of lifetime consumption). The aggregate consequences as regards the labor share and the real interest rate (which, respectively, fall by 0.1 percentage point and rise by 5bps annualized) are small, instead, and might easily go unnoticed.

Rather than providing a final verdict on potential winners and losers from a monetary stabilization policy, the current paper has a much more modest aim. We seek to highlight that systematic monetary stabilization policy, through affecting the distribution of average incomes and income risks, could have sizable distributional consequences. We show that assumptions matter for both the size and the sign of the gains from monetary stabilization policies. When we assume, for example, that wages are set such that the long-run labor share remains constant by design, employment falls by more. But so does the return to capital. Households, then, share more evenly in the fall of productive activity. The pattern of losses is also affected. Poor households would lose least from hawkish monetary policy (we keep the welfare and progressive tax system in place), the middle class most.

The rest of the paper is organized as follows. Next, we review the literature. Section 2 introduces the model. Section 3 highlights the calibration and business-cycle implications of household heterogeneity. Section 4 discusses the welfare effects of a switch to a different systematic monetary policy. The same section discusses optimal simple monetary rules for different segments of the population. So as to corroborate the results and mechanisms, Section 5 provides sensitivity analysis, namely, with regard to wage setting, with regard to fiscal policy, and with regard to the structure of household portfolios. A final section concludes. An extensive (online) appendix provides further details.

**Relation to the literature**

One can think about the distributional effects of monetary policy in different ways. One stream of the literature considers the distributional effects of surprise inflation. Doepke and Schneider (2006b) document that differences in portfolios negatively expose wealth-rich retirees to surprise inflation, whereas the young mortgaged middle class gains from surprise inflation. Doepke and Schneider (2006a), Meh et al. (2010), and Sterk and Tenreyro (2018) focus on modeling the aggregate effects of such wealth redistributions under flexible prices. Our paper, instead, thinks about *systematic* monetary stabilization policy rather than one-sided shocks. To make this clear, we fix the inflation target throughout. Instead, the disagreement among households in our setting comes from exposure to the real effects of systematic monetary policy: the valuation gains, the labor-market response, and fiscal effects.

Another stream of the literature considers the distributional effects of one-time shocks to the policy rate: "monetary shocks." This literature has seen strong growth in recent years, so we provide a selective overview only. This "HANK" literature emphasizes, in different guises, that the effect of inequality on monetary transmission in the aggregate crucially depends on how the shock affects households along the distribution of marginal propensities to consume (MPC, henceforth). This renders the response of labor and financial after-tax income and income risks central. Kaplan et al. (2018) highlight the importance of disposable income (shaped by fiscal policy) as opposed to intertemporal substitution.[6] Several papers provide insights into environments that do not have self-insurance in equilibrium (zero-liquidity). Ravn and Sterk (forthcoming) emphasize that countercyclical income risk makes the natural rate of interest fall in recessions, which deepens recessions if monetary policy does not adjust. Bilbiie (2020) shows that if the income of high-MPC households is procyclical, this provides further amplification. Acharya and Dogra (2020) provide an important perspective in a tractable environment with CARA utility. Broer et al. (2019) show that real wage rigidity, which we have, makes profits procyclical even in a New -Keynesian model without capital. This dampens wealth effects on labor supply (from which we abstract), and in their case ensures a reasonable monetary transmission channel. Relative to all these papers, what sets our contribution apart is that we study *systematic* monetary stabilization policy rather than the effect of monetary shocks. We do so in an environment in which valuation effects can be important, and we show that households' relative exposure to these can cause quantitatively meaningful disagreement about systematic stabilization policy.

Throughout, we compare the positive and normative implications of our HANK economy to RANK and TANK analogs. On the positive side, Debortoli and Galí (2017) conclude that TANK approximates the positive implications of a simpler HANK well, once HANK and TANK are calibrated to have comparable shares of borrowing-constrained/spender households. When we follow this strategy, TANK misses the sizable policy support for inflation targeting. Liquidity

[6] In their case, a large share of households tend to be wealthy, but invested in an illiquid asset. Our model's average MPC is of a size comparable to theirs, but it originates from impatience rather than modeling liquidity.

constraints are the wrong calibration target for our exercise. What matters for a household's evaluation of systematic monetary policy is the relative exposure to valuation gains and labor-market risk.[7]

A growing literature is concerned with optimal monetary policy in an incomplete-market setting. In a zero-liquidity economy, Challe (2020) argues that interest rates should be more accommodative in recessions since the desire to do precautionary saving reduces the natural rate of interest. Berger et al. (2019) look at a zero-liquidity environment in which layoffs have permanent scarring effects on human capital. They find that monetary policy should primarily focus on stabilizing unemployment. Our model also allows for long-term earnings losses. Still, households are not uniformly in favor of unemployment stabilization. One reason for this may be that our modeling of earnings losses is more rudimentary, and earnings losses are not permanent; another difference may originate from the fact that households in our model can self-insure in the first place. Another common thread in this literature is that monetary policy can provide consumption insurance *ex post*. Acharya et al. (2020) provide closed-form intuition for a HANK economy with CARA utility and self-insurance, but absent borrowing constraints. With countercyclical income risk, in response to productivity shocks they find that monetary policy should stabilize output more. This reduces the spread of consumption inequality in a recession. Comparably, Bhandari et al. (forthcoming) show the optimal monetary response to positive price markup shocks. In their setting, these shocks are distributed from labor earnings to dividends. If monetary policy is accommodative for a short time, it provides income insurance, and partly undoes the rise in price markups. Two dimensions set our work apart from the aforementioned papers. First, we look at a discrete set of simple, systematic monetary policy rules rather than a response that separates between shocks in real time. Second, we conduct our welfare assessment explicitly *not* under the veil of ignorance. Rather, we ask households at their current state of wealth, income, and employment – and thus, at their current exposure to systematic monetary policy changes – what policy they would prefer.

Our paper stands on the shoulders of a large and influential stream of research that emphasizes the inflation-unemployment trade-off in the New Keynesian model with search and matching frictions. Prominent examples in this literature are Faia (2009), Blanchard and Galí (2010), and Ravenna and Walsh (2011). This literature stresses that deviations from the Hosios (1990) condition, such as those caused by workers' "excessive" bargaining power or wage rigidities, can lead to the inefficient amplification of employment responses, which can induce monetary policy to deviate from price stability inspite of price adjustment costs (including when shocks are productivity shocks). Ravenna and Walsh (2012) show that such deviations can lead to quantitatively meaningful welfare gains, as they do in our setting. With Sala et al. (2008), who present an estimated New Keynesian

[7]Other important papers that discuss how inequality affects monetary transmission or the business cycle are McKay and Reis (2016), Auclert (2019), McKay et al. (2016), and Bayer et al. (2020), to name but a few.

model with search and matching frictions for the U.S. economy, our calibration shares the idea that most of the inflation-unemployment stabilization trade-off arises from markup shocks. The RANK counterpart to our model, indeed, has monetary policy balance inflation and unemployment variability. What sets our work apart is that we focus on the potential for disagreement about monetary stabilization policy, when conditioning on a household's current idiosyncratic state. We show that the disagreement can be large and that heterogeneity in savings plays an important role in this disagreement.

In terms of technique, we extend the perturbation method developed by Reiter (2009) and Reiter (2010a) to compute a second-order approximation with a parameterized law of motion for the distribution of households. The technique allows us to explicitly control the policy counterfactuals so that the average inflation rate remains constant. And it allows us to compute the transition path toward the new stochastic steady state.

## 2. Model

There is a unit mass of infinitely lived households. Households receive labor income, social security transfers, and financial income. Idiosyncratic employment risk fluctuates due to Mortensen and Pissarides (1994) search and matching frictions. The prices of goods are sticky. The central bank can, therefore, influence real activity and the distribution of employment risk over the business cycle. A household that loses its job faces the risk of persistent earnings losses. Households save to self-insure against idiosyncratic and aggregate risk, and they save for retirement, modeled as a transitory state such that the household no longer works but receives retirement benefits.

### 2.1. States

The model is defined in recursive form. The economy inherits from the previous period the aggregate capital stock, $K_{-1}$, and last period's level of wages, investment, and the central bank's policy rate, $w_{-1}$, $i_{-1}$, $R_{-1}$. Next, the economy inherits the type distribution of households from the previous period, $\mu_{-1}$. Let $\zeta$ be the vector of aggregate shocks.

For the decisions of firms and households during the period, the notation entertains two different state vectors. A tilde marks the time after aggregate shocks have been realized, but before employment-related transitions (separations, hiring, and earnings losses) have occurred. Let $\widetilde{X} = (K_{-1}, w_{-1}, i_{-1}, R_{-1}, \zeta, \widetilde{\mu})$ denote the state of the economy at that time. $X = (K_{-1}, w_{-1}, i_{-1}, R_{-1}, \zeta, \mu)$, in turn, marks the state of the economy once employment-related transitions have occurred. This is the state of the economy on which production and consumption decisions are based.

#### 2.1.1. Shocks

Vector $\zeta := (\zeta_I, \zeta_R, \zeta_{TFP}, \zeta_w, \zeta_P)$ collects the five aggregate business-cycle shocks. $\zeta_I$ is a shock to the marginal efficiency of investment and $\zeta_R$ a monetary policy (interest-rate) shock. $\zeta_{TFP}$ is a productivity shock, $\zeta_w$ a wage markup shock, and $\zeta_P$ a price markup shock. These shocks are the most common business cycle shocks.[8] Each shock follows an AR(1)-process with normally distributed innovation

$$\log({\zeta_j}'/\overline{\zeta}_j) = \rho_{\zeta_j} \log(\zeta_j/\overline{\zeta}_j) + \epsilon'_{\zeta_j},\, \epsilon_{\zeta_j} \overset{\text{iid}}{\sim} N(0, \sigma^2_{\zeta_j}), \rho_{\zeta_j} \in [0, 1).$$

Here and in the following, a bar over a variable refers to the variable's value in the non-stochastic steady state, and a prime marks the next period.

### 2.1.2. Individual states

Household heterogeneity can be summarized by six transitory idiosyncratic states $(n, a, l, e, b, s)$. The first three $(n, a, l)$ are affected by the business cycle, and so are endogenous to monetary policy. The last three $(e, b, s)$, instead, evolve independently of the business cycle. $n \in \{0, 1\}$ denotes the household's employment state, $a \in [0, 1]$ marks the household's holdings of shares of a representative mutual fund, and $l \in \{0, 1\}$ the household's earnings-loss state. $e \in \{e_L, e_H\}$ marks the household's education level (high or low). $b \in \{0, 1\}$ marks the household's impatience. $s \in \mathcal{S}$ marks an exogenous component of a household's current labor productivity ("skills").

Transitory labor productivity $s$ follows a first-order Markov process with $s \in \mathcal{S} = \{s_0, s_1, s_2, s_3\}$. $\pi_S(s, \hat{s})$ denotes the probability of a transition from $s$ to $\hat{s}$. Skill state $s_0 = 0$ is associated with retirement: the household does not work but receives retirement benefits. If $s \in \mathcal{S}_+ := \mathcal{S} \backslash s_0$, the household is in the labor force and $s$ captures differences in productivity after conditioning on education and the household's employment history. The household draws a fresh $s$ at the beginning of every period. This is so regardless of the current employment status. The probability of retiring is the same for each skill state $s \in \mathcal{S}_+$, so that $\pi_S(s, s_0) = \pi_{s_0}$ for each $s \in \mathcal{S}_+$. Each period, a retired household returns to the labor force (is "born") with probability $\pi_S(s_0, \hat{s})$, $\hat{s} \in S_+$.

A household draws the education level each time it transitions from $s = s_0$ to $s \in \mathcal{S}_+$ (that is, at the beginning of a household's working life), and only then. $\pi_E(e, \hat{e})$ marks the probability of moving from education level $e$ to education level $\hat{e}$. We allow for a correlation between $e$ and $\hat{e}$ so as to capture intergenerational persistence in income. The risk of a lower education status upon birth means that highly educated retired households have an incentive to retain savings.

Let $\beta(e, b)$ mark the household's time discount factor. Time preferences depend on education and the impatience state $b$. A household draws $b$ every time that the education level is drawn (and only then). $\pi_{\Delta_\beta}(b)$ marks the probability of drawing impatience state $b$. Conditional on education, with probability $\pi_{\Delta_\beta}(0)$ the household will have time preference $\beta(e, b) = \beta_e$ (with $\beta_e \in \{\beta_{e_L}, \beta_{e_H}\}$); otherwise the household has time preference $\beta_e - \Delta_\beta$ $(b = 1)$. We assume that

[8] Christiano et al. (2016) identify the first three. Smets and Wouters (2007), in addition, identify a "wage-markup" shock and a "price-markup" shock as important.

both education groups have the same share of rather impatient households, and the same gap in patience $\Delta_\beta$.[9]

It remains to specify the evolution of the endogenous individual states $(n, a, l)$. Share holdings $a$ are determined by the savings behavior of the household (the household's optimization problem is described in Section 2.3). For households in the labor force, the evolution of the employment state $n$ is governed by the search and matching structure of the model, also described in Section 2.3. $l$ captures an earnings loss. When the household is employed, its idiosyncratic productivity is given by the product $e \cdot s \cdot (1 - \varrho l)$. Parameter $\varrho$ in $[0, 1)$ measures the size of the earnings loss $(l = 1)$. We are agnostic about the microeconomic source of the loss of earnings, be it a temporary loss of skills or temporarily poorer match quality. The earnings-loss state evolves with the household's employment history. $\pi_L^{uem}(1)$ is the probability of suffering an earnings loss when moving from unemployment to employment. $\pi_L^{emp}(l, \hat{l})$ is the probability of the earnings loss state changing from $l$ to $\hat{l}$ if the household enters the period employed. Households change their earnings-loss state after employment transitions have occurred.

The mass of households that are born, by construction, equals that of retiring households. After having drawn the education state, the newborn household draws states $n$ and $l$ such that the mass of households of type $(n, l, e)$ is not affected by transitions to and from retirement. Section 2.3.3 provides details.

Let $\mu(n, a, l, e, b, s)$ mark the type distribution of households at the time that production takes place, that is, after all idiosyncratic transitions have taken place. $\mu$ has support on $\mathcal{M} := \{0, 1\} \times [0, 1] \times \{0, 1\} \times \{e_L, e_H\} \times \{0, 1\} \times \mathcal{S}$.[10]

### 2.1.3. Employment transitions

We assume that job-finding rates $f(\widetilde{X})$ are the same for *all* unemployed households. Flow rates into unemployment, instead, depend on education. To accommodate this in a parsimonious way, we proceed as follows. Hiring decisions in the model will be made by firms. The common-to-all job-finding rate will fluctuate over the business cycle. Let $\lambda(e)$ be the (constant) probability that a firm and household separate. We split this rate in two: $\lambda(e) = \lambda_x(e) + \lambda_n(e)$. At rate $\lambda_x(e)$, households flow directly into the unemployment pool for the period. At rate $\lambda_n(e)$ the household can search for a job in the same period. If successful, the household will not go through an unemployment spell. Otherwise, the household will be unemployed. By choosing $\lambda_x(e)$ and $\lambda_n(e)$, we can control the cyclical fluctuation of the risk of becoming unemployed.[11]

[9] Time-discount factors depend on education. We use this to match the wealth distribution by education. Heterogeneity in discount factors within an education group is used to match the low net worth of the poor.

[10] Only some combinations of idiosyncratic states are admissible. We consider all retired households $(s = s_0)$ as unemployed $(n = 0)$. Only the employed $(n = 1)$ can be subject to skill loss $(l = 1)$.

[11] There is an alternative large-firm interpretation of our setup. Namely, one may think of the $\lambda_n(e)$-type separations as including cases in which firms have to expend costs in order to

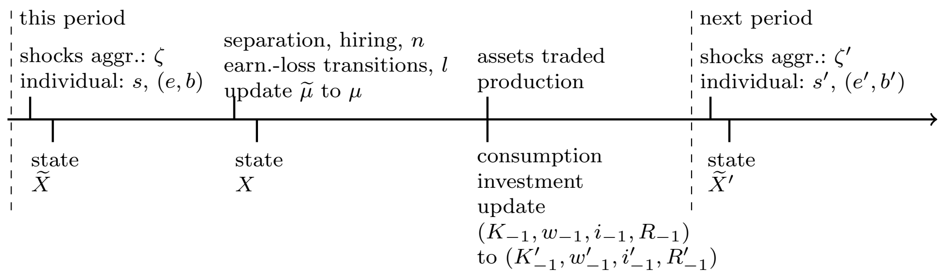


**Figure 1: Timing of decisions**

## 2.2. Timing

The timing is shown in Figure 1. At the beginning of each period, households draw new skills $s$. If a household is born (a transition from $s_0$ to some $s \in \mathcal{S}_+$), the household draws an education level from $\pi_E(e, e')$ and time preferences $b \in \{0, 1\}$. A household that is born is randomly assigned to states $n$ and $l$ in such a way that it replaces a retiring household with these employment and earnings-loss characteristics and the same education level.[12] Aggregate shocks are drawn. The tilde marks the time at the beginning of the period after all those shocks have been realized, but before employment transitions (separations and hiring) have occurred. Denote by $\widetilde{\mu}$ the corresponding type distribution at that point in time. Let $\widetilde{X} = (K_{-1}, w_{-1}, i_{-1}, R_{-1}, \zeta, \widetilde{\mu})$ denote the corresponding state of the economy. Before production takes place, firms separate from a household of education $e$ with probability $\lambda_x(e) + \lambda_n(e)$. Thereafter, the employed with earnings losses shed those with probability $\pi_L^{emp}(1, 0)$. Then, firms post vacancies. A share $\lambda_n(e)/(\lambda_x(e) + \lambda_n(e))$ of the separated households of education level $e$ search for a new job in the same period, as do the unemployed. All other separations flow directly into the unemployment pool for the period. Matching takes place. Households hired out of unemployment face the earnings-loss probability $\pi_L^{uem}(1)$. Accounting for the employment transitions, and subsequent transitions in the earnings-loss state, the aggregate state becomes $X = (K_{-1}, w_{-1}, i_{-1}, R_{-1}, \zeta, \mu)$, where $\mu$ marks the type distribution at the time of production. Then the remaining decisions are made and firms produce.

## 2.3. Households' problems

Household preferences are time-separable with education- and shock-dependent time-discount factor $\beta(e, b) \in (0, 1)$. Households derive utility from consumption,

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make an existing match fit a changing job profile.

[12]We assume that households begin their working life at age 25. The assumptions above ensure that the households at that age have reasonable employment rates.

$c$. Period felicity is given by $u(c) = c^{1-\sigma}/(1-\sigma), \sigma > 0$. In addition, retired households derive utility from leaving bequests to the newborn upon "death." The utility from leaving a bequest of $a$ shares worth $p_a(X)a$, conditional on death, is $\gamma_1 \cdot (p_a(X)a + \gamma_2)^{1-\sigma}/(1-\sigma)$, where $\gamma_1, \gamma_2 \geq 0$. The approach and functional form for this warm-glow utility of bequest follow De Nardi (2004).[13] Government consumption enters household prefences in an additively separable way. Since it is held constant throughout the paper, we do not model this part of preferences. We first describe the problem of a household that is employed after the employment transitions have taken place. Thereafter, we describe the problem of an unemployed household. Last, we describe the problem of a household that is retired.

### 2.3.1. Employed households

Let $W(X, n, a, l, e, b, s)$ be the value of a household at the time of production. The employed household's Bellman equation ($n = 1,\ s \in \mathcal{S}_+$) is given by

$$\begin{aligned}
W(X,1,a,l,e,b,s) = \max_{c,a' \geq 0} \Big\{ & u(c) + \pi_{s_0}\, \mathbb{E}_\zeta \left[\beta(e,b) W(X',0,a',0,e,b,s_0)\right] \\
& + \textstyle\sum_{s' \in \mathcal{S}_+} \pi_S(s,s') \beta(e,b) \cdot \\
& \mathbb{E}_\zeta \Big[ \, [1 - \lambda_x(e) - \lambda_n(e)(1 - f(\widetilde{X}'))] \textstyle\sum_{\hat{l}} \pi_L^{emp}(l,\hat{l}) \cdot \\
& \qquad W(X',1,a',\hat{l},e,b,s') \\
& + [\lambda_x(e) + \lambda_n(e)\big(1 - f(\widetilde{X}')\big)] W(X',0,a',0,e,b,s') \, \Big] \Big\}
\end{aligned}$$

s.t.

$$\begin{aligned}
(1+\tau_c)c + p_a(X)a' \quad = \quad & [p_a(X) + d_a(X)]\, a \\
& + w(X) es(1 - l\varrho)\,[1 - \tau_{RET} - \tau_{UI}] \\
& - w(X) es(1 - l\varrho) \tau(X, w(X) es(1 - l\varrho)).
\end{aligned}$$

The household chooses consumption and non-negative share holdings. On the right-hand side of the Bellman equation appear period felicity and the continuation values. Next period, the household will enter retirement with probability $\pi_{s_0}$, carrying with it its asset holdings and education status, the household's value being $W(X', 0, a', 0, e, b, s_0)$.[14] Otherwise, the household will remain in the labor force at newly drawn skill state $s'$ (second row). The expectation operator $\mathbb{E}_\zeta$ marks expectations formed with regard to aggregate shocks. Conditional on not retiring next period, with probability $1 - \lambda_x(e) - \lambda_n(e)(1 - f(\widetilde{X}'))$, the household will be employed. The household draws a new idiosyncratic earnings-loss state $\hat{l}$, with $\pi_L^{emp}(l, \hat{l})$ marking the transition probability of the earnings-loss state for an employed household (third row). The household's value then

[13] $\gamma_1$ can be thought to control the strength of the bequest motive, while $\gamma_2$ determines how much of a luxury good giving a bequest is.

[14] In terms of notation all households that enter retirement or unemployment are moved to the no-earnings-loss state $l = 0$. This is without consequence: Retired households do not have labor income; in addition, unemployment insurance benefits do not depend on the earnings-loss state. Unemployed households redraw the earnings-loss state upon moving to employment. The transition of the aggregate and idiosyncratic states that are not affected by the household's decisions is described in Section 2.1.

is $W(X',1,a',\hat{l},e,b,s')$ (fourth row). Otherwise, the household will move into unemployment (fifth row), with associated value $W(X',0,a',0,e,b,s')$.

As per the budget constraint, the household buys consumption goods, $c$, pays consumption tax $\tau_c$, and purchases shares at cost $p_a(X)a'$. On the income side, the household has the cum-dividend value of shares brought into the period (first row) and labor earnings, $w(X)es(1-l\varrho)$. $w(X)$ is the real wage per efficiency unit of labor and $\varrho \in [0,1)$ is the loss of earnings associated with the earnings-loss state. Three types of taxes are applied to earnings: social security taxes, $\tau_{RET}$, and unemployment-insurance taxes, $\tau_{UI}$ (second row), as well as a progressive labor-income tax ($\tau(X,.)$ third row).

#### 2.3.2. Unemployed households

The unemployed household's Bellman equation ($n=0$, $s \in \mathcal{S}_+$) is given by

$$\begin{aligned}
W(X,0,a,0,e,b,s) = \max_{c,a'\geq 0} \Big\{ & u(c) + \pi_{s_0}\,\mathbb{E}_\zeta[\beta(e,b)W(X',0,a',0,e,b,s_0)] \\
& + \textstyle\sum_{s'\in\mathcal{S}_+} \pi_S(s,s')\beta(e,b)\cdot \\
& \mathbb{E}_\zeta\Big[ \quad f(\widetilde{X}')[\quad \pi_L^{uem}(1)W(X',1,a',1,e,b,s') \\
& \qquad\qquad + \pi_L^{uem}(0)W(X',1,a',0,e,b,s')] \\
& \qquad + \big(1-f(\widetilde{X}')\big)W(X',0,a',0,e,b,s')\Big] \qquad \Big\} \\
& \text{s.t.} \\
(1+\tau_c)c + p_a(X)a' = \quad & [p_a(X)+d_a(X)]\,a + b_{UI}(es)[1-\tau(X,b_{UI}(es))].
\end{aligned}$$

With probability $\pi_{s_0}$, the household moves into retirement (first row). Otherwise, next period, the household will move into employment with state-dependent probability $f(\widetilde{X}')$. Upon reemployment, with probability $\pi_L^{uem}(1)$, the household will suffer an earnings loss (third row), or else no earnings loss (fourth row). If the household does not find a new job, it will stay unemployed next period (last row). As per the budget constraint, instead of labor earnings the unemployed household receives unemployment benefits, $b_{UI}(es)$. They are assumed to depend on the household's earnings capacity. This is meant to capture, in a parsimonious way, that benefits depend on past earnings.

### 2.3.3. Retired households

The retired household's Bellman equation ($s = s_0$) is given by

$$\begin{aligned}
W(X,0,a,0,e,b,s_0) = \max_{c,a'\geq 0} \Big\{ \quad & u(c) \\
& +\pi_S(s_0,s_0)\beta(e,b)\mathbb{E}_\zeta\left[W(X',0,a',0,e,b,s_0)\right] \\
& +(1-\pi_S(s_0,s_0))\mathbb{E}_\zeta\left[\gamma_1\cdot(p_a(X')a+\gamma_2)^{1-\sigma}/(1-\sigma)\right] \\
& +\beta(e,b)\textstyle\sum_{s'\in\mathcal{S}_+}\sum_{e'}\sum_{b'}\sum_{l}\pi_S(s_0,s')\pi_E(e,e')\pi_{\Delta_\beta}(b')\cdot \\
& \quad \Pr(n=1,l|X,e')\mathbb{E}_\zeta\Big[[1-\lambda_x(e')-\lambda_n(e')(1-f(\widetilde{X}'))]\cdot \\
& \qquad \textstyle\sum_{\hat{l}}\pi_L^{emp}(l,\hat{l})W(X',1,a',\hat{l},e',b',s') \\
& \qquad +[\lambda_x(e')+\lambda_n(e')\big(1-f(\widetilde{X}')\big)]W(X',0,a',0,e',b',s')\Big] \\
& +\beta(e,b)\textstyle\sum_{s'\in\mathcal{S}_+}\sum_{e'}\sum_{b'}\pi_S(s_0,s')\pi_E(e,e')\pi_{\Delta_\beta}(b')\cdot \\
& \quad \Pr(n=0|X,e')\mathbb{E}_\zeta\Big[f(\widetilde{X}')\big[\pi_L^{uem}(1)W(X',1,x',1,e',b',s') \\
& \qquad +\pi_L^{uem}(0)W(X',1,x',0,e',b',s')\big] \\
& \qquad +[1-f(\widetilde{X}')]W(X',0,a',0,e',b',s') \quad \Big]\Big\}
\end{aligned}$$

s.t.

$$(1+\tau_c)c+p_a(X)a' = [p_a(X)+d_a(X)]\,a+b_{RET}(e)[1-\tau(X,b_{RET}(e))].$$

The second row describes that next period the household will stay in retirement with probability $\pi_S(s_0,s_0)$. The following rows concern a household that is born (joins the labor force out of retirement). Upon "death," the household receives utility from a bequest (third row). The newly born household then draws new idiosyncratic skills, $s$, and also redraws the education level. In terms of employment and earnings-loss status $(n,l)$, we assume that the newborn household randomly replaces a retiring household. This is reflected by the terms $\Pr(n,l|X,e')$. The fourth to seventh rows concern a household that is employed after birth. As before, that household may remain employed or lose the job during the next period. The final four rows concern a household that is born unemployed at the beginning of next period. The household may find a new job and become employed or may not find a job. The budget constraint is the same as for the unemployed, but features retirement benefits $b_{RET}(e)$ instead of unemployment benefit payments.

In order to define the transition probabilities Pr, let $N(X,l,e)$ mark the mass of employed households with earnings-loss state $l$ and education level $e$, and let $U(X,e)$ mark the mass of households of the same education level that are unemployed, all measured during the production stage of this period.[15] Then, for any $l\in\{0,1\}, e'\in\{e_L,e_H\}$

$$\Pr(n=1,l|X,e') := \frac{N(X,l,e')}{\sum_l N(X,l,e')+U(X,e')},$$

[15] So that $N(X,l,e)=\sum_{s\in\mathcal{S}_+}\int_x d\mu(1,x,l,e,s)$ and $U(X,e):=\sum_{s\in\mathcal{S}_+}\int_x d\mu(0,x,0,e,s)$.

and

$$\Pr(n = 0|X, e') := \frac{U(X, e')}{\sum_l N(X, l, e') + U(X, e')}.$$

## 2.4. Non-financial firms

Non-financial firms are owned by competitive mutual funds. The funds discount the future using discount factor $Q(X, X')$. The funds and the discount factor are described in Section 2.5. There is a unit mass of producers of differentiated intermediate goods, indexed by $j \in [0, 1]$. These are subject to nominal rigidities. Intermediate goods are used both directly in the production of final consumption and investment goods, and expended as costs for adjusting prices and employment. Since all firms in the economy are owned by the household sector (through shares in the mutual funds), all profits flow to households.

### 2.4.1. Final goods

There is a representative competitive final goods firm that transforms differentiated intermediate goods into homogeneous final goods. Let $X_p := (X, \eta_p)$ be state $X$ augmented by the distribution $\eta_p$ of last period's prices, $P_{j,-1}$, across differentiated goods firms.[16] Final goods can be used for personal consumption expenditures, government consumption, and physical investment. The firm solves

$$\begin{aligned} \max_{y_f, (y_{f,j})_{j \in [0,1]}} \quad & (1 - \tau_d) \left( P(X_p) y_f - \int_0^1 P_j(X_p) y_{f,j} dj \right) \\ & \text{s.t. } y_f = \left( \int_0^1 y_{f,j}^{\frac{\vartheta \cdot \exp\{\zeta_P\} - 1}{\vartheta \cdot \exp\{\zeta_P\}}} dj \right)^{\frac{\vartheta \cdot \exp\{\zeta_P\}}{\vartheta \cdot \exp\{\zeta_P\} - 1}}, \end{aligned}$$

where parameter $\vartheta > 1$ marks the elasticity of demand. $\zeta_P$ is a shock to the elasticity of demand that directly affects price-setting firms' markups (a "price-markup shock"). $y_f$ marks output of final goods. $P_j(X_p)$ marks the price of differentiated input $j$ and $y_{f,j}$ the quantity demanded of that input by final goods firms. $P(X_p)$ is the consumer price index.

### 2.4.2. Intermediate inputs

For the sake of exposition, we assume that different activities are conducted by different firms. Next to final goods firms, there are firms that produce intermediate inputs: homogeneous labor services, capital services, and adjustment services, as well as differentiated intermediate goods that are used in final good production. A setting in which the producers of differentiated intermediate goods make all the related decisions would be isomorphic; see Appendix A.

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[16] In equilibrium, all differentiated goods producers will set the same price. Therefore, in equilibrium, $X$ describes the state of the economy. Anticipating this, in much of the exposition we use $X$ to index the state of the economy, rather than $X_p$. We use $X_p$ whenever necessary for clarity.

**Differentiated goods producers**. There is a unit mass of producers of differentiated goods. Producer $j \in [0,1]$ produces type $j$ of the good. Differentiated goods are sold in monopolistically competitive markets. Producers face Rotemberg (1982) quadratic price adjustment costs. Dividends are taxed at a fixed rate $\tau_d$, The value of the producer of variety $j$ (after taxes) is

$$\begin{aligned} J_D(X_p;j) = \max_{P_j,\ell_j,k_j} \quad & (1-\tau_d)\Big(y_j(X,P,P_j)\Big(\tfrac{P_j}{P(X_p)}\Big) - r(X)k_j - h(X)\ell_j - \Xi \\ & -\tfrac{\psi}{2}\Big(\tfrac{P_j}{P_{j,-1}} - \overline{\Pi}\Big)^2 y(X)\Big) \\ & + \mathbb{E}_\zeta\left[Q(X,X')J_D(X_p';j)\right] \end{aligned}$$

s.t.

$$y_j(X,P_j,P(X_p)) = \zeta_{TFP} k_j^{\theta} \ell_j^{1-\theta}, \tag{2.1}$$

$$y_j(X,P_j,P(X_p)) = \left(\frac{P_j(X_p)}{P(X_p)}\right)^{-\vartheta\cdot\exp\{\zeta_P\}} y(X). \tag{2.2}$$

After setting price $P_j$, producer $j$ faces demand $y_j(X,P_j,P(X_p))$, where $P(X_p)$ marks the aggregate price level. In order to meet demand, producer $j \in [0,1]$ rents capital and labor services $k_j$ and $\ell_j$ at the competitive rates $r(X)$ and $h(X)$ (first line). $\Xi > 0$ is a fixed cost of production. Price adjustment is costly. In order to adjust the price by more or less than the steady-state inflation rate, $\overline{\Pi}$, the producer has to buy adjustment services (second line). Parameter $\psi > 0$ indexes the extent of nominal rigidities. In terms of constraints, equation (2.1) is the production function of differentiated good $j$, with $\theta \in (0,1)$. Constraint (2.2) is the demand function, where $y(X)$ is total demand for differentiated goods. In equilibrium, all differentiated goods producers face the same marginal costs and will, therefore, set the same price and choose the same amount of labor and capital inputs, so that $k_j$ and $\ell_j$ will be identical for all firms $j$.

**Labor services.** Labor services are homogeneous. They are intermediated by employment agencies, which operate under constant returns to scale. The value of a household to the employment agency depends on the household's characteristics $(l,e,s)$. It is given by

$$\begin{aligned} J_L(X,l,e,s) \quad = \quad & (1-\tau_d)[h(X)-w(X)]\cdot es(1-\varrho l) \\ & + \textstyle\sum_{s'\in\mathcal{S}_+} \pi_S(s,s'|s'\neq s_0)\big(1-\lambda_x(e)-\lambda_n(e)\big)\cdot \\ & \mathbb{E}_\zeta\big[Q(X,X')\textstyle\sum_{\hat{l}} \pi_L^{emp}(l,\hat{l}) J_L(X,\hat{l},e,s')\big]. \end{aligned}$$

A household with characteristics $l,e,s$ produces $es(1-\varrho l)$ units of labor services, which the agency sells at competitive price $h(X)$ to producers of differentiated goods. Per efficiency unit of labor, the agency pays a real wage of $w(X)$. The remaining lines concern the continuation value. The household has transitions in temporary skills $s$. A household leaving the agency into retirement will immediately be replaced by a "newborn" household of the same payoff-relevant characteristics for the firm. At the same time, the household may separate into unemployment with probability $1 - \lambda_x(e) - \lambda_n(e)$. If not, the household remains with the agency at next period's production stage, has an earnings-loss transition from $l$ to $\hat{l}$, and provides value $J_L(X, \hat{l}, e, s')$ to the agency.

After separations have occurred, and before production, employment agencies can recruit new households. Let $V(\widetilde{X})$ be the aggregate number of vacancies posted and $M(\widetilde{X}, V)$ the mass of new matches. The job-filling probability is identical for all vacancies, and given by $q(\widetilde{X}) = \frac{M(\widetilde{X}, V(\widetilde{X}))}{V(\widetilde{X})}$. Letting $\kappa(\widetilde{X})/q(\widetilde{X})$ be the average cost per hire, the free-entry condition for recruiting is given by

$$\begin{aligned}&\textstyle\sum_{e,s\in\mathcal{S}_+} \pi_S(s|s \in S_+) \frac{U(\widetilde{X},e)}{\sum_e [U(\widetilde{X},e)+\lambda_n(e)\sum_l N(\widetilde{X},l,e)]} \sum_{\hat{l}} \pi_L^{uem}(\hat{l}) J_L(X,\hat{l},e,s) \\ &+ \textstyle\sum_{e,l,s\in\mathcal{S}_+} \pi_S(s|s \in S_+) \frac{\lambda_n(e) N(\widetilde{X},l,e)}{\sum_e [U(\widetilde{X},e)+\lambda_n(e)\sum_l N(\widetilde{X},l,e)]} \sum_{\hat{l}} \pi_L^{emp}(l,\hat{l}) J_L(X,\hat{l},e,s) \\ &\qquad = (1-\tau_d)\kappa(\widetilde{X})/q(\widetilde{X}).\end{aligned}$$

In equilibrium, recruiting will occur until the expected gain of a hire (left-hand side) equals the average after-tax cost per hire. The gain is given by the expected value of a household to the employment agency, accounting for the distribution of household characteristics in the pool of households searching for employment, and their subsequent earnings-loss transitions. The pool of searching households is composed of the unemployed and of those households that were separated from their firm in the same period and they look for new employment in the same period.

Recruiting requires purchasing adjustment services. Following Christiano et al. (2016), we shall assume that there are two components to the cost of recruiting: a cost per hired household and a cost of posting a vacancy:

$$\kappa(\widetilde{X}) := (\kappa_H \cdot q(\widetilde{X}) + \kappa_v) \cdot \left( \frac{M(\widetilde{X}, V(\widetilde{X}))/\left(\sum_{l,e} N(\widetilde{X}, l, e)\right)}{\overline{M}/\overline{\widetilde{N}}} \right)^2.$$

Here $\overline{M}$ and $\overline{\widetilde{N}}$ mark steady-state values of matches and employment. $\kappa_H$ marks the steady-state cost upon hiring. $\kappa_V$ marks the steady-state cost for posting a vacancy. Both of these costs fluctuate with the hiring rate in the economy as reflected by the quadratic term.[17]

Matches emerge according to the following matching function (see den Haan et al. (2000)), which links the mass of households searching for a job to the mass

[17] Translated to a multi-household setup, this means that the marginal costs per hire are convex in the hiring rate, as in Gertler and Trigari (2009) and Yashiv (2000). This leads to a more drawn out response of vacancies in response to shocks.

of vacancies:

$$M(\widetilde{X}, V(\widetilde{X})) = \frac{\left(\sum_e \left[U(\widetilde{X},e) + \lambda_n(e)\sum_l N(\widetilde{X},l,e)\right]\right) V(\widetilde{X})}{\left(\left(\sum_e \left[U(\widetilde{X},e) + \lambda_n(e)\sum_l N(\widetilde{X},l,e)\right]\right)^{\alpha} + V(\widetilde{X})^{\alpha}\right)^{\frac{1}{\alpha}}},$$

with $\alpha > 0$. Searching households have the job-finding rate

$$f(\widetilde{X}) = \frac{M(\widetilde{X}, V(\widetilde{X}))}{\sum_e \left[U(\widetilde{X},e) + \lambda_n(e)\sum_l N(\widetilde{X},l,e)\right]}.$$

A wide range of wages is bilaterally efficient. We postulate that the wage evolves according to a wage rule that allows for wage rigidity. In particular, the wage evolves according to

$$\log(w(X)/\overline{w}) = \phi_w \log(w_{-1}(X)/\overline{w}) + (1-\phi_w)\log\left(\frac{y(X)}{\overline{y}}\right) + \zeta_w. \tag{2.3}$$

This rule has the potential to amplify the effect of business-cycle shocks on unemployment and to propagate the shocks over time; see Blanchard and Galí (2010) and the literature overview in Rogerson and Shimer (2011). Above, $\overline{w}$ is the steady-state wage level. Parameter $\phi_w \in [0,1)$ governs wage rigidities over time, and how much the wage reacts to economic activity. Last, there is the wage-markup shock.

**Capital services**. There is a representative producer of homogeneous "capital services." The value of the producer is

$$\begin{aligned} J_K(X, k_{-1}, i_{-1}) \quad &= \quad \max_{v,i,k}(1-\tau_d)(r(X)k_{-1}v - i) + \mathbb{E}_\zeta\left[Q(X,X')J_K(X',k,i)\right] \\ &\quad\quad \text{s.t.} \qquad k = \left[1-\delta(v)\right]\cdot k_{-1} + \zeta_I \cdot \left[1-\Gamma(i/i_{-1})\right]i. \end{aligned}$$

Capital services are the product of the capital stock, $K$, and the utilization rate of capital, $v$. Depreciation of capital depends on utilization as in Greenwood et al. (1988).

$$\delta(v) = \delta_0 + \delta_1 v^{\delta_2},\ \delta_1 > 0, \delta_2 > 1.$$

The extent to which outlays for investment today, $i'$, result in new capital, $k'$, depends on the marginal efficiency of investment, $\zeta_I$, and on the past level of investment.[18] The transformation function that governs how investment is transformed into physical capital is given by

$$\Gamma\left(\frac{i}{i_{-1}}\right) = \phi_K/2\left(\frac{i}{i_{-1}} - 1\right)^2,\ \ \phi_K \geq 0.$$

[18]Note that $i'$ will be measurable with respect to $X$.

This form of investment adjustment costs is customary in the New Keynesian literature, and follows Christiano et al. (2005). Parameter $\phi_K$ indexes the ability of the economy to generate new capital (aggregate savings) at short horizons.

**Adjustment services**. The activity of recruiting and of adjusting prices requires homogeneous adjustment services. The competitive representative adjustment-services firm solves

$$\max_{y_a,(y_{a,j})_{j\in[0,1]}} \quad (1-\tau_d)\left(P(X_p)y_a - \int_0^1 P_j(X_p)y_{a,j}dj\right)$$
$$\text{s.t. } y_a = \left(\int_0^1 y_{a,j}^{\frac{\vartheta\exp\{\zeta_{P,t}\}-1}{\vartheta\exp\{\zeta_{P,t}\}}} dj\right)^{\frac{\vartheta\exp\{\zeta_{P,t}\}}{\vartheta\exp\{\zeta_{P,t}\}-1}},$$

where $y_a$ are total adjustment services produced and $y_{a,j}$ is demand for differentiated good $j$ by the adjustment-services firm. Appendix B provides the first-order conditions related to the firms' problems.

### 2.5. Financial firms

Households can own claims to firms' cash flows only indirectly, through holding shares in representative mutual funds that cater equally to all households. In equilibrium, all the funds hold the same relative portfolio shares. It remains to fix the stochastic discount factor that the funds apply and endow onto the firms. With incomplete financial markets, the stochastic discount factor is not necessarily unique. For tractability, we assume that the funds discount the future using

$$Q(X, X') = \frac{p_a(X)}{p_a(X') + d_a(X')}.$$

This discount factor is consistent with the fund-holding households' Euler equations by construction. Next to this, it can be constructed by the mutual fund from market information.[19] The way that households' demand for savings will affect investment decisions by firms, then, is as follows. If aggregate demand for savings rises temporarily, for a given dividend stream the market-clearing price of shares, $p_a(X)$, rises. By the above discount factor, this induces the mutual fund and the firms it owns to value future cash flow more. In turn, this induces a rise in investment. Appendix C discusses this choice in more detail.

We use the cashless limit assumption (Woodford, 1998), by which the central bank controls the nominal gross rate of return $R(X)$ on the risk-free nominal bonds that the funds trade. Letting $\Pi(X)$ denote the gross rate of inflation, the mutual funds' optimal decisions yield a standard Euler equation (for the mutual fund rather than a household)

$$1 = \mathbb{E}_\zeta\left[Q(X, X')\frac{R(X)}{\Pi(X')}\right].$$

[19] In the absence of aggregate risk or in a model solution with certainty equivalence, this discount factor would simply equal the real interest rate.

The mutual fund distributes to the households all income that is not reinvested, after paying taxes to the government. After-tax dividends are given by

$$d_a(X) \quad = \quad (1-\tau_d)\left(y_f(X) - i(X) - \int_{\mathcal{M}} w(X) se(1-\varrho l)\mathbb{1}_{n=1}\, d\mu\right),$$

where $\mathbb{1}$ marks the indicator function, meaning $\mathbb{1}_{n=1}$ marks employment of the household.

### 2.6. Central bank and fiscal authority

The central bank sets the gross nominal interest rate according to Taylor rule

$$\begin{aligned}\log\left(\frac{R(X)}{\overline{R}}\right) \quad = \quad & \phi_R \log\left(\frac{R_{-1}}{\overline{R}}\right) \\ & +(1-\phi_R)\left[\phi_\Pi \log\left(\frac{\Pi(X)}{\overline{\Pi}}\right) - \phi_u\left(\frac{U(X)-\overline{U}}{\pi_S(\mathcal{S}_+)}\right)\right] + \log \zeta_R.\end{aligned} \tag{2.4}$$

The first term on the right-hand side reflects interest persistence, with $\phi_R \in [0, 1)$ ($R_{-1}$ is the rate set in the previous period). Interest persistence apart, the central bank raises the nominal rate above its steady-state level $\overline{R}$ whenever inflation exceeds the inflation target of $\overline{\Pi}$ ($\phi_\Pi > 1$) or the unemployment rate is lower than its steady-state value (parameter $\phi_u \geq 0$).[20]

The fiscal authority is bound by a balanced-budget rule. The government budget constraint is given by

$$\begin{aligned} & \int_{\mathcal{M}} \mathbb{1}_{s\in\mathcal{S}_+}\mathbb{1}_{n=0}\, b_{UI}(es)\; d\mu + \int_{\mathcal{M}} \mathbb{1}_{s=s_0}\, b_{RET}(e)\; d\mu + g \\ = \quad & \tau_d \frac{d_a(X)}{1-\tau_d} + \tau_c \int_{\mathcal{M}} c(X,n,a,l,e,s)\, d\mu \\ & + \int_{\mathcal{M}} \mathbb{1}_{s\in\mathcal{S}_+}\mathbb{1}_{n=1}\, (\tau_{UI}+\tau_{RET}) w(X) es(1-l\varrho)\; d\mu \\ & + \int_{\mathcal{M}} \mathbb{1}_{s\in\mathcal{S}_+}\mathbb{1}_{n=1}\, \tau(X, w(X)es(1-l\varrho))\,[w(X)es(1-l\varrho)]\; d\mu. \\ & + \int_{\mathcal{M}} \mathbb{1}_{s\in\mathcal{S}_+}\mathbb{1}_{n=0}\, \tau(X, b_{UI}(es)) b_{UI}(es)\; d\mu. \\ & + \int_{\mathcal{M}} \mathbb{1}_{s=s_0}\, \tau(X, b_{RET}(e)) b_{RET}(e)\; d\mu. \end{aligned}$$

The fiscal authority spends on unemployment and retirement benefits, and government consumption expenditures, $g$ (first line). These expenditures are financed through a tax on dividends ($d_a(X)/(1-\tau_d)$ marks dividends pre-tax) and consumption ($c(X, n, a, l, e, s)$ marks the consumption policy of households), second line. In addition, there are unemployment insurance and social security taxes on earnings (third line), and progressive income taxes on earnings, unemployment benefits, and retirement benefits.[21]

[20] In terms of notation, $U(X) := \sum_e U(X, e)$ is the mass of unemployed households at the production stage, and $\pi_S(\mathcal{S}_+)$ is the mass of households in the labor force (that is, not retired), so that $U(X)/\pi_S(\mathcal{S}_+)$ is the unemployment rate.

[21] The model has non-Ricardian households. Fiscal policy, therefore, shapes the equilibrium allocations. We consider the balanced-budget rule to be transparent. At the same time, this is but one set of fiscal rules. It prevents us from examining interesting dimensions of government policy, such as active debt management policies or, more fundamentally, tax smoothing.

### 2.7. Market clearing and equilibrium

Our notion of equilibrium is fairly standard; we collect the full definition in Appendix D, including the law of motion for the distribution. Here we only state the market-clearing conditions. Market clearing for final goods requires that all final output be used for personal consumption, investment, or government consumption:

$$y_f(X) = \int_{\mathcal{M}} c(X, n, a, l, e, s)\; d\mu + i(X) + g.$$

Total demand for differentiated goods is given by

$$y(X) = y_f(X) + y_a(X).$$

The market for differentiated goods clears if demand equals production (using symmetry in both price setting and demand for each differentiated good $j$), so

$$y(X) = \zeta_{TFP} k_j^{\theta} \ell_j^{1-\theta}$$

with $k_j$ and $\ell_j$ identical for all $j \in [0, 1]$. The market for adjustment services clears if all such services are used for adjusting prices or employment or as fixed costs,

$$y_a(X) = \frac{\psi}{2} \left( \Pi(X) - \overline{\Pi} \right)^2 y(X) + \kappa(\widetilde{X}) V(\widetilde{X}) + \Xi.$$

The market for labor services clears if all labor services supplied are used in the production of differentiated goods,

$$\int_{\mathcal{M}} se(1 - \varrho l) \mathbb{1}_{n=1}\; d\mu = \int_0^1 \ell_j\; dj,$$

The market for capital services clears if

$$v(X) K_{-1}(X) = \int_0^1 k_j\; dj.$$

Normalizing the supply of shares to unity, and mark with $a(X, n, a, l, e, s)$ the savings policies of households, the market for shares in the mutual fund clears if

$$\int_{\mathcal{M}} a(X, n, a, l, e, s)\; d\mu = 1.$$

Last, the bond market clears if inside bonds are in zero net supply.

Throughout the paper, we will compare results for the HANK model shown above to a simple two-agent saver-spender analogue, which Appendix E describes (the TANK model) and the corresponding representative-agent version (RANK).

## 3. Stylized facts and calibration

We calibrate the HANK model (and the RANK/TANK variants) to the U.S., one period being a quarter. The calibration sample is 1984Q1 to 2008Q3. It covers the Great Moderation and stops right before the zero lower bound on nominal interest rates becomes binding. The solution method is a version of the method developed by Reiter (2009) and Reiter (2010a), described in detail in Appendix F. We use splines to approximate households' decision rules along their asset dimension and approximate the distribution of households as a histogram on the product of a household's skill, education, employment, and a grid on the wealth distribution. All agents use this function to construct their forecasts about the evolution of the economy. We start by documenting stylized facts about income, wealth, and employment risk that we wish the model to replicate. Then, we discuss the calibration of the model.

### 3.1. Households' source of income and unemployment risk

This section documents that U.S. households' sources of income differ starkly by net worth and that those households that tend to rely most on labor income also tend to have the most volatile employment pattern. Table I reports the share of income derived from different sources, by age and percentiles of net worth. All data are from the 2004 Survey of Consumer Finances (SCF), the last wave before the financial crisis. The table shows this split of income sources

TABLE I

DATA. INCOME SOURCES BY NET WORTH (PERCENT OF TOTAL INCOME)

| | Percentile of net worth | | | | | | |
|---|---|---|---|---|---|---|---|
| ages 25-65 | 0-20 | 20-40 | 40-60 | 60-80 | 80-95 | Top 5 | Top 1 |
| Labor income | 90.4 | 93.2 | 90.0 | 86.5 | 76.5 | 58.3 | 51.6 |
| Financial income | 1.2 | 3.5 | 8.0 | 12.1 | 23.0 | 40.6 | 47.6 |
| Transfers | 8.4 | 3.3 | 2.1 | 1.5 | 0.5 | 0.9 | 0.8 |
| ages 66-99 | 0-20 | 20-40 | 40-60 | 60-80 | 80-95 | Top 5 | Top 1 |
| Financial income | 2.8 | 6.8 | 22.8 | 33.5 | 50.5 | 78.5 | 89.1 |
| Transfers | 97.2 | 93.2 | 77.2 | 66.5 | 49.5 | 21.5 | 10.9 |

*Notes:* Based on SCF 2004. Households with heads ages 25 to 65 and households with heads ages 66 to 99. All entries in percent. Share of annual income coming from labor income, financial income, social security, and transfers other than social security (such as unemployment benefits). For the block with households ages 25-65, we exclude households receiving social security income. For this age group transfers reported here are transfers other than social security. For the block with households ages 66-99, the measure of annual income excludes labor income. Transfers are the sum of social security and other transfers. For the exact definitions, see Appendix G.

for the two stylized age groups that we will have in the model. Working-age households are defined to be aged 25 to 65 years, retired households are ages 66 and over. The first block reports sources of income and wealth for what we define as working-age households (household heads aged 25-65 with no social security income). The table splits income into three sources: labor income (including a share of 60 percent of the income derived from actively managed businesses), financial income, and transfers (transfers other than social security income, since we exclude working-age households that draw social security income). Earnings are the dominant source of income for all but the wealth-richest working-age households.

Financial income, instead, becomes notably more important for older households (the second block of the table). In keeping with our modeling, the composition of income for the retired focuses only on financial income and transfers (the shares of income reported exclude any remaining labor income). Transfers (primarily social security) are the dominant source of income for the wealth-poorest households of retirement age. Already for the median-wealth old household, however, financial income makes up roughly a quarter of income. For the wealth-richest 5 percent of older households, financial income accounts for 78 percent of income. Retirees are more exposed to changes in financial wealth than households of working age.

At the same time, working-age households are exposed to unemployment risk, exposure to which is unevenly distributed across the population, see Cairó and Cajner (2018) and Elsby et al. (2010). For calibrating the model, we are interested in quarterly flow rates into and out of employment for the working-age population. Following the methodology of Cairó and Cajner (2018), we compute these from the Current Population Survey. Appendix H provides details. We split the population into two education groups. The low-education group comprises workers with less education than a completed college degree. The high-education group is composed of workers with a college degree or higher educational attain-

TABLE II

Data. Moments of (Un)employment and Labor-Market Flow Rates

| Variable | edu | std | corr | AR | mean |
|---|---|---|---|---|---|
| Unemployment rate | nclg | 0.63 | -0.83 | 0.97 | 5.33 |
| | clg | 0.33 | -0.81 | 0.97 | 2.36 |
| Flow rate unempl. → employ. | all | 4.06 | 0.81 | 0.97 | 82.37 |
| Flow rate employ. → unempl. | nclg | 0.31 | -0.87 | 0.96 | 4.60 |
| | clg | 0.15 | -0.77 | 0.93 | 1.92 |

*Notes:* The table reports labor-market moments in the data. Second moments are based on detrended data. The trend is an HP-trend with weight 1,600 and derived on a sample from 1977Q1 to 2015Q4. The moments reported here refer to the detrended data from 1984Q1 to 2008Q3. The second column gives the definition of the model. The third column reports the sample (all workers, no college degree, or college degree first column). Thereafter, "std." reports the standard deviation of each series; "corr" shows the correlation of the series with GDP. The next column ("AR") shows the first-order autocorrelation of the series. The final column (if applicable) shows the mean of the unfiltered series.

ment. Table II reports first and second moments of the resulting labor-market series. Unemployment rates are about twice as high and volatile for the low-educated as for the high-educated. The flow rate into unemployment, too, differs notably by education. For the low-educated it is on average about twice as high as the flow rate for the high-educated. And it is about twice as volatile as well. What this means is that the low-educated are exposed to both average and cyclical unemployment risk to a larger extent. In line with the findings in Cairó and Cajner (2018), the flow rates into employment of the two groups, instead, are very similar; Appendix H documents this. Hence, we report and model only a job-finding rate that is common to all education levels.

### 3.2. Calibration

In calibrating the model, wherever possible we choose parameters based on direct outside evidence or based on targets for the steady state. Unless mentioned otherwise, these targets are to be met exactly. We calibrate the shock processes with a view toward the business-cycle properties of the model.

#### 3.2.1. Preferences, skills, and education

Table III reports the calibration of parameters pertaining to the household problem. The coefficient of relative risk aversion is set to $\sigma = 2.5$, a value within the typical range in the literature; see, for example, Blundell et al. (2016). We assume that the mass of patient and impatient households is equal, so that $\pi_{\Delta_\beta}(0) = \pi_{\Delta_\beta}(1) = 0.5$. In order to pin down time and bequest preferences, we need five targets for the steady state so as to jointly determine $(\beta_{e_L}, \beta_{e_H}, \Delta_\beta, \gamma_1, \gamma_2)$. We target an aggregate post-tax real rate of return of 3.2 percent, which is the value we inferred from the SCF; see Appendix G. Next to this, we target a wealth share of the low-educated of 30 percent, a wealth share for the poorest 20 percent of the working-age population of close to zero, and a wealth share of 5.25 percent for the poorest 50 percent of the retired; all taken from the SCF. Last, we minimize the distance of the wealth Lorenz curve for working-age households in the SCF and the steady state of the model.[22] Taken together, this gives $\beta_{e_L} = 0.974$, $\beta_{e_H} = 0.984$, $\pi_{\Delta_\beta} = 0.5$, $\Delta\beta = 0.11$, $\gamma_1 = 3182$, and $\gamma_2 = 6.1$.[23] The labor productivity of the low-educated is set to $e_L = 1$, by way of normalization. We fix $e_H = 1.5$ to match the college premium as in Mukoyama and Sahin (2006).

Next, two targets determine the two free parameters of the transition matrix of education levels upon birth. First, of working-age heads of households

[22] To be more precise we minimize $\sum i \in \{5, 10, ...95\} \left(\frac{max(L_i^D,0)-L_i^M}{max(L_i^D,0.001)}\right)^2$. Here, $L_i^D$ is the wealth share of the lower $i$ percent in the SCF and $L_i^M$ is the corresponding model quantity. As the model has a strict borrowing limit at zero, we replace negative shares in the data with zero as shown in the formula. See Appendix I.1 for the fit.

[23] These values imply that 50 percent of low-educated households have a subjective discount factor of 0.86 and 50 percent of high-educated households have a subjective discount factor of 0.874 at any point in time.

TABLE III

PREFERENCES, EDUCATION, EARNINGS LOSSES. TARGETS AND PARAMETERIZATION

| Parameter | Value | Target |
|---|---|---|
| Preferences | | |
| $\sigma$ | 2.5 | Blundell et al. (2016). |
| $\pi_{\Delta\beta}(0)$ | 0.50 | Equal mass of patient and impatient. |
| $\beta_{e_L}$ | 0.974 | low-educated hold 30% of aggregate net worth, SCF. |
| $\beta_{e_H}$ | 0.984 | Real rate of interest of 3.2% p.a. |
| $\Delta\beta$ | 0.110 | Wealth share poorest 20% of working-age, SCF. |
| $\gamma_1$ | 3182 | Wealth share of the poorest 50% of retirees, SCF. |
| $\gamma_2$ | 6.1 | Minimize distance wealth Lorenz curve working-age, SCF. |
| Education | | |
| $e_L$ | 1 | Normalized to unity. |
| $e_H$ | 1.5 | College wage premium, Mukoyama and Sahin (2006). |
| $\pi_E(e_L, e_L)$ | 0.8 | Share of low-educated, SCF. |
| $\pi_E(e_H, e_H)$ | 0.7 | Intergen. elasticity of income of 0.5. |
| Earnings losses | | |
| $\varrho$ | 0.25 | Initial loss, Couch/Placzek (2010), Altonji *et al.* (2013) |
| $\pi_L^{emp}(1,0)$ | 0.025 | Loss of 14% after six years, Couch/Placzek (2010). |
| $\pi_L^{emp}(0,1)$ | 0 | Cannot acquire earnings loss while employed. |
| $\pi_L^{uem}(1)$ | 0.975 | $\pi_L^{uem}(1) = 1 - \pi_L^{emp}(1,0)$. |

*Notes:* Calibrated parameters for preferences, education, and earnings losses. The main text provides further details.

in the SCF 60 percent have low education by our definition, Second, we target an intergenerational elasticity of incomes of about 0.5, in the mid-range of what the literature finds, for example, Solon (1992) and Mazumder (2005). This implies $\pi_E(e_L, e_L) = 0.8$ and $\pi_E(e_H, e_H) = 0.7$. Regarding the transition of education levels upon birth, we impose $\pi_E(e_L, e_L) = \pi_E(e_H, e_H) = 0.75$, implying an intergenerational elasticity of incomes of about 0.5, in the mid-range of what the literature finds, for example, Solon (1992) and Mazumder (2005). As regards earnings losses, Couch and Placzek (2010) report that earnings losses upon displacement are 30 percent, Altonji et al. (2013) report an initial drop of 20 percent; We set $\varrho = 0.25$ to match the midpoint. Couch and Placzek (2010) report that earnings losses still run at 13-15 percent six years after displacement. We set $\pi_L^{emp}(1,0) = 0.025$ to match a loss of 14 percent after that time. Comparable estimates of earnings losses are in Davis and von Wachter (2011) and the literature reviewed in Berger et al. (2019). While employed, households can shed an earnings loss, but cannot acquire one, so $\pi_L^{emp}(0,1) = 0$. We set the probability of acquiring an earnings loss when leaving unemployment to $\pi_L^{uem}(1) = 1 - \pi_L^{emp}(1,0)$. This makes sure that a household is not more likely to shed an earnings loss through a spell of unemployment than in employment.

Turning next to skills, $s$, we entertain four skill states. $s_0$ marks retirement.

$s_1$ is the lowest skill level during working age, and $s_2$ is a medium skill level. $s_3$ is used to capture vastly more productive households, the "super-skilled," as in Castañeda et al. (2003). Skills follow a first-order Markov process. For the skills, we have three sets of targets.

The first set of targets concerns the life-cycle transitions. We target an average working life of 40 years and average length of retirement of 12 years. The latter in line with the average age of households of retirement age in the SCF. Transitions into retirement are assumed to be independent of a working-age worker's skill level. Upon entering working age, workers draw a skill level according to the ergodic distribution of skills. The second set of targets involves the transitions between skill states for working-age households. We follow Nakajima (2012b) and assume that 1 percent of the working-age population is super-skilled, and that the probability of remaining super-skilled (if not retiring) is 0.975, the probability of drawing the highest skill state $s_3$ being independent of the current skill state $s_1$ or $s_2$. We assume that the probability of moving to the lower-skill states from $s_3$ is based on the ergodic distribution. We do so with an eye toward keeping the distribution of households by skill $s$ constant over time. Last, we assume that low- and medium-skill households have the same mass in the ergodic distribution of skills. This imposes symmetry on the transitions between $s_1$ and $s_2$. The transitions between $s_1$ and $s_2$ are based on Floden and Lindé (2001). The authors estimate the persistence of residual earnings after removing age, education, measurement error, and time fixed effects. The third set of targets concerns the level of skills. We normalize the average skill of working-age workers to 1. We obtain the gap between skill levels $s_1$ and $s_2$ by targeting the standard deviation of residual earnings from Floden and Lindé (2001). Last, we choose skill level $s_3$ so as to replicate the dispersion of wealth of the working-age population in the SCF, as measured by the Gini index. Appendix I.2 provides the targets in table form and lists how many restrictions each delivers. We meet the targets exactly. Table IV provides the skill levels and the transition matrix of skills that result.

TABLE IV

SKILLS. PARAMETERIZATION.

| | Level | Transition probabilities, $\pi_S(s,s')$: $s'_0$ | $s'_1$ | $s'_2$ | $s'_3$ |
|---|---|---|---|---|---|
| $s_0$ | 0 | 0.9792 | 0.0103 | 0.0103 | 0.0002 |
| $s_1$ | 0.490 | 0.0063 | 0.9812 | 0.0122 | 0.0003 |
| $s_2$ | 1.301 | 0.0063 | 0.0122 | 0.9812 | 0.0003 |
| $s_3$ | 11.375 | 0.0063 | 0.0124 | 0.0124 | 0.9689 |

*Notes:* Levels of idiosyncratic productivity (left), transition probabilities of skills per quarter (right). $s_0$ : retirement, $s_1$ : lowest skill group, $s_3$ : highest skill group. Rounding means that rows may not sum to 1. See the text for the targets.

### 3.2.2. Firms and production

Table V shows the parameterization of the production sector. We target a capital depreciation rate of 1.5 percent per quarter, a unitary capacity utilization rate in steady state, and a curvature of the depreciation rate in utilization of $\delta_2 = 1.33$; see, for example, Comin and Gertler (2006). Together with our target for the real rate of return, this gives $\delta_0 = -0.022$ and $\delta_1 = 0.0172$. As to the investment adjustment costs, we assume that $\phi_K = 10$, the mid-point of the range of estimates in Christiano et al. (2016).

For the labor services, we calibrate wage persistence to $\phi_w = 0.837$, the estimate in Barattieri et al. (2014) for job stayers. We determine $\lambda_x(e_L)$, $\lambda_x(e_H)$, $\lambda_n(e_L)$, and $\lambda_n(e_H)$ as follows. Throughout, we target a steady-state job-finding rate as implied by the sample averages of Table II. Using this with the two education groups' average unemployment rates and their relative standard deviations of the flow rate into unemployment and into employment in the table, gives us estimates of the share of exogenous separations for the two groups, $\lambda_x(e)/[\lambda_x(e) + \lambda_n(e)(1 - f)]$. These shares serve as two of our targets. Next, we target the relative unemployment rates of the two groups as in Table II. In addition, we decided to scale average unemployment rates to the average value for the whole economy. We target an economy-wide unemployment rate of 6 percent; which is the average value for workers of all ages during our sample period.[24] The four targets lead to $\lambda_x(e_L)$, $\lambda_x(e_H)$, $\lambda_n(e_L) = 0.076$, and $\lambda_n(e_H) = 0.037$.

Conditional on a target for the labor income share of 66 percent (used below), we obtain the remaining labor-market parameters $\overline{w}, \alpha, \kappa_V$, and $\kappa_H$ jointly by matching the target for the job-finding rate and three additional targets. Namely, we target a steady-state job-filling rate of $q = 0.71$ as in den Haan et al. (2000). Next, we target that the total cost per hire amounts to 50 percent of a quarterly wage, in line with a broad concept of hiring costs; see, Silva and Toledo (2009). And, following Christiano et al. (2016), we target that 94 percent of these costs are paid upon making a successful hire.[25] This gives us matching function parameter $\alpha = 2.63$, the steady-state wage per efficiency unit of labor $\overline{w} = 0.898$, and parameters $\kappa_V = 0.014$ and $\kappa_H = 0.310$.

Next, for the differentiated goods, we set $\psi = 179.11$ such that the Phillips curve's slope is in line with a Calvo stickiness of 0.85, the estimate of Galí and Gertler (1999). We set the demand elasticity to a value of $\vartheta = 6$, implying a 20 percent markup over marginal costs. We target a steady-state investment-GDP ratio of 0.18. Together with the above-mentioned target for the labor share, this gives $\theta = 0.2836$ and implies fixed costs of $\Xi = 0.130$.[26] The remaining

[24]These two targets scale the unemployment rates for each education group reported in Table II in proportion so that they are 7.7 and 3.4 percent, respectively.

[25]These are joint targets. The wage, in particular, has to be consistent with the targeted job-finding rate. For given parameter values, changing the wage would change the steady-state job-finding rate and, therefore, unemployment.

[26]The implied ratio of capital to quarterly GDP is 12. The ratio of *ex-dividend*, after-tax wealth to quarterly GDP implied by the calibration is 10.3.

TABLE V

Production Sector. Parameterization and Targets

| Parameter | Value | Target |
|---|---|---|
| Capital services | | |
| $\delta_0$ | -0.0022 | depreciation rate of 1.5% per quarter, NIPA. |
| $\delta_1$ | 0.0172 | unitary utilization in steady state. |
| $\delta_2$ | 1.33 | Comin and Gertler (2006). |
| $\phi_K$ | 10 | mid-point of estimates in Christiano et al. (2016). |
| Labor services | | |
| $\phi_w$ | 0.837 | Barattieri et al. (2014) for job stayers. |
| $\lambda_x(e_L)$ | 0.048 | 69.5% of separations for $e_L$ exogenous; see text. |
| $\lambda_x(e_H)$ | 0.019 | 65.7% of separations for $e_H$ exogenous; see text. |
| $\lambda_n(e_L)$ | 0.116 | rel. unempl. rate $e_H$ and $e_L$ as in Table II. |
| $\lambda_n(e_H)$ | 0 .074 | economy-wide average unempl. rate of 6%; sample average. |
| $\overline{w}$ | 0.898 | st.-st. job-finding rate, $f = 0.82$. |
| $\alpha$ | 2.63 | st.-st. job-filling rate $q = 0.71$, den Haan et al. (2000). |
| $\kappa_V$ | 0.014 | share fixed hiring costs 94%, Christiano et al. (2016). |
| $\kappa_H$ | 0.310 | total hire cost 50% of qtrly wage, Silva and Toledo (2009). |
| Differentiated goods | | |
| $\psi$ | 179.11 | slope of Phillips curve as in Galí and Gertler (1999). |
| $\theta$ | 0.284 | investment-GDP ratio of 0.18. |
| $\vartheta$ | 6 | 20% markup. |
| $\Xi$ | 0.13 | labor-income share of 0.66. |
| Implied steady-state values used as parameters | | |
| $\overline{y}$ | 1.16 | implied steady-state level of production $y$. |
| $\overline{M}$ | 0.092 | implied steady-state value of matches $M$. |
| $\overline{\widetilde{N}}$ | 0.737 | implied steady-state value of employment, $N(\widetilde{X})$. |
| $\overline{N}$ | 0.737 | implied steady-state value of employment, $N$. |

*Notes:* Calibration for capital services, labor services, differentiated goods, and parameters that are related to steady-state values. The main text provides further details.

parameters listed in Table V refer to the steady-state values implied by the calibration that are used elsewhere in the model.

### 3.2.3. Central bank and fiscal authority

Table VI shows the parameterization for the central bank and the fiscal authority. Interest-rate persistence is set to $\phi_R = 0.8$, a conventional value. The responses to inflation and unemployment, $\phi_\Pi = 1.5$ and $\phi_u = 0.15$, are based on Taylor (1993).[27] $\overline{\Pi} = 1.005$ implies a steady-state inflation rate of 2 percent annualized, in line with the Federal Reserve System's inflation objective. The

[27] Taylor (1993) has a response of annualized interest rates to the log output gap of 0.5. Regressing the CBO's measure of the output gap on unemployment, and realizing that the Taylor rule here is specified for quarterly interest rates, we arrive at the value for $\phi_u$.

unemployment target is $\overline{U} = 0.0462$. Since 77 percent of households in the calibration are of working age this is line with a steady-state unemployment rate of 6 percent. $\overline{R}$ is set to the steady-state interest rate consistent with an annual after-tax real interest rate of 3.2 percent; a target used earlier.

TABLE VI

CENTRAL BANK AND FISCAL AUTHORITY. PARAMETERIZATION AND TARGETS.

| Parameter | Value | Target |
|---|---|---|
| Central bank | | |
| $\phi_R$ | 0.8 | Christiano et al. (2016). |
| $\phi_\Pi$ | 1.5 | Taylor (1993) |
| $\phi_u$ | 0.15 | Taylor (1993). |
| $\overline{\Pi}$ | 1.005 | inflation target 2% p.a. |
| $\overline{U}$ | 0.0462 | steady-state level of unemployment rate of 6%. |
| $\overline{R}$ | 1.013 | in line with annual real rate of 3.2% p.a. |
| Fiscal authority – expenditures | | |
| $g$ | 0.19 | NIPA, share of government spending in GDP. |
| $\bar{b}_{UI}$ | 0.5 | based in Graves (2020); see text. |
| $b_{RET}(e_L)$ | 0.32 | Huggett and Parra (2010). |
| $b_{RET}(e_H)$ | 0.46 | Huggett and Parra (2010). |
| Fiscal authority – revenues | | |
| $\tau_{RET} \cdot 100$ | 13.2 | balances social security system in steady state. |
| $\tau_{UI} \cdot 100$ | 1.5 | balances UI system in steady state. |
| $\tau_c \cdot 100$ | 7 | NIPA, as in Fernández-Villaverde et al. (2015). |
| $\tau_d \cdot 100$ | 36 | NIPA, as in Fernández-Villaverde et al. (2015). |
| $\tau_0$ | 0.182 | Guner et al. (2014). |
| $\tau_1$ | 3.044 | Guner et al. (2014). |
| $\tau_2$ | 1.496 | Guner et al. (2014). |

*Notes:* The table shows the calibrated parameters for the monetary and fiscal authority. The main text explains the calibration targets.

Government consumption is constant, and set to 19 percent of steady-state GDP, the average value in the data. We model unemployment benefits as $b_{UI}(es) = \min(\bar{b}_{UI} \cdot e \cdot s \cdot \overline{w}, \bar{b}_{UI} \cdot$ steady-state average economy-wide earnings$)$. For unemployment benefits we set a replacement rate of 50 percent with a cap at two thirds of average earnings based on the summary in Graves (2020); the values are close to the ones reported in Shimer (2005) and Chetty (2008).[28] Next, we discuss the social security system. Huggett and Parra (2010) model retirement benefits as a piecewise linear function of past earnings. In the current paper, we cannot condition payments on the entire history of past earnings. Rather, we index retirement benefits to the education level of the household,

[28] In the calibration, the average drop in consumption in the first quarter after becoming unemployed is 11 percent, a value well within the range of estimates in the literature; see, for example, the survey in Chodorow-Reich and Karabarbounis (2016).

which serves as a rough guide to lifetime earnings. Using the replacement schedule reported in Huggett and Parra (2010), we arrive at a replacement rate of 47 percent for the low-education group, resulting in $b_{RET}(e_L) = 0.47 \cdot \bar{L}(e_L) \cdot \overline{w}$=0.32, where $\bar{L}(e)$ denotes the average productivity of a worker of education $e$ in the steady state. For the high-education group, instead, the replacement rate is 41 percent, meaning $b_{RET}(e_H) = 0.41 \cdot \bar{L}(e_H) \cdot \overline{w} = 0.46$. Social security taxes and UI taxes are set to balance their respective scheme in the steady state. The choices made here imply steady-state unemployment insurance and social security payroll tax rates of $\tau_{UI} = 0.015$ and $\tau_{RET} = 0.13$. We construct consumption and capital taxes from the National Income and Product Accounts as in Fernández-Villaverde et al. (2015). This gives tax rates on consumption and capital income of $\tau_c = 0.07$ and $\tau_d = 0.36$, respectively. For the functional form of labor-income taxes, we follow Gouveia and Strauss (1994) setting

$$\tau(X, w(X)es(1-l\varrho)) \\ = \tau_{BC}(X) + \tau_0 \left[1 - (\tau_1 \left(\frac{w \cdot e \cdot s \cdot (1-l\varrho)}{\text{economy-wide avg. earn. in st.-st.}}\right)^{\tau_2} + 1)^{-1/\tau_2}\right].$$

We follow the estimates of Guner et al. (2014) and set $\tau_1 = 0.008 \cdot (53,063/1000)^{\tau_2}$, and $\tau_2 = 1.496$.[29] $\tau_0 = 0.182$ is normalized to balance the budget in the steady state. $\tau_{BC}(X)$ is zero in the steady state.

### 3.2.4. Shocks

There are five shocks in the calibrated model: shocks to the marginal efficiency of investment, monetary shocks, productivity shocks, wage-markup shocks, and price-markup shocks. For each of these, we have to parameterize the steady-state value, the persistence, and the standard deviation of the innovation. The steady-state values are mere normalizations. We set $\overline{\zeta}_{TFP} = 0.6920$ such that steady-state GDP is normalized to unity. Last, $\overline{\zeta}_I = \overline{\zeta}_R = \overline{\zeta}_w = \overline{\zeta}_P = 1$ to normalize the corresponding shocks such that they have zero mean in logs. We set $\rho_{\zeta_{TFP}} = 0.95$, so as to match the persistence utilization-adjusted TFP in Fernald (2014). We set the persistence of the wage-markup shock to $\rho_{\zeta_w} = 0$ (it is propagated through wage persistence). As is customary, the monetary shock is white noise, too, $\rho_{\zeta_R} = 0$.

This leaves seven parameters of the shock processes to be calibrated ($\rho_{\zeta_I}, \rho_{\zeta_P}, \sigma_{\zeta_I}, \sigma_{\zeta_{TFP}}, \sigma_{\zeta_R}, \sigma_{\zeta_w}, \sigma_{\zeta_P}$). Conditional on the calibration sketched above, we estimate a linearized version of the representative-household version of the model by maximum likelihood, having six time series as observables: the growth rate of real consumption, the growth rate of real investment, the growth rate of the real wage, the interest rate, the inflation rate, and the unemployment rate. All series are demeaned. Appendix I.5 provides an exact definition of the data source. The sample is 1984Q1 to 2008Q3. We allow for iid measurement error in each of the observation equations, setting the variance of the measurement error equal to

[29] Parameters are based on the "only-labor-income" case in Guner et al. (2014) (their Table 12). We re-normalize parameter $\tau_1$ to reflect scaling. US$ 53063 is the average income in their sample for the year 2000, on which the estimates are based.

1 percent of the underlying series' unconditional standard deviation. Table VII summarizes the resulting parameter values for the shocks.

TABLE VII

PARAMETERS CHOSEN FOR THE SHOCK PROCESSES

| | $\bar{\zeta}_x$ | $\rho_{\zeta_x}$ | $\sigma_{\zeta_x}$ |
|---|---|---|---|
| MEI shock, $\zeta_I$ | $1^{a)}$ | $0.0^{e)}$ | $0.3487^{e)}$ |
| TFP shock, $\zeta_{TFP}$ | $0.6925^{b)}$ | $0.95^{c)}$ | $0.0028^{e)}$ |
| Monetary shock, $\zeta_R$ | $1^{a)}$ | $0^{d)}$ | $0.0020^{e)}$ |
| Wage shock, $\zeta_w$ | $1^{a)}$ | $0^{d)}$ | $0.0073^{e)}$ |
| Price-markup shock, $\zeta_P$ | $1^{a)}$ | $0.8475^{e)}$ | $0.0514^{e)}$ |

*Notes:* Calibrated parameters for the shock processes. $^{a)}$: normalization so log process has unit mean. $^{b)}$: normalizes steady-state GDP to unity. $^{c)}$: based on Fernald (2014). $^{d)}$ : customary normalization. $^{e)}$: determined using maximum likelihood (see main text for details).

### 3.3. Parameterization of the RANK/TANK variant

Wherever possible, parameters are identical in HANK/RANK/TANK. The RANK model has a representative family of households of all ages and education levels. The TANK variant is identical to the HANK model, other than that it strips the ability to self-insure from households. Instead, there are two infinitely lived families of savers and spenders, respectively. Each family includes households of different ages and pools all the member households' income. We continue to target a real rate of 3.2 percent per annum, and so set the time-discount factor for the saver family to $\beta^{saver} = 0.992$ (likewise in RANK, where all households are savers). In keeping with the HANK calibration, spenders in the TANK model have time-discount factor $\beta^{spend} := \beta^{saver} - \Delta\beta = 0.882$. We set the mass of spenders in TANK to 15 percent. We choose 15 percent of spenders so as to match the share of households in HANK that hold zero net worth. This strategy is akin to Debortoli and Galí (2017).

### 3.4. Properties of the calibrated model variants

Appendix I.3 shows that the HANK model closely matches the wealth distribution in the U.S. economy. Appendix I.4 reports the distribution of income sources implied by the HANK model (the counterpart to Table I). Appendix I.5 shows that the standard deviation of consumption is higher in HANK than in RANK/TANK, but somewhat smaller than in the data. Still, the model matches the data remarkably well. Appendix I.6 reports impulse responses for the three variants. In the baseline, the MEI shock works like a demand shock, generating comovement in the GDP aggregates, employment, interest rates, and inflation. The TFP shock, instead, raises output, reduces inflation, and – due to nominal rigidities – reduces employment in the short term. The price-markup and wage shocks work like cost-push shocks, moving output and inflation in opposite directions, and implying positive comovement of employment and output.

A monetary shock persistently raises interest rates and reduces output, employment, and inflation. The impulse responses do not show a hump-shaped pattern, though. Crucial elements that bring this about in New Keynesian models are habit persistence in consumption or sticky information, both of which the current model does not consider. See Auclert et al. (2020) for a detailed discussion of the hump-shaped response to monetary shocks in HANK models. Appendix I.8 reports a forecast error variance decomposition. The MEI shock accounts for 75 percent of the fluctuations in investment and about half of fluctuations in GDP. The TFP shock accounts for about a third of the variance in GDP. The price- and wage-markup shocks, respectively, account for about 10 and under 2 percent of the variance of output. Appendix I.9 documents marginal propensities to consume for different groups of households. On average households would consume about 33.5 percent of a smaller gift within the course of one year. MPCs differ starkly, but are not exactly unity for any of the groups shown, a difference from the TANK economy. Appendix I.10 documents the corresponding consumption policies by idiosyncratic states. Appendix I.11 discusses the extent to which the model matches Guvenen et al. (2014) in that the cross-sectional skewness of earnings growth is countercyclical.

## 4. A political economy of systematic monetary policy?

We are now in a position to ask what type of systematic monetary stabilization policy different types of households would wish to have. We first show that household net worth and exposure to labor income are important predictors of who wins from inflation-centric policy. Thereafter, we explain the disagreement and contrast the results for the HANK model with the results for RANK/TANK.

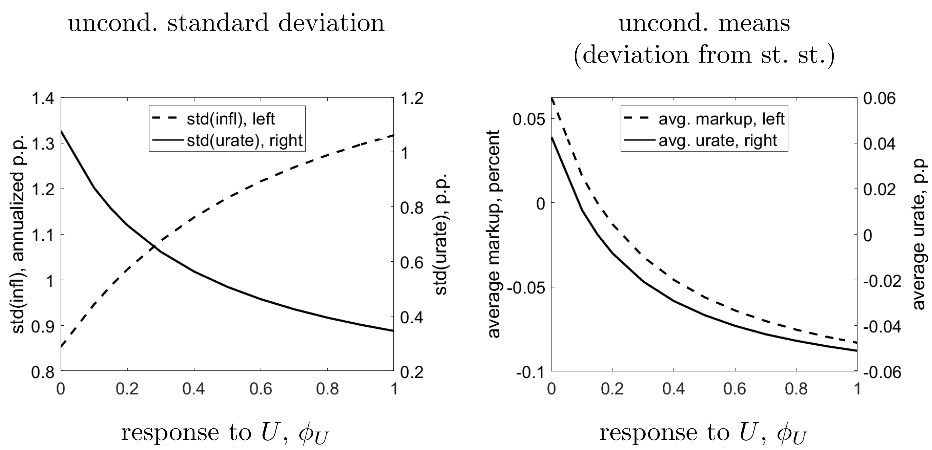
### 4.1. The experiments

We consider an unanticipated, permanent change in the parameters of the monetary policy rule (2.4). As is customary in exercises of this kind, we abstract from monetary shocks and set $\sigma_{\zeta_R} = 0$. The welfare assessments are predicated on the initial aggregate state (including the distribution of households across idiosyncratic states) being the ergodic mean under the calibrated policy rule. We wish to make sure that the results do not arise from a change in the average inflation rate (with commensurate price adjustment costs). Therefore, both in the baseline and when we change policies, we always adjust the Taylor rule's intercept such that the average inflation rate remains at exactly 2 percent annualized; Appendix J describes the algorithm.

### 4.2. Inflation-unemployment trade-off

Households differ in their exposure to inflation-centric monetary policy. Toward this end, Figure 2 shows the inflation-unemployment trade-off that is inherent in the model by varying the response to unemployment in the Taylor rule. The left panel shows the unconditional standard deviation of inflation (annualized percentage point scale, left axis) and the unemployment rate (percentage point scale, right axis). The right panel shows the effect of the same variation on the average unemployment rate (in percentage points). The average inflation rate, by design, is held constant. The panel on the right also shows the effect of stabilization policy on average markups. The more the central bank responds to

**Figure 2: HANK – Inflation-unemployment trade-off, varying $\phi_U$**




*Notes:* Left panel: unconditional standard deviation of inflation (dashed line, left axis) and the unemployment rate (solid line, right axis). Right panel: unconditional means of the markup and unemployment in deviation from the mean under baseline policy. In each of the panels, the x-axis varies the response to unemployment in the Taylor rule, $\phi_u$. The value of $\phi_u$ in the baseline is 0.15. The monetary shock is set to zero.

unemployment, the less volatile is unemployment and the more volatile inflation becomes. The standard deviation of inflation varies between somewhat a little over 0.8 p.p. annualized and a little over 1.3 p.p. annualized over the range of parameters shown here (left panel, dashed line, left axis). The standard deviation of unemployment falls from 1.2 percentage points to 0.4 percentage point. A more unemployment-centric monetary policy reduces not only the cyclicality of unemployment, but also average unemployment. The presence of such an effect is well-established in the search and matching literature (Jung and Kuester 2011, Hairault et al. 2010). Over the range of parameters shown here, the average unemployment rate varies by about 0.1 percentage point. The right panel documents that systematic monetary policy affects not only average unemployment, but also average markups. Namely, going from $\phi_U = 0$ to $\phi_U = 1$, the average markup of price setters falls by about 0.15 percent (in terms of magnitude, think of a fall in the average markup from 20 percent to 19.85 percent). Most of the movement in average markups is due to the price-markup shocks, suggesting precautionary pricing by firms. To see the logic, consider for example, a negative aggregate shock to price markups (a rise in the elasticity of demand). Such a shock is disinflationary. If monetary policy seeks to stabilize inflation in the face of such a shock (as hawkish policy would do), it has to stimulate demand. This raises marginal costs precisely at a time of low markups. Faced with the risk of attracting demand precisely when their marginal costs are high, firms may precautionarily choose higher average markups to start with. Appendix K shows that these trade-offs are present in the RANK/TANK variants, too. Systematic monetary stabilization policy in our model affects average incomes and their cyclical fluctuations.

### 4.3. Welfare gains and net worth

We now document the welfare effects of systematic stabilization policy in the HANK economy. Table VIII groups the HANK households by their position in

TABLE VIII

HANK – Welfare effects of changing monetary stabilization policy

| | | Response to unemployment, $\phi_u$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.1 | 0.15 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | $\Pi = \overline{\Pi}$ |
| | | Consumption-equivalent welfare gain (in percent) | | | | | | | | |
| Wealth percentile | 0-20 | -0.027 | -0.006 | — | 0.006 | 0.009 | 0.010 | **0.016** | 0.015 | -0.118 |
| | 20-40 | -0.023 | -0.005 | — | **0.003** | 0.001 | -0.003 | -0.001 | -0.005 | -0.109 |
| | 40-60 | 0.004 | **0.007** | — | 0.001 | -0.008 | -0.020 | -0.029 | -0.039 | 0.001 |
| | 60-80 | 0.021 | 0.014 | — | 0.001 | -0.014 | -0.030 | -0.047 | -0.062 | **0.112** |
| | 80-95 | 0.024 | 0.010 | — | -0.008 | -0.025 | -0.039 | -0.058 | -0.072 | **0.238** |
| | 95+ | 0.025 | 0.009 | — | -0.008 | -0.025 | -0.037 | -0.052 | -0.065 | **0.255** |

*Notes:* Welfare effects of a permanent policy change from the baseline policy to a policy that has a different response to unemployment, $\phi_u$; left-most columns. Right-most column: a change toward strict inflation targeting ($\phi_\Pi = \infty$). From top to bottom: average lifetime consumption-equivalent welfare gains (in percent of consumption) by wealth percentile. Households are grouped by their position in the wealth distribution at the time of the policy change.

the initial wealth distribution at the time of the policy change, reporting the average consumption-equivalent welfare gain in the group. These account for both the long-run effects of the change in policy and the transition path. Disagreement about systematic monetary stabilization policy is pronounced. Households in the lower wealth percentiles (rows "0-20" and "20-40") favor more accommodative monetary policy. The wealth-richer, instead, favor a stricter focus on inflation. To see this most starkly, focus on the extreme: a change toward a policy of strict inflation targeting (the table's right-most column). Although the policy raises the average unemployment rate by 0.17 percentage point, support for this policy extends well into the middle class: 43 percent of households would favor moving toward strict inflation targeting. Under this policy, the welfare gains of the wealth-richest 5 percent of households would amount to about a quarter of a percent of lifetime consumption. The losses of the poor run to about half of that.

To have a better idea of the magnitude of these gains and losses, Table IX reports the endowment one would need (in dollars) to finance the lifetime consumption-equivalent welfare gains reported in Table VIII.[30] Financing a

TABLE IX

HANK – ONE-TIME DOLLAR-EQUIVALENT GAIN FROM POLICY CHANGE – 2004 US$

| Wealth percentile | | Response to unemployment, $\phi_u$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.1 | 0.15 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | $\Pi = \overline{\Pi}$ |
| | 0-20 | -546 | -119 | — | 114 | 185 | 199 | **327** | 293 | -2,371 |
| | 20-40 | -506 | -108 | — | **58** | 38 | -45 | -4 | -67 | -2,438 |
| | 40-60 | 100 | **168** | — | 28 | -196 | -474 | -674 | -906 | -30 |
| | 60-80 | **444** | 312 | — | 15 | -321 | -702 | -1,095 | -1,444 | 2,573 |
| | 80-95 | **712** | 291 | — | -263 | -771 | -1,238 | -1,825 | -2,271 | **7,649** |
| | 95-100 | **2,889** | 921 | — | -852 | -2,477 | -3,637 | -4,987 | - 6,095 | **24,037** |

*Notes:* This table reports the endowment, valued in 2004 US$, that is needed to finance the consumption-equivalent welfare gains of each group reported in Table VIII. A positive entry is a gain for the household.

comparably sized consumption-equivalent welfare gain requires fewer dollars for the poor than for the wealth rich. The dollar stakes are, therefore, highly unequal. Transitioning to a policy of strict inflation targeting would translate into a loss of $2,400 for a poor household, but a ten-fold gain for the richest 5 percent by net worth.

Appendix L reports the welfare gains assuming that only one shock is present at a time. If there were only price-markup shocks, 26 percent of households would favor strict inflation targeting; If the MEI shock were the only shock, 77 percent of households would. For wage-markup shocks and the productivity shock, all households favor inflation targeting. This suggests that a failure of divine coincidence as in Faia (2009), Blanchard and Galí (2010), and Ravenna and Walsh (2011) quantitatively is not the central driving force behind the disagreement that we find. Appendix M reports the welfare effects of a one-time monetary shock: all but the wealth-richest 1 percent of households dislike the shock. The important take-away of the current section is that households may disagree not only about monetary shocks, but even more so about systematic (rule-based) monetary stabilization policy.

### 4.4. Welfare gains and exposure to labor income

This section shows that a household's relative exposure to the labor-income effects and the financial effects matters for its assessment of monetary stabilization policy. The first block of Table X groups households by the transitory skill

[30]In the model, we compute the endowment required as a percent of the average quarterly earnings per household in the economy. The table, then, maps these numbers into 2004 US$ terms, using the average quarterly earnings of working-age households in the SCF. The SCF for 2004 puts the quarterly earnings of working-age households at 20,675 US$.

TABLE X

HANK – ONE-TIME DOLLAR-EQUIVALENT GAIN BY DIMENSION OF HETEROGENEITY

| | | Response to unemployment, $\phi_u$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.1 | 0.15 | 0.2 | 0.3 | 0.4 | 0.5 | $\Pi = \overline{\Pi}$ |
| skills | $s_0$ (retired) | 1,672 | 665 | — | -276 | -1,087 | -1,807 | -2,528 | **7,815** |
| | $s_1$ (low) | -284 | -24 | — | **38** | -28 | -134 | -206 | -162 |
| | $s_2$ (middle) | -337 | -12 | — | **35** | -72 | -232 | -343 | **166** |
| | $s_3$ (super) | 2,048 | 753 | — | -742 | -2,279 | -3,548 | -4,786 | **19,636** |
| empl., loss | $n = 0$ (unemp.) | -360 | -30 | — | **54** | -6 | -128 | -185 | -905 |
| | $n = 1, l = 1$ | -318 | -20 | — | **41** | -37 | -169 | -253 | -127 |
| | $n = 1, l = 0$ | -220 | **10** | — | 1 | -149 | -321 | -468 | **992** |

*Notes:* Same as Table IX, but sorting the population by residual skill (retired, low skill, medium skill, super-skill) or current employment status (unemployed, employed with skill loss, employed without skill loss). Average dollar-equivalent gains for each group (2004 US$).

state, $s$. Retirees (skill state $s_0$) account for roughly 23 percent of households. As a group they hold a quarter of the economy's net worth, and the average retiree derives a notable share of income from financial sources (compare Table I in the main text and Appendix I.3). Besides, they are completely insulated from the direct effects of monetary stabilization policy on labor income. For them, what matters is that monetary stabilization policy can affect the value of their savings and the amount of taxes they pay. Retirees are among the strongest beneficiaries of a move toward strict inflation targeting with a gain equivalent to roughly \$7,800 (last column, row $s_0$). In terms of the working-age population, the average household of normal skill ($s_1$ and $s_2$), instead, is close to indifferent to a policy change. The super-skilled, instead, tend to accumulate wealth, and on average firmly favor inflation-centric policy. Appendix N shows the decomposition for the idiosyncratic states. Among the working-age population, it shows, for example, that the currently unemployed and employed households that suffer from an earnings loss tend to favor more dovish policy, while the rest favor more hawkish policy. The next section shows that there is disagreement not only for the specific policies considered here, but also with regard to optimal monetary policy.

### 4.5. Optimal simple rules

This section chooses the unemployment response $\phi_u$ and the inflation response $\phi_\Pi$ in the Taylor rule such that they maximize the *ex-ante* utilitarian welfare of a subset of the population.[31] The rules can, thus, accommodate a desire for

[31] We keep conditioning on the initial state being the non-stochastic steady state. The grid points we allow are $\phi_\Pi \in \{1.25, 1.5, ..., 8\}$ and $\phi_u \in \{0, 0.25, ..., 1.5\}$. Parameter $\phi_R = 0.8$ as in the calibrated baseline.

more stabilization in general while at the same time stabilizing inflation more than unemployment, or *vice versa*.

For three wealth percentiles, Table XI shows the implied optimal rule, the support, and the effect that the rules have on average unemployment and the business cycle. The left column shows results for a rule that is optimal for the bottom 20 percent by wealth, the middle panel that of the central wealth percentiles, and on the right that of the wealthiest 5 percent of households. Appendix O shows the gains and losses for all rules on the grid.

TABLE XI

HANK – (Dis-)agreement about Optimal Simple Policies

| | | Optimal for wealth percentile | | |
|---|---|---|---|---|
| | | 0-20 | 40-60 | 95-100 |
| | | Consumption-equivalent welfare gain (in percent) | | |
| Wealth percentile | 0-20 | 0.028 | -0.027 | -0.174 |
| | 20-40 | 0.016 | -0.011 | -0.153 |
| | 40-60 | -0.019 | 0.037 | -0.040 |
| | 60-80 | -0.035 | 0.082 | 0.068 |
| | 80-95 | -0.028 | 0.115 | 0.177 |
| | 95+ | -0.021 | 0.110 | 0.192 |
| Share in favor | | 56 | 56 | 38 |
| Sum 2004 US$ | | -296 | 1,463 | 504 |
| Std | $\Pi$ | 1.16 | 0.71 | 0.28 |
| | u rate | 0.43 | 0.92 | 1.55 |
| Mean | u rate | -0.04 | 0.04 | 0.15 |
| | | Parameters of the optimal rule | | |
| | $\phi_\Pi$ | 2.25 | 3.25 | 7.75 |
| | $\phi_u$ | 1.00 | 0.25 | 0.00 |

*Notes:* Changing policy to an optimal rule for a specific wealth percentile. From top to bottom: consumption-equivalent welfare gains by wealth percentile, share of households in favor of the change, and average dollar-equivalent gain for all households. Continued from top to bottom: standard deviation of inflation (ann. pp) and the unemployment rate (in percentage points). The numbers reported are the raw standard deviations. Next: change in the average unemployment rate (in percentage points). Last: parameters of the optimal simple rule.

Focus on the bottom block of rows in the table first, which report the optimal coefficients of the rules. All groups of households would favor a policy that is more responsive to the business cycle than the baseline. As regards the balance between inflation and unemployment, however, there is a strong wealth gradient. The wealth-poor favor dovish policy (left column); the wealth-rich favor hawkish policy (right column). A utilitarian planner for the entire population would choose $\phi_\Pi = 5.5$ and $\phi_u = 0.75$ (result not reported in the table). Next focus on the middle block of rows. In line with the inflation-unemployment stabilization trade-off in the model, the unemployment rate is notably more volatile for the policy favored by the wealth-rich than the wealth-poor (the standard deviation of unemployment is 1.57 percentage points and 0.42 percentage point, respectively). Similarly, average unemployment is 0.2 percentage point higher in the policy favored by the wealth-rich.

Two results are noteworthy. First, rather different policies could attract support by a majority of households. To see this, focus on the top block of rows. We see that 56 percent of households each favor the policies for the wealth-poor and the middle-class (the particular similarity in numbers is a coincidence) over the *status quo* in spite of these having fundamentally different distributional implications: the policy for the middle-class hurts the wealth-poor and benefits the wealth-rich. *Vice versa* the policy for the wealth-poor hurts the wealth-rich. The second result that is noteworthy is the spread in consumption-equivalent welfare gains and losses across households. This spread is about 0.05 percentage point for the policy targeted at the wealth-poor, and 0.37 percentage point, almost an order of magnitude larger, for a transition to a policy targeted at the wealth-rich.

### 4.6. Explaining the disagreement

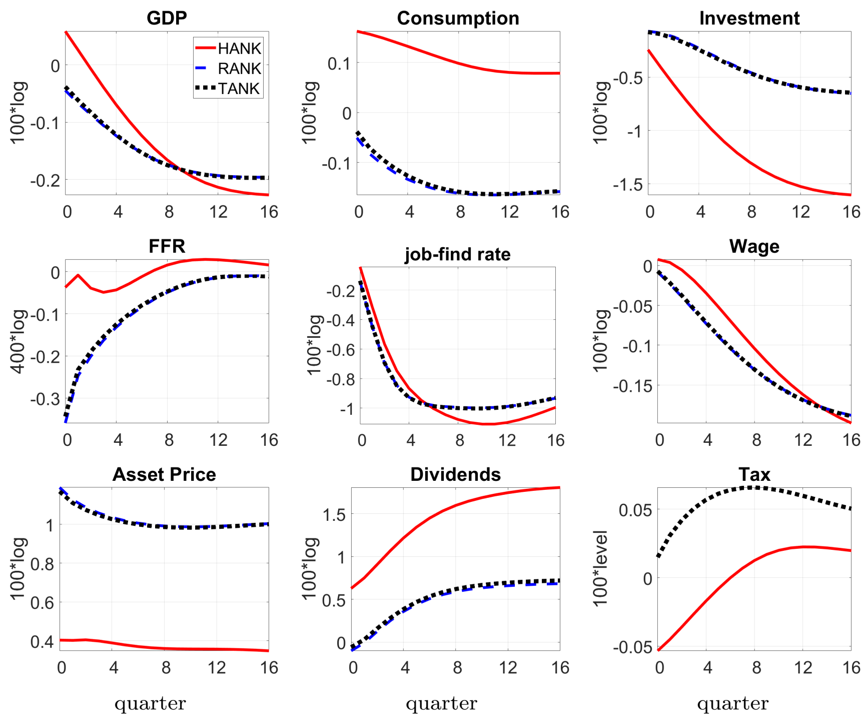
Households in the HANK economy strongly disagree about systematic monetary stabilization policy. In order to illustrate the channels at work, throughout this section we focus on one of the polar cases: a transition toward strict inflation targeting.

#### 4.6.1. The transition path

All of the welfare assessments that we show take into account the transition path. The current section shows why: a change in systematic stabilization policy sets in motion pronounced transition dynamics. Abstracting from this transition would, therefore, lead to erroneous welfare assessments for the HANK model (for comparison, Appendix P shows the welfare assessments that focus on the long run only). Figure 3 shows the first four years (16 quarters) of the average transition path after the new policy is implemented. Each panel shows the difference between the expected path after strict inflation targeting is introduced and the expected path in the baseline. Appendix Q reports the algorithm employed. Appendix R presents the same transitions over a longer horizon (125 years). The panels plot the transition path in the HANK economy as solid red lines, and in the RANK and TANK variants (the virtually indistinguishable dashed and dotted blue and black lines).

Upon implementing inflation targeting, all three economies see valuation gains for owners of shares: In the HANK economy, the asset price jumps by 0.4 percent (bottom left panel, solid red line). Since in HANK asset holders are neither infinitely lived, nor necessarily patient, many owners of shares have high marginal propensities to consume (compare Appendix I.9). Even for the average owner of shares (using wealth weights to average), the marginal propensity to consume out of wealth over the course of a year is about 8.5 percent compared to only 3.1

**Figure 3: Transition toward policy of $\Pi = \overline{\Pi}$**




*Notes:* Short-run expected transition path after strict inflation-targeting is introduced. Quarter 0 is the quarter of the policy change. HANK: solid red, RANK: dashed blue, TANK: dotted black. In terms of scale: "100*log" means percent deviation from the baseline path. "400*log" means annualized percentage points. "100*level" means p.p. change of rate in levels.

percent in RANK/TANK. The windfall gains to wealth are, therefore, effective for aggregate consumption demand in HANK. In HANK consumption demand supports real activity (first row, left) and wages (second row, right). Dividends rise. Since dividends are taxed and there is an initial expansion in incomes, in the short run, income taxes fall in HANK, further supporting consumption demand. In RANK/TANK, instead, real activity falls and taxes rise. This is so in spite of a sharper rise in the asset price than in RANK/TANK (bottom-left panel).[32] Nevertheless, in the RANK/TANK economies this is not met by a consumption boom. This is reasonable. In both RANK and TANK, the valuation gains do not accrue to any household with a higher marginal propensity to consume. All households either are not exposed to the valuation gains of assets, because they

[32]The sharper rise in asset prices in RANK/TANK is in line with more monetary accommodation on impact and persistently lower real rates than in HANK. Appendix S shows this.

do not hold shares (the spenders), or are infinitely lived families. What is also noteworthy is the fall in investment on the transition path (top right panel) that is much more pronounced in HANK than in RANK/TANK.

What sets the HANK economy apart from RANK/TANK is that households are exposed to risk and can self-insure against that. Namely, households seek to self-insure against income fluctuations that are life-cycle related (retirement), purely idiosyncratic (skill shocks), or business-cycle related (the risk of persistent unemployment, for example). This strengthens two channels in HANK that are muted in RANK and TANK. We turn to these next.

#### 4.6.2. Precautionary savings

To the extent that monetary policy increases idiosyncratic risk by stabilizing inflation at the expense of employment, in HANK working-age households would be expected to increase their precautionary savings. As the demand for funds rises, this would put upward pressure on the asset price and increase the mutual funds' investment in the capital stock. Appendix I.10 shows the households' consumption policies as a function of net worth for households in different idiosyncratic states. Upon moving toward inflation targeting, the consumption policies, for a given level of savings shift downward (toward higher savings). And consistent with a precautionary savings channel, they shift downward by more for working-age households than for retirees. Section 4.6.3 will revisit this.

Still, the precautionary savings channel likely is not the dominant explanation for the differences between the HANK and RANK/TANK economies shown above. The reason is simple: the effect on investment in Figure 3 goes in the wrong direction, relative to RANK and TANK. The capital stock falls faster and by more in the HANK economy.

#### 4.6.3. Valuation gains and the supply of capital

Instead, we emphasize that a change in systematic monetary policy in our calibration affects the income distribution, the cash flow of firms, and the discounting of cash flows. A policy change can, therefore, induce *valuation gains* or losses on financial assets, giving rise to the second channel that is specific to HANK. To the extent that systematic monetary stabilization policy increases, say, the profitability of firms, it raises the value of financial assets. The corresponding increase in the effective supply of assets is inconsequential in RANK and TANK, where the demand for funds is rather interest-elastic. In HANK, instead, the demand for funds is not, because funds serve a purpose. Namely, households purchase funds so as to insure consumption against fluctuations in income, over both the life and business cycle. Therefore, if the value of assets rises, for a given stock of capital and employment, all else equal the economy can provide the same degree of insurance with less productive capacity. This puts downward pressure on the price of assets and upward pressure on the discount factor that firms apply, until productive capacity has fallen sufficiently so as to realign the supply of assets with the demand for funds.[33] At the same time, there are second-round effects that affect the demand for funds. Namely, a fall in the capital stock reduces the wages that workers receive and, thus, it reduces permanent income for wage earners, and with it their savings.

TABLE XII

CHANGE IN LONG RUN, STRICT INFLATION TARGETING

| | HANK | RANK | TANK |
|---|---|---|---|
| $E(urate)$ (p.p) | 0.17 | 0.17 | 0.17 |
| $E(\log(k))$ (%) | -2.12 | -0.36 | -0.37 |
| $E(\log(w))$ (%) | -0.39 | -0.23 | -0.23 |

*Notes:* Change of average unemployment rate (p.p.), long-run average capital stock and wage (in percent) induced by a change to inflation targeting. Negative numbers mean unemployment, capital, or the wage falls.

Table XII reports the long-run effect that systematic monetary stabilization policy has on average unemployment, capital, and wages across the model variants (HANK/RANK/TANK). The first line focuses on the unemployment rate. In line with an average-employment effect running through unemployment variability, the central bank's focus on inflation raises the average unemployment rate (by 0.17 percentage point). This effect, though, is strikingly similar across model variants. Differences in the strength of the average employment channel, therefore, do not seem to be a candidate explanation for the different response of the three model variants to the policy change.

The next row, instead, shows that the average capital stock shows sharply different effects in HANK and RANK/TANK. In all the variants, a fall in employment reduces the marginal product of capital, and so would be expected to go hand in hand with a fall in the capital stock. The fall in capital is much more pronounced in HANK, however, than in RANK/TANK. A move toward strict inflation targeting makes the long-run average capital stock in HANK fall by 2.1 percent. In the RANK and TANK economies, instead, the same policy change would induce a fall in the capital stock of only about a fifth of this magnitude. With this, economic activity in the long run shrinks more in HANK than in RANK/TANK, and so do wages (last row).[34]

### 4.6.4. Policy and the distribution of net worth

The interplay of the channels affects the wealth distribution. Table XIII documents the long-run effect of a shift in systematic monetary policy on the market

[33]We abstract from government debt. This is not innocuous. In particular, suppose that there was government debt. Then, a government debt management policy could counteract the rise in the supply of assets on the transition path. Since government debt is net worth for individual households, we would conjecture that a policy that reduces debt after the change in systematic monetary policy would cushion the fall in the capital stock.

[34]Note that the average capital stock and employment do not need to move exactly in lock-step since the model features a capacity-utilization decision.

TABLE XIII

HANK – Effect of systematic monetary policy on net worth of groups

| | | Response to unemployment, $\phi_u$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.1 | 0.15 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | $\Pi = \overline{\Pi}$ |
| | | Savings change at long-run mean | | | | | | | | |
| Wealth percentile | 0-20 | -0.02 | 0.00 | — | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | -0.09 |
| | 20-40 | 0.01 | 0.00 | — | 0.00 | -0.01 | -0.01 | -0.01 | -0.01 | **0.10** |
| | 40-60 | **0.23** | 0.05 | — | -0.03 | -0.09 | -0.12 | -0.12 | -0.13 | **1.21** |
| | 60-80 | -0.11 | -0.02 | — | 0.01 | 0.03 | **0.04** | 0.02 | 0.03 | -0.70 |
| | 80-95 | -0.32 | -0.08 | — | 0.06 | 0.15 | 0.20 | 0.25 | **0.28** | -1.54 |
| | 95-100 | -7.24 | -1.79 | — | 1.48 | 3.50 | 4.97 | 6.39 | **7.20** | -31.30 |
| | Total | -0.39 | -0.10 | — | 0.08 | 0.19 | 0.26 | 0.34 | 0.38 | -1.69 |

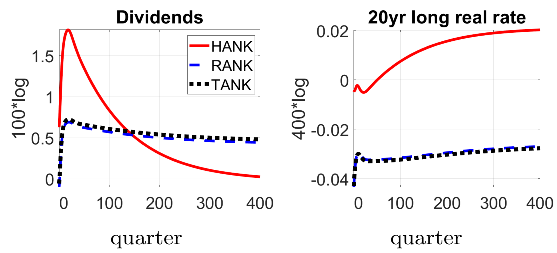
*Notes:* By wealth percentile. Entries are expressed as per-household multiples of per-household quarterly GDP. An entry of -1.54 means that wealth per household of the respective group falls by an amount equivalent to 1.54 percent of quarterly per-household GDP. By way of reference, the per-household net worth of the respective groups (from top row to bottom row) are: 0.01 (0-20), 0.43 (20-40), 2.38 (40-60), 9.02 (60-80), 26.46(80-95), 154.21 (95-100) and 14.05 (for the total) times per-household quarterly GDP. Net worth here is defined as $p(X) \cdot a$, that is, by *ex-dividend* net worth.

value of *ex-dividend* net worth held by different segments of the wealth distribution that then prevails. In order to gain an idea of how much they shape the aggregate, the numbers are multiples of steady-state quarterly GDP per household. As monetary policy becomes more inflation-centric, for the wealth-poorest 20 percent, net worth hardly changes. They save little to start with and their average earnings fall, whereas, by design, the generosity of social insurance does not. Households around the median of the wealth distribution, instead, increase their net worth. Under strict inflation targeting, their net worth rises by about 1 percent of steady-state per-household GDP, equivalent to half a percent of an increase in the group's net worth. This is in line with the group's rising exposure to employment risk and occurs in spite of a fall in labor income. Households at the top of the wealth distribution, instead, have lower net worth than under the baseline policy. The net worth of the 5 percent wealthiest households falls by about 0.2 percent, commensurate (in levels) with a fall in ex-dividend net worth by a third of per-household GDP.

### 4.6.5. The real rate of interest

Figure 3 shows dividends and the long real rate along the transition path, for a longer horizon. Namely, shown is a long horizon of 400 quarters (100 years). Dividends in RANK and TANK rise by about half a percent in the long run (left panel, blue dashed and black dotted lines that overlap). In HANK dividends per share rise on the transition path, but eventually return to about the level they had prior to the policy change. The right panel plots a putative long real rate of

**Figure 4: Transition induced by policy change to $\Pi = \overline{\overline{\Pi}}$ − 125 years**




*Notes:* Same as Figure 3, but for a longer horizon.

interest (for a 20-year real bond). In the long run, the effect of a move toward inflation targeting in HANK is to raise the average real rate by 2 bps (annualized). In HANK/RANK, instead, the average real rate falls. The difference in the real rate between HANK and RANK/TANK is 4.7 bps annualized.[35] Note that, on purpose, we have used the term "real rate" rather than the term "natural rate." Monetary policy in all three variants affects allocations and the real rate only when there are nominal rigidities. The natural (flex-price) rate of interest, thus, is not affected by systematic monetary policy in either variant. Instead, the real rate of interest is.

### 4.7. Do the RANK and TANK variants capture the trade-offs?

We have built a HANK business-cycle model with substantial heterogeneity. A central element of that model is the households' ability to save. At the same time, this makes solving the model computationally involved. So the question arises of whether simpler models would be an equally adequate guide to the welfare consequences of systematic monetary stabilization policy. Toward this end, this section explores the welfare assessments provided by the RANK and TANK variant.

Appendix E describes the TANK economy in more detail. Appendices I.5 through I.8 show that in terms of fluctuations alone, the three economies for the baseline policy provide a rather similar view at first glance. Namely, second moments in the HANK and TANK/RANK economies are comparable. Similarly, the impulse responses to shocks in the TANK/RANK economies differ somewhat from HANK, but not fundamentally so. The same is true of (first-order) forecast error variance decompositions. And also the unemployment-inflation trade-off is comparable in the three model variants (Figure 2 and Appendix K).

In spite of this, as we show next, neither the RANK nor the TANK vari-

[35] The mechanics are reminiscent of Krusell et al. (2009), who find in a real business-cycle model that removing cyclical fluctuations reduces the capital stock and raises the real rate of interest, which significantly raises the welfare of the wealth richest. Here, the gains to the rich, instead, arise when business-cycle volatility *increases*.

ant captures the policy trade-offs in HANK, adding to the differences in the mean dynamics that we highlighted earlier. Table XIV provides consumption-

TABLE XIV

RANK/TANK – Consumption-equivalent welfare gains from changing policy

| | | Response to unemployment, $\phi_u$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0.0 | 0.1 | 0.15 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | $\Pi = \overline{\Pi}$ |
| TANK | saver | -0.044 | -0.009 | — | 0.006 | **0.016** | 0.015 | 0.011 | 0.007 | -0.195 |
| | spender | -0.068 | -0.016 | — | 0.012 | 0.041 | 0.053 | 0.059 | **0.063** | -0.279 |
| RANK | | -0.046 | -0.010 | — | 0.007 | 0.020 | **0.021** | 0.019 | 0.016 | -0.215 |

*Notes:* Same as Table VIII, but for RANK and TANK. For the latter, welfare is reported for the saver family and the spender family. Boldface marks the maximum welfare gains.

equivalent welfare gains for the RANK and TANK economies. Compare these to the corresponding numbers for the HANK model in Table VIII. The most striking observation here is that in TANK, disagreement is mild at best, whereas in HANK 43 percent of households supported inflation targeting. In RANK and TANK alike, all households dislike this policy (the right-most column). In the presence of markup shocks inflation targeting is socially costly.[36] Also for smaller policy changes all households in the two models agree on the direction, preferring a monetary policy that is *more* responsive to unemployment than in the baseline.[37]

One may then wonder if the TANK model can be *made* to provide guidance similar to that of the HANK economy, through a judicious choice of calibration strategy. Qualitatively it can, if one calibrates wealth to be more concentrated, but not too concentrated. Table XV reports the welfare and long-run effects in TANK, when doing so by increasing the calibrated mass of spenders. Then, as wealth is more concentrated, the TANK model does feature heterogeneity in policy assessments. Spenders always dislike inflation targeting (see Appendix T.2). Once wealth is sufficiently concentrated, however, *savers* begin to approve of inflation targeting. Note that this requires a mass of spenders beyond 70 percent of the population, however, so that the share of households favoring this policy is at most 30 percent. This falls considerably short of the 43 percent of households that support moving toward inflation targeting in the HANK baseline. Accounting for the relative exposure that households have to the employment effects and financial effects that systematic monetary stabilization policy may have, thus, is important for determining support for the policies.

[36] Appendix T.1 provides the consumption-equivalent welfare gains for spenders when spender households do not pool incomes across idiosyncratic labor-market state, education, and age. Still, there is no disagreement about policy.

[37] A utilitarian planner that would choose optimal simple policies in RANK and TANK would pick, respectively, $\phi_\Pi = 1.59$ and $\phi_u = 0.59$ and $\phi_\Pi = 1.71$ and $\phi_u = 0.66$ (numbers not reported in the table).

TABLE XV

TANK – Welfare gains for SAVERS by share of spenders

| Share of spenders | Response to unemployment, $\phi_u$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.0 | 0.1 | 0.15 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | $\Pi = \overline{\Pi}$ |
| 50 | -0.033 | -0.006 | — | 0.003 | **0.003** | 0.000 | -0.004 | -0.010 | -0.112 |
| 70 | -0.022 | -0.002 | — | -0.001 | -0.008 | -0.017 | -0.028 | -0.037 | -0.003 |
| 75 | -0.018 | 0.000 | — | -0.003 | -0.012 | -0.024 | -0.036 | -0.048 | **0.041** |
| 80 | -0.013 | 0.002 | — | -0.004 | -0.017 | -0.032 | -0.047 | -0.060 | **0.099** |

*Notes:* TANK model. Consumption equivalent welfare gains for saver households. Share of spenders varies between 50 percent (first row) and 80 percent (last row). Otherwise, the exercise is analogous to Table XIV.

## 5. Sensitivity analysis

The paper is concerned with the distributional effects of systematic monetary policy when households have different sources of income and, therefore, different exposure to a policy change. In our model, this runs through windfall gains to owners of capital, falling average labor income, and different exposures to a rise in average labor-market risk. This section probes the wage rule, the role of household portfolios, fiscal policy, and the role of price adjustment costs. All of these dimensions are important for the distributional effects of systematic monetary stabilization policy. In order to keep the dimensionality limited, we report results for a move toward strict inflation targeting only.

Table XVI reports results of the sensitivity checks we run. The first column repeats the results for the baseline. The remaining columns report results for the sensitivity checks (to be described in detail below). For each scenario, we report the welfare gains in the HANK model by wealth percentile and the share of households in favor of the policy change from the baseline policy rule. This is the first set of rows. The second set of rows reports results for the corresponding TANK variant: the welfare gains for saver and spender households (at the baseline calibration of a share of spenders by 0.15 percent), and the rise in the average unemployment rate (in p.p.) that the change to inflation targeting brings. In all but one scenario, the share of households in favor of inflation targeting is on the order of 29 to 51 percent in HANK, while the TANK model (in our baseline calibration) indicates losses for both savers and spenders.

### 5.1. The wage rule

Wages allocate the surplus in the employment-services sector. This matters both for the business cycle (Shimer, 2005 and Hagedorn and Manovskii, 2008) and the long run. To the extent that average aggregate economic activity is affected by monetary stabilization policy, as it is in the current model environment, the wage rule determines how much of this is passed on to the wage (and potentially the labor share) or to employment. If adjustment is through the

TABLE XVI

HANK – SENSITIVITY ANALYSIS

| | | | Wage rule | | | | Lever. | Balanced | Price |
|---|---|---|---|---|---|---|---|---|---|
| | | Basel. | Nash | High | Share | Flex | portf. | taxation | adj. cost |
| HANK | Wealth percent. 0-20 | -0.12 | -0.07 | -0.08 | -0.41 | -0.08 | -0.13 | -0.10 | -0.09 |
| | 20-40 | -0.11 | -0.04 | -0.13 | -0.54 | -0.05 | -0.11 | -0.10 | -0.10 |
| | 40-60 | 0.00 | 0.05 | -0.03 | -0.65 | 0.04 | 0.04 | 0.02 | -0.05 |
| | 60-80 | 0.11 | 0.12 | -0.02 | -0.80 | 0.15 | 0.12 | 0.13 | 0.02 |
| | 80-95 | 0.24 | 0.23 | 0.07 | -0.75 | 0.26 | 0.23 | 0.29 | 0.13 |
| | 95-100 | 0.26 | 0.23 | 0.09 | -0.63 | 0.26 | 0.22 | 0.30 | 0.16 |
| | In favor | 0.43 | 0.48 | 0.29 | 0 | 0.50 | 0.51 | 0.46 | 0.38 |
| TANK | saver | -0.20 | -0.15 | -0.49 | -1.22 | -0.10 | -0.20 | -0.19 | -0.21 |
| | spender | -0.28 | -0.21 | -0.52 | -0.74 | -0.17 | -0.28 | -0.26 | -0.20 |
| | $\Delta E(urate)$ | 0.17 | 0.14 | 0.40 | 1.06 | 0.48 | 0.17 | 0.17 | 0.17 |

*Notes:* First block: HANK economy. Consumption-equivalent welfare gains (in percent) by wealth percentile, and share of households in favor of a change toward strict inflation targeting. Second block: consumption-equivalent welfare gains for savers and spenders in TANK, and change in the average unemployment rate. Scenarios described in the main text.

wage, share holders favor stabilizing inflation at the expense of employment. If adjustment goes through employment, instead, the marginal product of capital falls, hurting the corporate sector as well. To show the role that the wage response plays in assigning winners and losers of monetary stabilization policy, we have run several counterfactuals. Throughout, unless noted otherwise, the values of namesake parameters are the same as under the wage rule we used for the baseline HANK model.

First, we let wages in the long run emerge as implied by the Nash-bargaining protocol. The wage rule that would prevail in the simple search-and-matching analog with a risk-neutral household, through surplus sharing, would lead the wage to respond to the price of labor services and to market tightness. Adding wage rigidity to this gives the following wage rule

$$w(X) - \overline{w}(X) = \omega + \phi_w\left(w_1(X) - \overline{w}\right) + (1-\phi_w)\eta\left[h(X) + \beta\mathbb{E}_\zeta\kappa(\widetilde{X}')\frac{f(\widetilde{X}')}{q(\widetilde{X}')}\right] + \zeta_w.$$

We choose the new parameter $\omega$ here to have the same average unemployment rate as under the baseline wage rule if policy were to follow the baseline's monetary rule. In addition, we choose a bargaining-power parameter of $\eta = 0.5$, a customary value. Not only does the model with the Nash wage rule show second moments similar to the baseline (not shown here), but also the welfare implications are rather similar to the baseline; see column "Nash" of Table XVI. Indeed, still more households would support strict inflation targeting, a support that the TANK model would miss. Second, we highlight how the policy assessment would be affected if wages in the long run do not fall in lock-step with economic activity, but remain high. We assume that the wage moves according to $\log(w(X)/\overline{w}) = \phi_w \, \log(w_{-1}(X)/\overline{w}) + \frac{1}{2}\left[(1-\phi_w)\cdot\log\left(\frac{y(X)}{\overline{y}}\right)\right] + \zeta_w$. Under this scenario (labeled "High" in Table XVI), unemployment rises by about twice as much as with the baseline wage rule. The support for inflation targeting shrinks, but at 29 percent of households remains sizable. The TANK model again would miss this support. Third, we choose a wage rule that is designed to explicitly make sure that under all circumstances the long-run labor share can never be affected by monetary policy. The measured labor share in the long run is given by $\frac{w(X)\int_{\mathcal{M}} se(1-\varrho l)\mathbb{1}_{n=1}\ d\mu}{GDP(X)}$, so we entertain the following wage rule $\log(w(X)/\overline{w}) = \phi_w \, \log(w_{-1}(X)/\overline{w}) + (1-\phi_w)\cdot\log\left(\frac{GDP(X)}{\int_{\mathcal{M}} se(1-\varrho l)\mathbb{1}_{n=1}\ d\mu}\right) + \zeta_w$. The column "Share" shows the results. With this wage rule, average unemployment rises strongly upon a move to inflation targeting (the unemployment rate rises by 1.06 percentage points). All segments of the population then agree that inflation targeting is not a preferable policy, the middle class now being the biggest losers from a change toward inflation-centric monetary policy. Fourth, we abstract from wage rigidity, setting $\phi_w = 0$ in the baseline wage rule, column "Flex" in the Table. The support for hawkish monetary policy rises to slightly above 50% of households, the gradient remains.[38]

In sum, in our model systematic monetary stabilization policy affects economic activity in the short and the long run. It is central, then, to form a view of how the wage-setting process distributes the gains and losses.

### 5.2. Household portfolio and exposure to financial gains

An important literature has shown that monetary shocks in part propagate through the heterogeneity of household portfolios; see, for example, Cloyne et al. (2019). The current paper is concerned with systematic monetary stabilization policy, rather than monetary shocks. Still, the portfolio structure will matter for two reasons at least: first, because it determines the exposure that different households have to the gains and losses from a change in systematic monetary policy; second, because systematic monetary policy determines the response of incomes following economic shocks. To the extent that monetary policy allows inflation to fall in a recession, for example, this provides a windfall gain to holders of nominal assets, providing them with additional insurance; see Bhandari et al. (forthcoming). The current section seeks to illustrate the role of portfolios through a simple counterfactual. Namely, we assume that household portfolios now are composed of two assets: short-term nominal bonds and shares of a mutual fund. The mutual fund is the counterparty for bond holdings. A household can be short or long in bonds. We then assign the portfolio weights in bonds and shares that emerge, by age, education, and net worth, from the 2004 SCF. Appendix U provides details. We wish to emphasize that the mapping is coarse.

[38] We have also run a counterfactual with the Nash rule above, but flexible wages. Then, the support for strict inflation targeting rises further to 88%. Again, however, the effect on average unemployment (an increase of 0.9 percentage point) is large.

In the data, we assign non-nominal assets, including housing, to the share component. For the bond counterpart, we disregard maturity.[39] The column labeled "Leveraged portfolio" in Table XVI shows the results. Namely, the support for inflation targeting rises to above 51 percent of households. This is so because the working-age middle class tend to hold highly levered portfolios. Even though their *net worth* is small, they now receive a larger share of the financial windfall gains that inflation targeting assigns to owners of shares. The portfolios of retirees are more nominal on the asset side to start with. They, therefore, benefit less than in the baseline. At the same time, they were so solidly in favor of inflation targeting in the baseline that they remain so now. This channel, too, would be missing in the TANK model, where the composition of portfolios does not play a role.

### 5.3. Monetary stabilization policy and the tax system

In the HANK baseline, the gains from unemployment stabilization accrue to the factor labor, the gains from inflation stabilization to the owners of shares. The move toward more inflation-centric policy on average leads to lower employment and wages. If taxes were kept constant, the government would have lower tax revenue and higher expenditure (for unemployment benefits, in particular). In the baseline, therefore, labor-income taxes rise to balance the budget. This burdens labor twice, through lower income and higher taxes. By design, dividend taxes, instead, were kept constant before. In a sensitivity check, we have made the financing more balanced, having both labor and dividend taxes move to finance the government budget. In particular, we assume that they move in lock-step: whenever the labor tax rate rises by 1 percentage point, so will the tax on dividends. The column labeled "Balanced taxation" of Table XVI reports the results. A more balanced financing spreads the gains from hawkish monetary stabilization policy more widely and the assessment is slightly more favorable to inflation targeting than in the baseline.

### 5.4. How important are the costs of price adjustment themselves?

We have kept an important question until the end of the paper, namely, the role of price adjustment costs. A long literature in monetary economics discusses the costs of inflation variability and whether they fall on households or firms. The baseline assigns price adjustment costs to owners of firms. In order to show how sensitive the results are to the distribution across society of these costs, scenario

[39] Many other dimensions of the portfolio structure will likely matter: how liquid a household's assets are, for example, or how households can finance leverage. For example, in a model in which a riskless bond is used for precautionary savings (as in Kaplan et al. (2018)) the demand for funds may be channeled there rather than into capital. More generally, it will also matter if the valuation gains accrue equally to all real assets. One may wonder, in particular, about the implicit assumption here that housing wealth moves in lock-step with business wealth. A more detailed analysis of such spillovers is beyond the scope of the current paper, however. The more the valuation gains in equilibrium are concentrated only on the asset classes held by the top of the wealth distribution, the lower we suppose will be the support for a change toward hawkish policy.

"Price adjustment cost" in Table XVI assumes that price adjustment costs affect firms' policies at the margin, but that these costs do not enter the firms' profits. Instead, we assume that the government reimburses the firm sector for the price adjustment costs in a lump-sum fashion, with the expenses financed through labor-income taxes. This means that the nominal rigidities continue to affect economic outcomes, but that the direct costs of price fluctuations are borne by all households, each in proportion to its non-financial income. Doing this, the direct gains from inflation stabilization policy no longer accrue to financial capital. The support for strict inflation targeting shrinks somewhat, but at 38 percent of households remains sizable. We conclude that the costs of price adjustment themselves are not essential for our finding of disagreement.

## 6. Conclusions

Monetary policy affects aggregate economic activity, the distribution of income, and income risks that households face. To assess the distributional effects of the systematic conduct of monetary policy, we have built a New Keynesian heterogeneous-agent DSGE model that features asset-market incompleteness, heterogeneity in preferences, skills, and age, a frictional labor market, and sticky prices. The model was calibrated to the U.S. in tranquil times.

The main finding is that households may strongly disagree as to how monetary policy should *systematically* respond to the business cycle. That disagreement can be traced to households' relative exposure to labor income and wealth. The reason was that the gains from stabilizing inflation and the costs of doing so were not evenly distributed across different households. If the central bank stabilizes inflation, it raises average markups. To the extent that wages fall with economic activity, as they do in the baseline, corporate profits are stabilized at the expense of labor income. Thus, stabilizing inflation may lead to winners and losers. We document that, in our model, this channel dominates the effect of precautionary savings on capital accumulation that arises from higher employment risk. The households that gain from inflation stabilization are the wealth-rich (for whom labor income is a small part of lifetime wealth) and retirees (who tend to have assets, but are not exposed to labor income). The wealth-poorest households (those who draw most or all of their income from labor) would be willing to forgo up to 0.12 percent of their lifetime consumption to avoid a move to strict inflation targeting. The wealth-richest 5 percent of households, instead, would gain the equivalent of abut 0.25 percent. To finance these changes in consumption, in 2004 US$, the wealth-poorest would need to be compensated by 2,400US$. The wealth-richest 5 percent, instead, would gain, and at 24,000 2004 US$ an order of magnitude more. Nominal redistribution does not play a role in these results. The results emerge with real assets only and when fixing the average inflation rate at 2 percent p.a. throughout.

Our results are, of course, neither model-free nor independent of the assumptions we make. The way in which society splits the surplus from employment matters in particular. In the baseline, the labor share falls with a move toward inflation-centric policy, a result that also emerges when we assume Nash-bargained wages. At the same time, we also showed that systematic monetary stabilization policy may be assessed more equally across the population, when wages are set to keep the labor share constant. The conundrum is that all the wage rules we look at are potential equilibrium wages. Our paper, thus, points to a need for evidence on how the valuation of assets and the labor share move with systematic monetary policy. We also discussed how the results depend on the prevailing sources of shocks and how the tax system shapes the support for an inflation-focused monetary policy. Last, we discussed that – to the extent that systematic monetary stabilization policy has a bearing on the income distribution – household portfolios can play an important role in distributing any gains and losses. The current paper certainly is not meant to be an indictment of monetary stabilization policy as it is. Rather, we hope to highlight that the choice of systematic monetary stabilization policy may not be entirely innocuous, be it for aggregate activity or the cross-section of households. We hope that future work will clarify that link and also the quantitative importance of the channels highlighted here.

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