Monetary policy and the persistent aggregate effects of wealth redistribution*

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December 13, 2023

Abstract

Monetary easing redistributes from savers, some of whom are retired and not adjusting labor supply, to borrowers who reduce their labor supply. This results in persistently lower aggregate labor and output. Hence the interaction of labor supply heterogeneity with heterogeneity in net nominal positions of households creates a monetary policy trade-off whereby short-term economic stimulus is followed by lower output over the medium term. The policy trade-off is stronger in economies with more nominal household debt and a larger wealth share of retired households but weakened by a more aggressive monetary policy stance and under price-level targeting.

Keywords: Monetary policy transmission, Monetary policy framework, Household heterogeneity, Fisher channel

JEL classifications: E21, E50.

*We thank Yuriy Gorodnichenko (editor), a very constructive associate editor Vincent Sterk and anonymous referee, Florin Bilbiie, Gino Cateau, Thibaut Duprey, Stefano Gnocchi, Xing Guo, Greg Kaplan, Katsiaryna Kartashova, Oleksiy Kryvtsov, Ralph Luetticke, James MacGee, Dmitry Matveev, Césaire Meh, Thomas Pugh, Rodrigo Sekkel, Yasuo Terajima, Carlos Van Hombeeck, Johannes Wieland and audiences at the Bank of Canada, Bank of Brazil, Czech National Bank, EEA 2020, ISCEF 2020, ESEWM 2020, CEF 2021, SED 2021, EcoMod 2021 and ESAM 2021 for helpful comments. We are indebted to Neil Maru and Ian Siqueira for research assistance. A previous version was titled *The persistent macroeconomic consequences of labor supply heterogeneity.* Emails of corresponding authors: martin.kuncl@gmail.com and alexander.ueberfeldt@bankofcanada.ca; address: Bank of Canada, 234 Wellington Street, Ottawa, ON, K1A 0G9, Canada.

1 Introduction

Household heterogeneity has important implications for the macroeconomy and the transmission of monetary policy (e.g., Kaplan et al. 2018, Auclert 2019 and Cloyne et al. 2019). Most recent work has focused on short-term implications of heterogeneity. We show that redistributive effects of aggregate shocks have medium-term aggregate consequences, due to the interaction of labor supply heterogeneity with heterogeneity in net nominal positions (NNPs) of households (nominal assets minus nominal liabilities). We build on Doepke and Schneider (2006b) and Doepke and Schneider (2006a), who find that inflation shocks in partial equilibrium (PE) can have persistent macroeconomic effects. In a general equilibrium (GE) setup, we show that the redistributive consequences of monetary policy create a trade-off between short-term and medium-term effects. The strength of this redistribution channel depends on the monetary policy stance and its framework. Our analysis proceeds in three steps.

First, we use a simple PE perpetual-youth model with incomplete financial markets, endogenous retirement and heterogeneous NNPs. We analytically show the mechanism whereby the redistributive effects of a monetary easing can result in persistently low aggregate consumption and labor supply. In the PE setting, we isolate these redistributive effects by focusing on the effects of an unexpected increase in inflation. Monetary easing redistributes wealth from savers to borrowers in nominal assets. Some of the savers are retired households, while borrowers are in the labor force. Most retirees do not adjust their labor supply, while borrowers would lower it to consume more leisure. Since unconstrained households spread their reaction over time, this asymmetry results in lower labor over the medium term. The strength of this effect increases with the wealth share of retired households. Borrowers have two margins of adjustment to shocks—consumption and leisure, but retirees use only the consumption margin and thus adjust consumption more than unconstrained borrowers. As a result, aggregate consumption also decreases over the medium term. We show that the introduction of binding borrowing constraints can increase consumption in the short term (consistent with the Fisher channel studied e.g. in Auclert 2019) but does not offset the medium-term effects. Since borrowing constraints are specified in nominal terms, constrained households cannot extract inflation-induced higher illiquid wealth for immediate consumption and have to spread their reaction over time. The presence of these persistent effects is consistent with evidence from empirical studies of persistent labor supply responses to transitory income shocks (e.g., Golosov et al. 2023, Imbens et al. 2001, Bulman et al. 2021, Cesarini et al. 2017, and Picchio et al. 2018—see Appendix A for a detailed overview) and heterogeneous household responses to monetary policy shocks (e.g. Coibion et al. 2017).

Second, we confirm the findings and show that they lead to persistent implications for output in GE. This is done in a small-scale heterogeneous agent New Keynesian model with perpetual-youth environment (Blanchard 1985 and Yaari 1965), idiosyncratic and aggregate risks, incomplete markets, endogenous retirement and indivisible collateralizable housing, which help to generate a realistic distribution of nominal debt.

We use our model to draw implications for the conduct of monetary policy. The wealth redistribution channel creates a policy trade-off: a short-term monetary stimulus of the economy is followed by persistently lower output over the medium term. The redistribution-induced negative consequences dissipate slowly, while the standard positive aggregate consequences wear off quickly.[1] This trade-off is stronger for economies with more nominal household debt. Monetary policy can reduce this trade-off by taking a more aggressive stance to inflation deviations from its target or adopting a less redistributive policy framework such as price-level targeting (PLT). In a PLT regime shocks affecting inflation are offset to bring the price level back to target. This implies that the redistributive effects from changes in the price level are counteracted. We run simulations of our model with estimated demand and supply shocks for different policy regimes and show that because PLT better stabilizes inflation than inflation targeting (IT), it reduces redistribution and thus better stabilizes output too. This provides an additional rationale for PLT's desirability, this time reliant on the presence of household heterogeneity. The wealth redistribution channel also implies that negative supply shocks can be more severe and persistent. A central bank that offsets the short-term negative impact on output at the expense of higher inflation creates additional redistribution from savers to borrowers that lowers the output over the medium term. If a

[1] Persistent effects are not permanently affecting aggregates. Due to mortality risk, the share of affected households diminishes over time.

central bank tries to bring the output back to the steady state over the medium term, it causes persistent inflation.

Finally, in an empirical section we study the heterogeneous responses of households earnings to monetary policy shocks following the approach in Coibion et al. (2017). Formalizing the characterization of winners and looser from inflation by Doepke and Schneider (2006b), we find that highly leveraged low net-worth households lower their earnings relative to high net-worth households after a monetary policy easing or after an inflation target increase. This is consistent with the heterogeneous labor responses that underpin our mechanism.

In the online appendix we include a detailed robustness section. First, we show that more restrictive borrowing constraints do not offset the medium-term aggregate effects in the GE model. Since housing is indivisible and borrowing constraints are specified in nominal terms, constrained households cannot use the full increase in home equity for immediate consumption after a monetary easing and thus spread their reaction over time, as shown in the PE section. Second, we show that the appreciation of real assets after a monetary easing does not offset our medium-term effects, because it is short lived. Third, we show that while price and wage stickiness influence the effects of monetary shocks in the short run, they do not affect the persistent medium-term implications. Finally, we show that following the global financial crisis countries with more monetary stimulus also had lower medium-term labor supply both at the extensive and intensive margins. While this result is purely suggestive, it is consistent with our redistribution channel.

Contributions to literature Our paper mainly relates to three strands of the literature. First, we contribute to the literature on the role of heterogeneity for monetary policy transmission. Recent theoretical and empirical work finds that household heterogeneity matters for the monetary policy transmission (Kaplan et al. 2018 or Cloyne et al. 2019). Several papers show the role of redistribution in the transmission of monetary policy. Auclert (2019) studies the short-term redistributive effects of monetary policy on consumption including those stemming from heterogeneity in the NNPs—the Fisher channel. In a flexible price model with money in the utility and durables, Sterk and Tenreyro (2018) show that monetary policy has aggregate effects due to redistribution from the revaluation of government debt. Similarly to ours, their model features lifecycle, retirement and labor adjustments in response to wealth redistribution. Differently from them, we study redistribution between saving and borrowing households in a New Keynesian model and show that monetary easing benefits current working households who respond by persistently reducing their labor supply.

Second, we add to the literature that studies the redistribution effects of unanticipated inflation shocks in heterogeneous household models with unhedged NNPs (Doepke and Schneider 2006b, Meh and Terajima 2011 and Adam and Zhu 2015) and show that an inflation shock can have negative and persistent aggregate implications in overlapping generations models with retirement (Doepke and Schneider 2006a and Meh et al. 2010). The latter papers analyze the effect of an unexpected one-time inflation shock in PE setups. Meh et al. (2010) find that if this shock is later reversed, as under a PLT regime, then the redistribution and its negative consequences are weaker. We contribute to this literature by showing analytically in a PE model that the medium-term aggregate implications of labor supply heterogeneity are driven by the presence of retirement interacted with occasionally binding borrowing constraints. Moreover, we study the redistribution effects of monetary and other aggregate shocks in a GE New Keynesian model.

Finally, our paper contributes to the literature that identifies intertemporal tradeoffs for monetary policy. Auclert et al. (2021) show that monetary easing in an open economy can result in current account deficits as domestic agents borrow abroad to buy imported goods, but this can restrict spending in the future as debt gets repaid. Similarly in a closed economy, Mian et al. (2021) find that monetary easing operates through an increase in debt that boosts demand in the short run but then creates drag on demand in the medium term. McKay and Wieland (2021) find that monetary stimulus increases durable goods consumption in the short run but lowers it in the medium run as the durables stock is large. Sterk (2010) shows that in a model with durables and collateral constraints monetary tightening can lead to a medium-term expansion as tighter credit constraints increase the purchases of collateralizable durables and the labor supply by borrowers. Models with mortgage refinancing (Berger et al. 2021 and Eichenbaum et al. 2022) show that monetary easing that allows mortgagors to refinance at lower rates reduces the potency of future monetary easing, since the stock of mortgagors with high rates is depleted.

The remainder of the paper is organized as follows. Section 2 presents our GE model with heterogeneous households. Section 3 shows the persistent aggregate effects of wealth redistribution analytically in a simplified PE version of the model. Section 4 discusses the calibration of the GE model. Section 5 shows that the wealth redistribution effects persist in GE and derives implications for monetary policy. Section 6 provides evidence of heterogeneity in earnings responses to monetary shocks consistent with our mechanism. Section 7 concludes.

2 Setup of the general equilibrium model

Building on the perpetual-youth environment of Blanchard (1985) and Yaari (1965), we develop a New Keynesian heterogeneous agent model. Households endogenously choose labor force participation. In particular, sufficiently rich households may retire. Households buy indivisible housing (they are renters or homeowners), that is illiquid and collateralizable. Thus households use mortgages subject to a borrowing constraint, which helps to generate a realistic nominal debt distribution. Non-trivial household heterogeneity arises due to mortality and earnings risk. Other aspects of the model are more standard: a New Keynesian framework with monopolistically competitive intermediate goods producers, price adjustment costs à la Rotemberg (1983) and monetary policy set by a Taylor rule (Taylor, 1993).

2.1 Households

The economy is populated by a continuum of households (indexed by i), which are characterized by their holdings of financial asset, $b_{i,t-1}$, and housing, $h_{i,t-1} \in \{0, 1\}$ (households are renters or homeowners), at the beginning of period t, as well as their idiosyncratic labor productivity, $z_{i,t-1}$ that was drawn at the end of the previous period.[2] An individual's state vector is given by $(b_{i,t-1}, h_{i,t-1}, z_{i,t-1})$. Therefore, the joint distribution of households

[2] This $t-1$ notation helps us to achieve consistency within the individual state vector $(b_{i,t-1}, h_{i,t-1}, z_{i,t-1})$ and thus simplifies our distributional notation $\mu_{t-1}(b, h, z)$. In terms of economic implications we are consistent with the standard incomplete markets literature by drawing the idiosyncratic productivity before individual choices in period t are made but after choices in period $t-1$.

$\mu_{t-1}(b, h, z)$ is part of the state space of the economy.

Households die with probability γ and are replaced by new households without financial assets and housing. There is a life-insurance market that redistributes wealth from recently deceased households to surviving households in proportion to their asset holdings. As a result, the return on assets of surviving households is adjusted by $1/(1-\gamma)$.

Households derive utility from consumption $c_{i,t}$, housing services $h_{i,t}$, and from leisure 1-$l_{i,t}$ (households have a unitary time endowment and work $l_{i,t}$ hours). They choose their consumption $c_{i,t}$, financial assets $b_{i,t}$, housing $h_{i,t} \in \{0, 1\}$ and labor supply $l_{i,t}$ to maximize their lifetime utility $E \sum_{t=0}^{\infty} \beta^t (1-\gamma)^t \left[u(c_{i,t}, l_{i,t}, h_{i,t}) - \xi_{i,t} \mathbf{1}_{h_{i,t} \neq h_{i,t-1}}\right]$, where $\xi_{i,t} \sim \mathcal{U}(0, \bar{\xi})$ is the realization of the idiosyncratic utility shock that captures the non-pecuniary costs of buying or selling a house.[3] The optimal individual choices can be expressed as functions of individual states, e.g. $c_t^i(b, h, z)$. The felicity function is

$$u(c_{i,t}, l_{i,t}, h_{i,t}) = \nu_t \log(c_{i,t}) + \psi \log(1 - l_{i,t}) + \phi \log(h_{i,t} + \underline{h}), \tag{1}$$

where ν_t, ψ, ϕ scale the preference for non-durable consumption, leisure and housing and ν_t is affected by a demand shock e_t^ν and follows a stochastic AR(1) process: $\log(\nu_t) = \rho^\nu \log(\nu_{t-1}) + e_t^\nu$. Also, $\underline{h}$ determines the utility of housing services to renters.

The household problem is subject to non-negative labor supply constraints, $l_{i,t} \geq 0$, the budget and borrowing constraints. The budget constraint takes the form

$$\begin{aligned} & q_t^h (h_{i,t} + \tau^H \mathbf{1}_{h_{i,t} < h_{i,t-1}} + \tau^I \mathbf{1}_{h_{i,t} > h_{i,t-1}} \mathbf{1}_{b_{i,t} < 0}) + b_{i,t} + c_{i,t} \\ & \quad \leq w_t z_{i,t-1} l_{i,t} (1 - \tau_{soc}) + \Gamma_{i,t}^U + \Gamma_t^G + \Gamma_t^F + \Gamma_t^P \\ & \qquad + \underbrace{\frac{1}{1-\gamma} \left[\left(\frac{(R_{t-1}^b + \zeta)}{\pi_t} \mathbf{1}_{b_{i,t-1} < 0} + r_t^s \mathbf{1}_{b_{i,t-1} > 0} \right) b_{i,t-1} + (1 - \delta^h) q_t^h h_{i,t-1} \right]}_{\text{Wealth}(\equiv \Psi_{i,t})}. \end{aligned} \tag{2}$$

Households receive earnings $w_t z_{i,t-1} l_{i,t} (1 - \tau_{soc})$, where w_t is the competitive real wage per unit of effective labor supply $z_{i,t-1} l_{i,t}$ and τ_{soc} is the tax rate used to finance the unemployment

[3]The introduction of $\xi_{i,t}$ shock is inspired by the literature on lumpy firm investment (Khan and Thomas, 2008) and improves the convergence of the model solution by smoothing the kink in the value function due to the discrete housing choice. See Appendix D.1 for details.

insurance. Households also receive the value of their wealth $\Psi_{i,t}(b_{i,t-1}, h_{i,t-1})$ at the beginning of the period which consists of non-depreciated housing assets $(1-\delta^h)q_t^h h_{i,t-1}$, where δ^h is the housing depreciation rate and q_t^h is the real house price, and the value of their financial assets. When households are borrowers, $b_{i,t-1} < 0$, they pay the long-term nominal gross risk-free rate R_{t-1}^b plus the constant nominal spread ζ.[4] Thus, to obtain the real gross return, we adjust the debt payment by the gross inflation rate $\pi_t \equiv P_t/P_{t-1}$, where P_t is the price level in period t. When households are savers in financial assets, $b_{i,t-1} > 0$, they hold a financial portfolio of long-term nominal bonds issued by a mutual fund and real assets, in our case direct claims on capital, k_{t-1}, with an average real portfolio return:

$$r_t^s = \frac{R_{t-1}^b}{\pi_t}(1-s_{t-1}^e) + \frac{r_t^k + (1-\delta^k)q_t^k}{q_{t-1}^k} s_{t-1}^e, \quad \text{where } s_{t-1}^e = \frac{\chi^e k_{t-1} q_{t-1}^k}{k_{t-1}q_{t-1}^k + D_{t-1}^h}. \tag{3}$$

s_{t-1}^e is the share of real assets in the portfolio of households, $D_{t-1}^h = -\int b_{i,t-1}\mathbf{1}_{b_{i,t-1}<0}di$ is the size of gross household debt in the economy, r_t^k is the rental rate of capital, q_t^k is the capital price and δ^k is the capital depreciation rate. For simplicity all savers have an equal portfolio composition. We set the fraction of capital directly owned by the household χ^e to match the share of real assets in the portfolio of retired households (see Section 4).[5] Households also receive lump-sum transfers from the government, Γ_t^G, the mutual fund, Γ_t^F, and goods producers, Γ_t^P.[6] Finally, unproductive households receive unemployment benefits conditional on the household's willingness to work if productive that are equal to a fixed fraction b^U of the average real steady-state earnings income w^*n^*: $\Gamma_{i,t}^U = b^U w^* n^* \mathbf{1}_{z_{i,t-1}=0}\mathbf{1}_{l_{i,t}(z_{i,t-1}>0)>0}$. Asterisks denote steady-state levels and $n^* = \int\int\int z_i^* l^{i*}(b,h,z)\mu^*(b,h,z)db\,dh\,dz$ is the aver-

[4] The spread between the bond borrowing and lending rate is a reduced form of capturing the market power of Canadian lenders in the mortgage market.

[5] This is a simplification in the absence of entrepreneurs in the model. Removing partial debt financing of capital would slightly lower the redistribution effects since most redistribution is due to household mortgage debt (see Figure A-15 in Appendix E). Note that households are indifferent between holding nominal and real assets in the steady state and due to our solution method for responses to aggregate shocks (first-order perturbation) aggregate risk does not affect portfolio shares.

[6] In the absence of entrepreneurs with high returns on wealth, we do not generate the far right tail of the distribution. In the real world, a large share of corporate profits is disbursed to these households. Since our channel is driven by heterogeneous labor adjustments between retirees and households in the labor force outside of this far right tail, we prefer to avoid having another layer of redistribution coming from profits, which we consider secondary, and distribute profits lump-sum. Note, that the ratio of all lump-sum transfers to other households' income in the model (17%) is close to the ratio of average transfers to households to average market income in the data (16% for 2019, Statistics Canada, Table 11-10-0190-01).

age of steady-state effective labor supply (adjusted for productivity) across the steady-state distribution of households.

Households use their resources to finance consumption $c_{i,t}$, a portfolio of financial assets $b_{i,t}$ and housing $h_{i,t}$. A housing sale is subject to pecuniary transaction costs $\tau^H q_t^h$, which capture standard real-estate agent fees and legal fees. When households purchase a house with a mortgage, they are subject to mandatory mortgage insurance costs $\tau^I q_t^h$. This insurance reflects the requirement that in Canada any mortgage with a loan-to-value (LTV) ratio above 80 per cent needs to be insured by a government-backed insurance company. Since mortgages are insured (or have a low LTV ratio) they are risk-free (or nearly risk free) from a lender's perspective, so we do not need to track the risk premium. The fees are sizable and will be lump-sum rebated via $\Gamma_{i,t}^G$ to all households.

Households are also subject to a borrowing constraint restricting the LTV ratio:

$$- b_{i,t}(R_t^b + \zeta) \leq \theta E_t h_{i,t} q_{t+1}^h \pi_{t+1}. \tag{4}$$

To capture the notion that households use fixed-term mortgages (and save in fixed-term saving instruments), the nominal interest rate R_t^b is persistent and can be expressed as

$$R_t^b = \rho^b R_{t-1}^b + (1 - \rho^b) R_t, \tag{5}$$

where R_t is the risk-free nominal rate set by the monetary authority. This restriction on interest rate adjustments captures the sluggish transmission from monetary policy to mortgage holders and bond savers, while keeping the model computationally tractable.[7]

Retirement The utility function belongs to the King-Plosser-Rebelo class of preferences. Importantly, this specification admits the possibility that households decide not to work (i.e. choose the corner $l_i = 0$ for any positive z_i level). Specifically, after paying off their mortgages, households continue to save and eventually, after their wealth reaches a certain

[7] Adding the contract duration and interest rate to the individual state would bring our model closer to the real-world problem households solve. However, this would significantly increase the dimensionality of our state space without clear benefits given the focus of the paper.

level, decide to stop supplying labor, effectively retiring.[8]

Income dynamics Earnings dynamics are driven by a Markov chain with transition probabilities, $M_{n\times n}$, between different states of labor productivity, $\bar{z} = \{z_1, .., z_n\}$. To capture unemployment, we introduce a state with $z_1 = 0$.

The optimality conditions for household choices, including the discrete housing choice $h_{i,t} \in \{0, 1\}$, are derived in the Appendix D.1.

2.2 Mutual fund

A mutual fund collects all the savings from households, lends to borrowing households, buys capital from capital producers and rents it to intermediate goods producers. The fund maximizes the net present value of its profits: $\max_{\{k_t\}} E_t \sum_{\tau=t}^{\infty} \Lambda_{t,\tau}\Gamma^F_\tau$, where the discount factor is $\Lambda_{t,\tau} = \prod_{s=t}^{\tau} \frac{\pi_{s+1}}{R^b_s}$.[9] The fund profits going to households are determined by the interest rate spread between borrowing and saving rates[10] on outstanding mortgages as well as the difference between the return to capital and the interest rate of bonds, for the share of capital funded via nominal bonds:

$$\Gamma^F_t = \frac{\zeta}{\pi_t} D^h_{t-1} + \left(\frac{r^k_t + (1-\delta^k)q^k_t}{q^k_{t-1}} - \frac{R^b_{t-1}}{\pi_t} \right) k_{t-1}q^k_{t-1}(1-\chi^e) - k_t q^k_t + \int b_{i,t} di,$$

where the last two terms cancel, since in equilibrium net savings equal the value of purchased capital, $\int b_{i,t} di = k_t q^k_t$.

[8]As Meh et al. (2010) show in Table 1, older people have positive net nominal positions across all income levels. While we do not have a large heterogeneity of wealth among retirees, we calibrate the model parameters to match the average wealth share of retirees in the population.

[9]Fund profits are distributed to households (as lump-sum transfers) and thus the fund discounts profits at the return on household savings who save in long-term bonds with nominal return R^b_t.

[10]For simplicity, we assume that the maturity of saver's bonds is equal to the maturity of mortgages, whose average term is fairly short is Canada (2.4 years). Thus the fund does not do maturity transformation. Since the 1980s, a large share of mortgage lending is securitized and thus financed by the issuance of long term bonds bought by households (Doepke and Schneider, 2006b).

2.3 Goods and capital production

Labor and capital is used in goods production, which is standard. The price setting of monopolistically competitive intermediary producers is subject to adjustment costs of price growth deviations from steady-state inflation π^* (Rotemberg, 1983) and generates a New Keynesian Phillips curve:

$$\left(\frac{\pi_t}{\pi^*}-1\right)\frac{\pi_t}{\pi^*} = E_t \frac{\Lambda_{0,t+1}}{\Lambda_{0,t}}\left(\frac{\pi_{t+1}}{\pi^*}-1\right)\frac{\pi_{t+1}}{\pi^*}\frac{y_{t+1}}{y_t} + \frac{\varepsilon}{\kappa}\left(m_t - m^*\right), \tag{6}$$

where y_t is the aggregate output, the pricing kernel is $\frac{\Lambda_{0,t+1}}{\Lambda_{0,t}} = \frac{\pi_{t+1}}{R^b_t}$, $m^* = \frac{\varepsilon-1}{\varepsilon}$ is the inverse of the optimal markup in the steady state, ε is the elasticity of substitution between goods, κ is the price adjustment cost parameter, $m_t = \frac{1}{a_t}\left(\frac{r^k_t}{\alpha}\right)^{\alpha}\left(\frac{w_t}{1-\alpha}\right)^{1-\alpha}$ is the real marginal cost, where α is the capital income share and a_t is the total factor productivity that follows a stochastic AR(1) process $\log(a_t) = \rho^a \log(a_{t-1}) + e^a_t$ affected by a productivity shock e^a_t. The profit of goods producers is distributed lump-sum to all households. Capital producers purchase goods from the final goods producers, and they convert them into investment goods subject to a quadratic adjustment cost. See Appendix D.1 for the full setup, derivations and the remaining optimality conditions.

2.4 Government policy

Monetary policy is implemented via an IT Taylor rule—the nominal interest rate is given by:

$$R_t = R_{t-1}^{\rho^R}\left(R^*\left(\frac{\pi_t}{\pi^*}\right)^{\alpha_\pi}\left(\frac{y_t}{y^*}\right)^{\alpha_y}\right)^{(1-\rho^R)}\exp(e^R_t). \tag{7}$$

Here, α_π and α_y are long-run response coefficients to inflation deviations from the central bank's inflation target π^* and the output gap, and ρ^R is a policy rate-smoothing parameter. R^* and y^* are the steady-state values of the nominal interest rate and output. The interest rate is subject to i.i.d. normal monetary policy shocks e^R_t. Fiscal policy is purely redistributive in that it collects fees (from realtors and the mortgage insurance) and taxes (unemployment insurance) and distributes all the revenue to household (via unemployment benefits and lump-sum transfers), balancing the budget each period.[11] Thus the lump-sum government transfers are: $\Gamma^G_{i,t} = \int \left(q^h_t \tau^H \mathbf{1}_{h_{i,t}<h_{i,t-1}} + q^h_t \tau^I \mathbf{1}_{h_{i,t}>h_{i,t-1}} - \Gamma^U_{i,t} + \tau_{soc} w_t z_{i,t-1} l_{i,t}\right) di$.

2.5 Market clearing conditions

There are four markets in this economy and respective clearing conditions. The consumption and investment goods market clears when $y_t \left[1 - \frac{\kappa}{2}\left(\frac{\pi_t}{\pi^*} - 1\right)^2\right] = c_t + k_t - \left(1 - \delta^k\right) k_{t-1} + \delta^h H$, where $c_t = \int c_{i,t} di$. The housing market clearing ensures that households' aggregate demand equals the exogenous fixed supply H, $\int h_{i,t} di = H$. Next, we have a capital rental market, $\int b_{i,t} di = k_t q^k_t$, and a labor market in effective hours worked, taking individual productivity levels into account, $n_t = \int z_{i,t-1} l_{i,t} di$.

3 Redistribution effects in partial equilibrium

Monetary policy in our GE model affects many prices including interest rates, price level and wages. For expositional purposes, we study the effects of an unexpected temporary increase in price inflation, which is a key force behind the persistent aggregate effects in GE. To intuitively show the redistribution channel, we first consider a simplified household problem in isolation. We analytically show that the redistribution effects of this shock persistently reduces aggregate labor and consumption due to the interaction of heterogeneity in the labor supply with heterogeneity in NNPs.

3.1 Simplified household problem

We simplify the household problem from Section 2.1 by assuming that households do not value housing, $\phi = 0$, have constant labor productivity $z_{i,t} = 1\ \forall i, t$ and their wealth is held in the form of nominal bonds, which are in zero aggregate supply at date $t = -1$, $\int b_{i,-1} di = 0$. They save or borrow at the short-term rate R_t. To retain borrowing in the model, we assume that newborn households start with negative bond holdings drawn

[11] Meh and Terajima (2011) show that an inflation shock would create a windfall for a government with large nominal debt. The presence of nominal debt, should qualitatively not affect our results, unless the resulting revenues/losses are concentrated on a particular subgroup (borrowers or savers).

from a continuous distribution with support $[\underline{b}, \overline{b}] < 0$. Finally, we abstract from taxes and lump-sum transfers and set $\nu_t = 1$.

The household problem simplifies to $\max_{\{b_{i,t}, l_{i,t}\}} E \sum_{t=0}^{\infty} \beta^t (1-\gamma)^t \left(\log(c_{i,t}) + \psi \log(1 - l_{i,t})\right)$, subject to $l_{i,t} \geq 0$ and the budget constraint $b_{i,t} + c_{i,t} \leq w_t l_{i,t} + \frac{1}{1-\gamma} \frac{R_{t-1}}{\pi_t} b_{i,t-1}$. We replace the LTV constraint with a borrowing constraint specifying a minimum debt repayment schedule in nominal terms:

$$- P_t b_{i,t} \leq \max \left\{0, -\varphi P_{t-1} b_{i,t-1}\right\}. \tag{8}$$

This is consistent with the fact that most long-term debt contracts including mortgages have repayment schedules specified in nominal terms. First-order conditions (FOCs) with respect to labor $l_{i,t}$ and bond holdings $b_{i,t}$ are

$$l_{i,t} = \max \left\{0, 1 - \frac{\psi}{w_t} c_{i,t}\right\}, \tag{9}$$

$$\frac{1}{c_{i,t}} = \beta E_t \frac{1}{c_{i,t+1}} \frac{R_t}{\pi_{t+1}} + \lambda_{i,t} - \varphi \frac{\lambda_{i,t+1}}{\pi_{t+1}}, \tag{10}$$

where $\lambda_{i,t}$ is the Lagrange multiplier associated with the borrowing constraint in period t.

3.2 Inflation shocks, redistribution and economic consequences

Consider a shock that unexpectedly increases gross inflation at $t = 0$, $d\pi_0 > 0$, and hits the economy with a continuous distribution of nominal bonds $\mu_{-1}(b)$. Inflation for $t > 0$ remains at the steady-state level $\pi_t = 1$, as do the nominal interest and wage rates for all periods t: $R_t = R^*, w_t = w^*$.

Since the expected return from savings and labor is not affected, the only direct impact of this shock is the redistribution of wealth from savers to borrowers at $t = 0$. Specifically, each household is subject to a transitory wealth shock $d\Psi_{i,0} = b_{i,-1} ds$ proportionally to the initial NNP of each household, $NNP_{i,-1} \equiv b_{i,-1}$, where $ds = -\frac{1}{1-\gamma} \frac{R^*}{\pi_0} \frac{d\pi_0}{\pi_0} < 0$.

3.2.1 Constant labor supply and no borrowing constraints

We start with the case of households that do not face binding borrowing constraints, $\varphi \to \infty$, and do not receive utility from leisure, $\psi = 0$. Hence, they supply all their time endowment as labor, $l_{i,t} = 1, \ \forall i, t$. Unconstrained households spread consumption over their lifetime according to the permanent income hypothesis and thus the intertemporal marginal propensity to consume (MPC) out of initial wealth changes is $MPC_{i,t} \equiv \frac{\partial c_{i,t}}{\partial \Psi_{i,0}} = (1-(1-\gamma)\beta)\,(\beta R^*)^t$ and grows at the rate βR^*. Since the individual MPCs are the same across households and aggregated NNPs are zero at $t = -1$, the individual consumption responses cancel in the aggregate: $dc_t = (1-\gamma)^t \int dc_{i,t} di = (1-\gamma)^t ds\, Cov(MPC_{i,t}, NNP_{i,t-1}) = 0$, where Cov denotes the cross-sectional covariance.

Lemma 1. *In an economy with constant labor supply and no borrowing constraints, inflation shocks result in persistent individual consumption responses without aggregate consequences, because* $Cov(MPC_{i,t}, NNP_{i,-1}) = 0$. *See Appendix D.3 for proof.*

3.2.2 Heterogeneous labor supply and no borrowing constraints

When households value leisure, $\psi > 0$, they adjust their labor supply based on the marginal utility of earned wages. From Equation (9), we can see that households are retired at t when $1 - \frac{\psi}{w} c_{i,t}(b_{i,-1}) < 0$. Since consumption increases in initial wealth, $\Psi_{i,0}(b_{i,-1})$, wealthier households are more likely to be retired. Consistent with the assumption that households are born with debt, we focus on the case where households accumulate wealth over time and thus their consumption increases over time, $\beta R^* > 1$. This implies that households work before retiring in period $T_i(b_{i,-1})$: $l_{i,t} > 0 \ \forall t < T_i$ and $l_{i,t} = 0 \ \forall t \geq T_i$ and richer households retire sooner $Cov(T_i, NNP_{i,-1}) < 0$.[12]

We define the intertemporal marginal propensity to earn (MPE) as the negative of the change in earnings in response to an unanticipated change in wealth, $MPE_{i,t} \equiv -w^* \frac{\partial l_{i,t}}{\partial \Psi_{i,0}}$. Households optimally allocate an increase in wealth to higher consumption and leisure over their lifetime, thus $\sum_{t=0}^{\infty} MPC_{i,t} + \sum_{t=0}^{\infty} MPE_{i,t} = 1$, which after the substitution of Equation (10) and the relationship between MPC and MPE from Equation (9), $MPE_{i,t} =$

[12]Having a continuous distribution together with analysing effects of small shocks implies that the mass of households who retire or become unconstrained because of the shock is zero. Abstracting from these households simplifies the notation.

$\mathbf{1}_{T_i>t}\psi MPC_{i,t}$, becomes

$$MPC_{i,t} = \frac{(1-(1-\gamma)\beta)(\beta R^*)^t}{1+\psi\left(1-((1-\gamma)\beta)^{max\{0,T_i\}}\right)}. \tag{11}$$

We can see that the MPC decreases in T_i. Intuitively, a household in the labor force at $t=0$, $T_i > 0$, has an additional margin of adjustment, labor, and thus adjusts consumption less than a retired household, $T_i \leq 0$, whose MPE is zero and MPC is the same as in the case with fixed labor. Moreover, the further away a household is from retirement (higher T_i), the smaller is the impact on her consumption in any given period.

Aggregate labor. Since households differ in their $MPE_{i,t}(b_{i,-1}) = \mathbf{1}_{T_i>t}\psi MPC_{i,t}(b_{i,-1})$, their labor responses do not necessarily cancel in the aggregate:

$$dl_t = (1-\gamma)^t \int dl_{i,t}di = -\frac{(1-\gamma)^t}{w^*}\underbrace{ds}_{<0} Cov(MPE_{i,t}, NNP_{i,-1}).$$

Thus aggregate labor declines $dl_t < 0$, if $Cov(MPE_{i,t}, NNP_{i,-1}) < 0$. Since wealthier household are more likely to be retired and thus to have an MPE of zero, this condition is satisfied, if the initial NNP of households who are retired at t, $\int \mathbf{1}_{T_i\leq t}NNP_{i,-1}di$, is sufficiently large:

$$\int \mathbf{1}_{T_i\leq t}NNP_{i,-1}di > \frac{Cov(\mathbf{1}_{T_i>t}MPE_{i,t}, \mathbf{1}_{T_i>t}NNP_{i,-1})}{\int \mathbf{1}_{T_i>t}MPE_{i,t}di}, \tag{12}$$

where the MPE of households in the labor force is increasing in the NNP:
$Cov(\mathbf{1}_{T_i>t}MPE_{i,t}, \mathbf{1}_{T_i>t}NNP_{i,-1}) > 0$. Intuitively, poorer household work longer before retiring, spread labor adjustment over a longer period and thus have lower MPEs in any given period while in the labor force. The condition (12) suggests that the persistent negative effects of monetary easing on labor supply is more likely in economies with a larger share of retired households for instance due to population ageing.

Note that in the absence of retirement in equilibrium, $T_i \to \infty\ \forall i$, the individual persistent adjustments of labor and consumption cancel in the aggregate because households have equal $MPC_{i,t} = \frac{(1-(1-\gamma)\beta)(\beta R^*)^t}{1+\psi}\ \forall i$, and $MPE_{i,t} = \psi\frac{(1-(1-\gamma)\beta)(\beta R^*)^t}{1+\psi}\ \forall i$.

Aggregate consumption. Since the MPC decreases in the retirement time T_i and

$Cov(T_i, NNP_{i,-1}) < 0$, the aggregate consumption decreases for all $t \geq 0$:

$$dc_t = (1-\gamma)^t \int dc_{i,t} di = (1-\gamma)^t \underbrace{ds}_{<0} \underbrace{Cov(MPC_{i,t}, NNP_{i,-1})}_{>0} < 0.$$

The negative effect of redistribution on consumption is not consistent with the short-run Fisher channel studied e.g. in Auclert (2019), thus in the next section we introduce binding borrowing constraints to reconcile those results.[13]

Both aggregate consumption and labor effects dissipate in the long run as the households affected by monetary easing are replaced by new households.

Proposition 1. *In an economy with heterogeneous labor supply, retirement and no borrowing constraints, inflation shocks have persistent individual and aggregate consumption and labor effects. A positive inflation shock persistently decreases aggregate consumption, since* $Cov(MPC_{i,t}, NNP_{i,-1}) > 0 \; \forall t \geq 0$*, and labor supply, if* $Cov(MPE_{i,t}, NNP_{i,-1}) < 0$*, which is satisfied if the wealth share of retired households is sufficiently high (condition 12). These effects dissipate in the long run. See Appendix D.4 for proof.*

3.2.3 Binding borrowing constraints

Constant labor supply We first study the impact of binding borrowing constraints in the absence of heterogeneous labor supply, $\psi = 0$. When $\varphi < \beta R^*$, borrowing households with high debt, $-\frac{b_{i,t-1}}{\pi_t} > -\tilde{b} > 0$, are constrained and their consumption is determined by their current cash-flows, instead of being an optimal fraction of their wealth:

$$c_{i,t} = w^* - \underbrace{\left(\frac{R^*}{1-\gamma} - 1\right)\frac{-b_{i,t-1}}{\pi_t}}_{\text{Interest payment}} - \underbrace{(1-\varphi)\frac{-b_{i,t-1}}{\pi_t}}_{\text{Min. principal repayment}} = w^* + \left(1 - \varphi\frac{(1-\gamma)}{R^*}\right)\underbrace{\frac{R^*}{1-\gamma}\frac{b_{i,t-1}}{\pi_t}}_{\Psi_{i,t}}. \tag{13}$$

[13] Another way to get a positive effect of unexpected inflation on consumption is the introduction of bequests, see Appendix D.7. This however strengthens the negative response of aggregate labor in response to higher inflation. Note also that in a realistic OLG model, older households would have a shorter expected lifetime unlike in our stylized perpetual-youth model. Thus older households might have higher MPCs than unconstrained young households, since they spread their response over a shorter period. This would be an alternative reason for positive $Cov(T_i, NNP_{i,-1})$ which would tend to offset the bequest motive.

Thus the MPC of a constrained household out of a change in illiquid wealth is

$$MPC_{i,t} \mid_{\frac{b_{i,t-1}}{\pi_t} < \tilde{b}} = \left(1 - \varphi \frac{1-\gamma}{R^*}\right) \varphi^t. \tag{14}$$

The MPC of constrained households evolves over time by the factor φ as this is the rate at which nominal debt is repaid. Thus, while constrained households benefit from higher inflation as their real debt is reduced, they cannot use all this increase in wealth for immediate consumption because the borrowing constraint is in nominal terms and thus they need to keep their debt at the new lower level, $d(-b_{i,0}) = \varphi \frac{b_{i,-1}}{\pi_0} \frac{d\pi_0}{\pi_0} < 0$. Instead their consumption increases are spread over time due to persistently lower real debt payments.

Since $\varphi < \beta R^*$, the MPC of constrained households is higher than the MPC of unconstrained households for $t < \tilde{t}$ and lower afterwards. This implies that aggregate consumption increases in the early periods after the shock consistently with the short-term Fisher channel but is negative afterwards.

Proposition 2. *In an economy with binding nominal borrowing constraints, $\varphi < \beta R^*$, and fixed labor supply, a positive inflation shock increases consumption in the short run $t < \tilde{t}$, since $Cov(MPC_{i,t}, NNP_{i,-1}) < 0 \; \forall t < \tilde{t}$ and decreases it in the medium run, since $Cov(MPC_{i,t}, NNP_{i,-1}) > 0 \; \forall t > \tilde{t}$. See Appendix D.5 for proof and definition of $\tilde{t}$ and $\tilde{b}$.*

Note that the MPC out of illiquid wealth is different from the MPC out of transitory income which is the subject of most empirical studies. To see that consider an unexpected shock to the wage rate at $t = 0$, $dw_0 > 0$. From the budget constraint of debt-constrained households (13) we can see that all this income would be consumed on impact, $MPC^w_{i,t} \equiv \frac{\partial c_{i,t}}{\partial w_0} = 1$ for $t = 0$, with no effects in later periods, $MPC^w_{i,t} = 0 \; \forall t > 0$.

Heterogeneous labor supply. We see two channels through which redistributive shocks have aggregate consequences: heterogeneous labor supply and binding borrowing constraints.

Proposition 3. *In an economy with heterogeneous labor supply and binding borrowing constraints, a positive inflation shock*

1. *decreases **aggregate consumption** over the medium term. The effect in the short*

term depends on the NNPs of constrained households, which increases aggregate consumption and the proportion of retired households, which decreases it.

2. *decrease* ***aggregate labor supply*** *in the short term. The effect in the medium term depends on the NNPs of retired households, which reduces it, and the proportion of constrained households, which tends to increase it.*

See Appendix D.5 for proof.

The degree to which the channels offset each other is low relative to a shock that would affect households' income, because higher inflation increases the illiquid wealth of constrained households, and thus both constrained and unconstrained households spread their reaction over time.

4 Calibration, estimation and model fit

To conduct quantitative analysis, we calibrate the GE model to match key characteristics of the Canadian economy in the steady state and then estimate the parameters for the aggregate shock processes. Given the nature of the model, we use a combination of quarterly aggregate data, household-level survey data and insights from the related literature. The calibrated and estimated parameters are in Table 1. For more detailed information please see Appendix C, which also compares the model MPEs and MPCs to those found in empirical literature. The comparison crucially shows that the size and persistence of the labor reaction to income shocks in the model matches empirical estimates.

5 Main general equilibrium results

In this section, we show that the wealth redistribution channel as outlined above in a PE setup carries over to a GE model version. In particular, the wealth redistribution effect creates a trade-off for monetary policy: a short-term stimulus implies a costly reduction of output over the medium term. Taking this logic further, we consider the trade-off under different monetary policy regimes and assess the implications for stabilizing the economy.

Table 1: A. Basic Parameters

		Value	Rationale
Inflation target (gross, qtr.)	π^*	1.005	2% inflation target
Taylor rule - inflation	α_π	2.5	Alpanda et al. (2018)
- output gap	α_y	0	Alpanda et al. (2018)
Probability of dying	γ	$\frac{1}{57*4}$	Life expectancy of 57y (at 25y)
Demand elasticity	ε	10	Markup on prices 10%
Price adjustment cost param.	κ	100	Slope of the Phillips curve
Capital income share	α	0.33	Literature
Capital adjustment cost param.	κ^k	2.6	Alpanda et al. (2018)
Capital depreciation	δ^k	0.025	Smets-Wouters (2007)
Housing stock depreciation	δ^h	$1-(1-0.015)^{1/4}$	Kostenbauer (2001)
Capital share financed by equity	χ^e	0.52	Portfolio share of real assets among retired of 70% (SFS)
Taxation for unempl. insur.	τ_{soc}	0.039	Government of Canada
Unempl. benefits (share of w^*l^*)	b^U	0.55	Government of Canada
Mortgage insurance fee	τ^I	0.0078	CMHC
Housing transaction fee	τ^H	0.05	Standard realtor fee of 5%
Loan-to-value constraint	θ	0.95	OSFI (5% min. downpayment)
Housing services of renters	$\underline{h}$	0.05	Normalized
Interest rate spread	ζ	0.0039	5y fixed mortgage to 5y GIC spread
Persistence of mortgage rate	ρ^b	0.90	Average mortgage term 2.4y
Idiosyncratic income state	(z)	$(0,1)$	Unemployed / Employed
Idiosyncratic income trans.	$M_{z',z}$	$\begin{pmatrix} 0.48 & 0.52 \\ 0.03 & 0.97 \end{pmatrix}$	Estimates based on state durations

B. Calibrated parameters

		Value
Discount factor	β	0.9905
Disutility of labor	ψ	2.0809
Utility from housing	ϕ	1.1683
House price	q^{h*}	41.3354

C. Moments

	Data	Model
Wealth share of retired households	0.29	0.29
Average LTV of mortgagors	0.51	0.51
Debt to net worth	0.20	0.19
Average hours of the employed (%)	38.5	38.4

D. Estimated shock processes

		Prior distribution			Posterior distribution	
		Distr.	Mean	St.Dev	Mode	Mean
TFP shock e_t^a	ρ^a	Beta	0.75	0.1	0.71	0.72
	σ^a	Invgamma	0.009	2	0.0056	0.0057
Demand shock e_t^ν	ρ^ν	Beta	0.8	0.1	0.89	0.89
	σ^ν	Invgamma	0.004	2	0.0057	0.0058
Monetary policy shock e_t^R	ρ^r	Beta	0.65	0.1	0.86	0.88
	σ^r	Invgamma	0.004	2	0.0022	0.0022

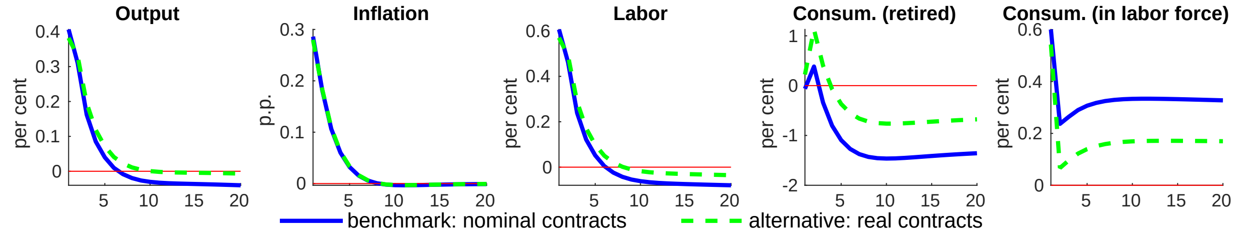
5.1 The wealth redistribution channel

5.1.1 Redistribution effects of a monetary easing shock

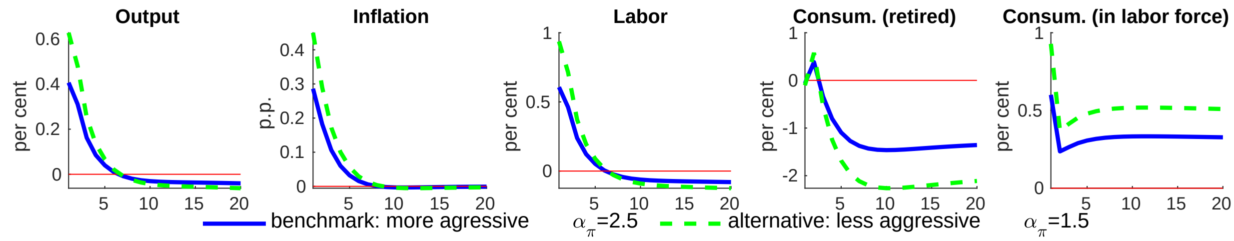
In response to a 25 bps monetary easing shock, output, labor and inflation increase in the short run, Figure 1 (Panel a, solid blue line), similar to what happens in a representative-agent New Keynesian (RANK) model. However, our model generates persistent negative responses of labor and output over the medium term. This is consistent with the results we previously highlighted in the PE analysis. The size of the persistent effect on output might appear small in contrast to the output deviation from steady state on impact. But the persistent nature of the effect imply a substantial cumulative reduction of 1.46 p.p. of quarterly output over 10 years, which is more than the output increase of 0.4 p.p. on impact.

To understand the forces behind the medium-term effect, we take a closer look at the consequences of the monetary easing shock for the wealth distribution. On impact the shock redistributes wealth from savers to borrowers, and the persistent nature of this redistribution effect is due to the slow-moving household wealth distribution. Figure 2 shows the effect of monetary easing on the wealth distribution (probability density function over Ψ) of borrowers (indebted homeowners) on impact, $t = 1$, in periods 10 and 20, respectively. Transforming the household distribution $\mu_t(b, h, z)$ to a distribution $\tilde{\mu}_t(\Psi(b, h), h, z)$ and then plotting it over $\Psi_{i,t}(b_{i,t-1}, h_{i,t-1})$ conditional on $h_{i,t-1} = 1$ and integrating over $z_{i,t-1}$ simplifies the illustration and reflects the effect of prices at t on wealth $\Psi_{i,t}$. The shock shifts the wealth distribution of borrowers to the right (left panel in Figure 2), which reflects the positive wealth transfer to borrowers proportional to the size of their nominal debt. For better visibility, we report distribution change (deviation from steady state) in the second panel in Figure 2.[14] Crucially for the aggregate response, this change in the distribution is very persistent. The unconstrained homeowners use the extra wealth to repay part of their mortgage, and thus the changes in the distribution slowly move toward higher wealth as affected households continue to accumulate wealth along their life-cycle path. The changes also become more dispersed over time due to idiosyncratic shocks. In the long run, the distribution will return to its steady state as affected households die and are replaced by

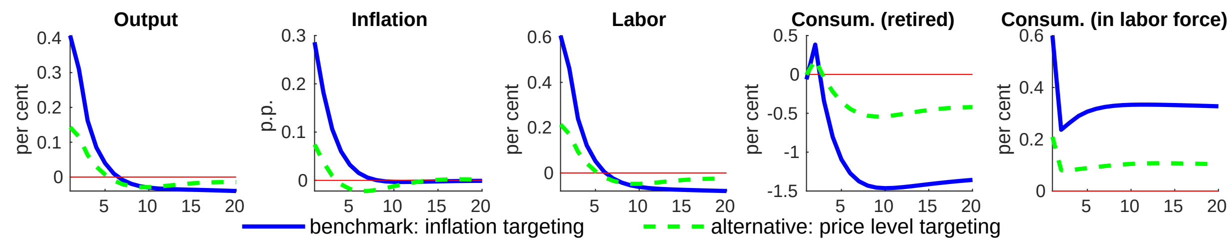
[14]Note that the shift to the right in the distribution implies less mass where the steady-state distribution is increasing and more mass where the steady-state distribution is decreasing.



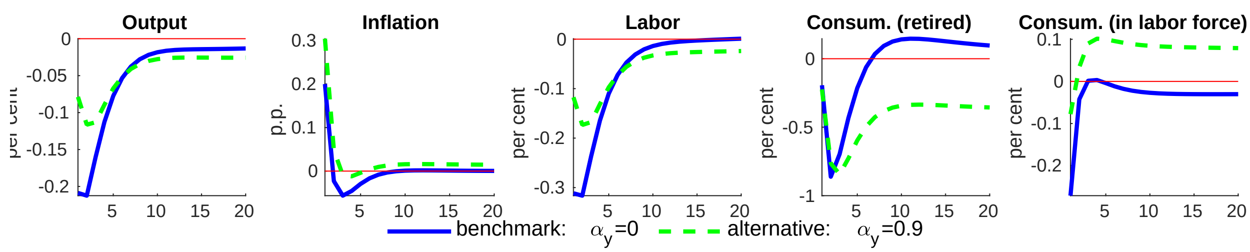
(a) Monetary easing: Models with and without nominal debt



(b) Monetary easing: Effect of more aggressive policy



(c) Monetary easing: Comparison of monetary policy regimes



(d) Markup shock: Comparison of monetary policy regimes

Figure 1: Responses to aggregate shocks. Panels (a-c) show responses to a 25 bps monetary easing. Panel (a) shows that both models with and without nominal debt have similar short-term responses but only the model with nominal debt shows persistent medium-term effects. Panel (b) shows that policy reacting more aggressively to inflation deviations stabilized the economy more in both the short and medium terms as it implies lower redistribution across households. Panel (c) shows that the PLT regime stabilizes the economy more in both short and medium terms and implies less redistribution. Panel (d) reports responses to a markup shock and shows that a more output-stabilizing policy redistributes more with medium-term consequences for inflation and output.

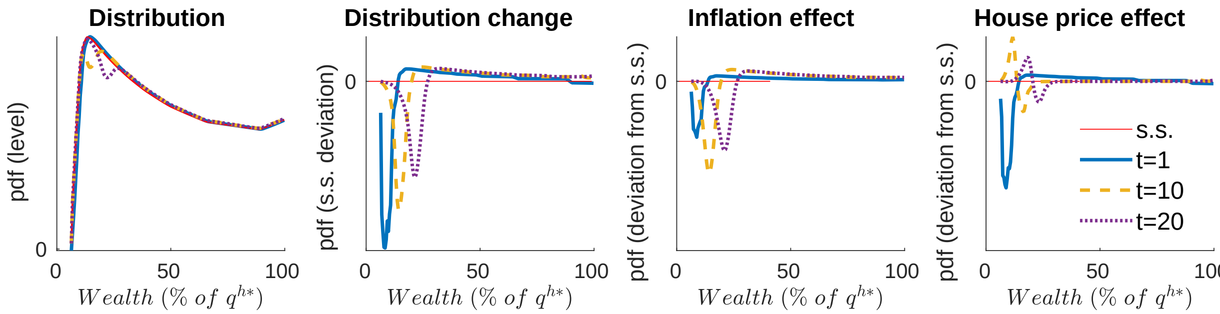


Figure 2: The effects of monetary policy easing on the wealth distribution dissipate slowly and are driven mainly by higher inflation. Left panel shows the evolution of the wealth distribution of indebted homeowners, $h_{i,t-1} = 1$, aggregated over $z_{i,t-1}$. Here we plot the transformed distribution $\int \tilde{\mu}_t(\Psi(b, h = 1), h = 1, z)\, dz$ substituting wealth for financial assets. The next panel shows the deviation of this distribution from the steady state in levels, $\int \hat{\tilde{\mu}}_t(\Psi(b, h = 1), h = 1, z)\, dz = \int \tilde{\mu}_t(\Psi(b, h = 1), h = 1, z)\, dz - \int \tilde{\mu}^*(\Psi(b, h = 1), h = 1, z)\, dz$. The two right panels isolate direct impacts of inflation and house price on the distribution deviation from its steady state.

new households.

To highlight the importance of the distribution, we show that consumption and labor supply of borrowers conditional on their idiosyncratic state, $c_t^i(b, h, z)$ and $l_t^i(b, h, z)$, respond only in the short run (Figure A-10 in Appendix E). So, monetary policy persistently changes the wealth distribution, but has only temporary effects on an individual's behavior conditional on their economic circumstances staying the same.

Next, we decompose the changes in the wealth distribution into cumulative direct effects of changes in prices (final goods prices, house prices, wages and nominal interest rates) and cumulative effects of households' changes in consumption and labor supply. We find that the increase in inflation is the most significant factor in terms of size and persistence. The induced house price increase also has a large impact on the wealth distribution, but it is only temporary. Twenty quarters after the monetary easing, we can still see a significant shift in the wealth distribution of borrowers due to higher inflation, but the most striking effect of the higher house prices is the lower wealth of households who bought the house at the time of the monetary easing (third and fourth panels of Figure 2). The remaining factors, including the change in labor income and the increase in consumption, have much smaller effects on the wealth distribution, as shown in Figure 4 (left panel).

5.1.2 Decomposing the distribution effects

Following our PE analysis, the aggregate consequences of the distribution effect is easiest to explain by focusing on the responses of two endogenous household groups: households in the labor force and retired households that stopped working and live off their savings. We aggregate consumption across individuals within these groups and report them in Figure 3. Moreover, to isolate the redistributive effects, we decompose the variable responses into two components: the *standard effect* captures changes in household choices for a fixed distribution and reflects e.g. the intertemporal substitution channel, while the *distribution effect* keeps household choices fixed conditional on their state and thus isolates the effect of changes of the distribution. An exact formula for this decomposition is in Appendix D.6.

The standard effect dominates in the short run and wears off quickly, consistent with canonical New Keynesian models (Figure 3).[15] In the absence of the distribution effect, consumption of both households and labor supply increase in the short term due to the standard intertemporal effect of lower interest rates and higher wages.

The distribution effect, on the other hand, is very persistent and dominates over the medium term, pulling output and labor supply down. This persistence is mainly driven by higher inflation, Figure 4(a). Following the monetary easing shock, households in the labor force who are on average net borrowers become richer as their nominal debt is devalued in real terms. When unconstrained, they increase their future path of consumption and of leisure. This leads to persistently lower aggregate labor. In contrast, retired households see their saving in nominal assets devalued by inflation and become poorer. In response, most retired households do not adjust labor supply[16] and adjust their consumption profile down more in absolute terms than unconstrained households in the labor force. As a result, the aggregate consumption declines over the medium term. The persistent labor and consumption declines imply a reduction of aggregate output over the medium term, Figure 3.

Hence, we find a monetary policy trade-off whereby an easing shock stimulates output

[15] Note that there is a small positive persistent effect on labor and output in the standard component. This is due to (i) capital adjustment costs leading to a slowly changing capital stock and importantly (ii) the feedback of distribution effects on prices in the GE setup. Persistently lower labor puts upward pressure on wages, which tends to increase the standard component of labor supply.

[16] Some retired households return temporarily to the labor force.

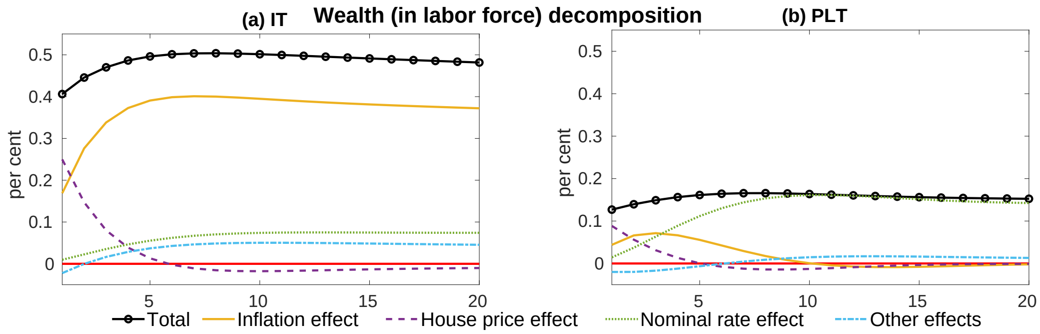


Figure 3: Decomposition of responses to monetary easing into distribution and standard effects. While the standard effect wears off quickly (light green line for model without distribution effects), the distribution effect is very persistent.

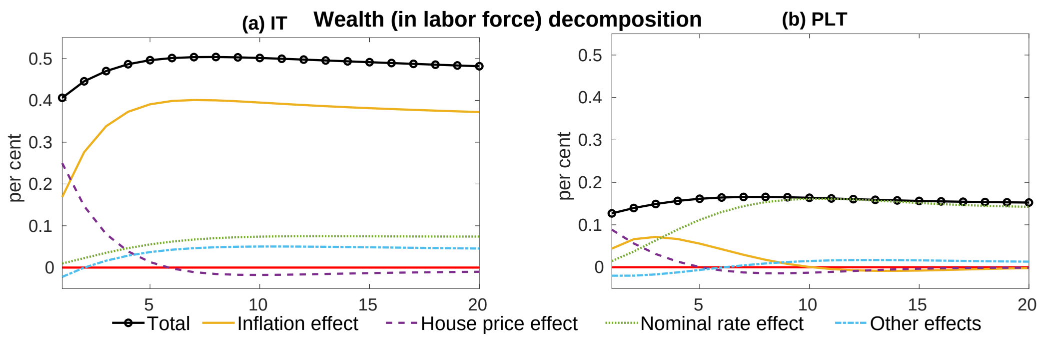


Figure 4: Decomposition of wealth response to monetary easing for households in the labor force under IT and PLT, respectively. Under IT regime the cumulative inflation response is the main driver of the persistent wealth effect. Under PLT regime the cumulative inflation response is offset, and the main driver of the persistent wealth effect are cumulative changes in nominal rates.

in the short term at the cost of persistently lowering it over the medium term. The persistently depressed output corresponds to lower potential, since an economy with flexible prices features a similar drop in output in the medium term (see Figure A-4 in Appendix E).

5.1.3 Importance of nominal debt

To shed more light on the mechanism, we show that the presence of nominal debt is crucial. We compare responses to monetary easing in our benchmark economy to an economy that differs only by mortgage contracts being specified in real terms (i.e. mortgage interest rate is predetermined in real terms and thus is not affected by inflation surprises) and households own all firms' capital directly through equity; see Figure 1, (Panel (a), dashed green line). The short-run aggregate responses are similar, but the model with real contracts does not generate sizeable medium-term output deviations from the steady state. This is consistent with the finding that the redistributive effects are mainly driven by inflation.

5.2 Policy implications

Next, we investigate the implication of the policy trade-off for the conduct of monetary policy. First, we find that the redistribution channel worsens the monetary policy trade-off after negative supply shocks. Second, we find that history-dependent regimes such as PLT imply less redistribution and a weaker trade-off than inflation targeting (IT).

5.2.1 Stabilization after demand and supply shocks

In the case of demand shocks, a more aggressive policy stance to inflation deviations from the target (higher α_π) lowers the volatility of the macroeconomy (both output and inflation) as in RANK models. It also lowers the redistribution and weakens its persistent medium-term effects; see Figure 1, Panel (b).

In contrast, supply shocks create an environment in which monetary policy faces a trade-off between stabilizing inflation and output. This trade-off becomes more severe and lasts longer in the presence of the wealth redistribution channel.

Consider a markup shock that increases inflation by 20 bps in the benchmark model, Figure 1, panel (d). We compare the economic response in an economy with a pure inflation targeting central bank (our benchmark) which does not put any weight on output stabilization ($\alpha_y = 0$), to that in an economy with a dual mandate central bank that aims to stabilize inflation and output ($\alpha_y = 0.9$). A pure inflation targeter accepts the higher output loss to bring inflation quickly back to the target with a short overshoot, and thus limits the price level impact and related redistribution effects. The dual mandate central bank in contrast limits the impact of the shock on output in the short run by stimulating the economy at the expense of higher inflation. Higher inflation and lower interest rates imply larger wealth redistribution from savers to borrowers, creating additional costs in the form of lower output over the medium term. If the central bank tries to bring the output back to steady state (as in this case), it causes persistently higher inflation over the medium term.

To show that redistribution effects due to nominal contracts are responsible for these medium-term effects, we compare the impulse responses under the dual mandate central bank to the comparable economy but with real contracts as in Section 5.1.3, see Figure A-11 in Appendix E. When contracts are real the redistribution part due to inflation is eliminated and output and inflation converge to the steady state in the medium term.

5.2.2 The distributive consequences of different monetary policy regimes

To study the role of the alternative monetary policy frameworks, we compare the impulse response to a monetary policy easing under IT and under PLT; Figure 1, Panel (c). The policy rule under PLT is given by $R_t = R_{t-1}^{\rho^R} \left(R^* \left(\frac{P_t}{P^*} \right)^{\alpha_\pi} \left(\frac{y_t}{y^*} \right)^{\alpha_y} \right)^{1-\rho^R} \exp(e_t^R)$. PLT is associated with less deviations from steady state of aggregate output and labor in the short term as well as in the medium term. The latter is due to weaker redistribution effects measured by consumption deviations of both household subgroups: households in the labor force and retired households.

To understand why this is the case, recall that PLT is history dependent (bygones aren't bygones). Under PLT an initial increase of inflation after a monetary policy easing will be offset with inflation below the steady state, so that the price level returns to its steady state (see illustration in Figure A-12 Appendix E). In contrast, under IT the inflation converges monotonically to the steady state, and the price level permanently increases. Note that the redistribution depends not only on initial impact on the inflation but on the whole evolution of the price level, whose expectations then affect the present value of nominal assets through their effect on the nominal term structure. Under PLT the firm-expectation channel reduces the initial impact of the shock on inflation. Forward-looking firms expect the price level to return to steady state, and thus increase prices less in response to the shock (see expectation channel in Dittmar and Gavin 2000). Later the period of higher-than-steady-state inflation is followed by a period of lower-than-steady-state inflation so that the price level returns to target. Since the effect on the price level is completely offset, the redistribution is strongly reduced. When we decompose the changes in the wealth distribution of monetary easing under PLT, we find that the cumulative effect of inflation has no persistent effect on the distribution because the shocks to inflation are offset as the economy converges back to the same price level. Therefore, redistribution is smaller under PLT. The driving force behind the persistent change in wealth under PLT is the cumulative effect of nominal rate changes, which are larger under PLT. This is because the smaller increase in inflation triggers a weaker systematic policy response that tends to increase nominal rates and thus offsets less the initial monetary easing shock under PLT, Figure 4, Panel (b).

For additional analysis of the role of distributive effects across various monetary policy regimes see Appendix B.4. There we highlight the role of expectations and the GE setup under IT and PLT. We also run simulations of our model with estimated demand and supply shocks under IT, average inflation targeting (AIT) and PLT. Since PLT better stabilizes inflation, it reduces redistribution and thus better stabilizes output too.

6 Heterogeneous earnings responses to monetary shocks

The redistributive effects in this model rely on heterogeneous responses of labor supply across households to monetary policy (MP) shocks. To empirically support this, we show that MP shocks lead to heterogeneous earnings responses that are consistent with the wealth redistribution channel. Our approach builds on Coibion et al. (2017) who provide evidence of wealth redistribution between borrowers and savers in their Section 4.3., including evidence for the differential responses of labor earnings. The statistical significance of the latter over the medium term is weak. We build on their work by conditioning on the size of debt leverage and considering alternative shocks to achieve a stronger economic focus and improve the significance of the results.

We use CEX data for the U.S., due to a lack of quarterly data for Canada with similar information on earnings and other income and expenditures. The focus is on earnings, since we cannot identify labor supply responses in the data.[17] Similarly to Coibion et al. (2017), we define household groups following the characterization in Doepke and Schneider (2006b). They argue that the main losers from inflation are "rich, old households" and the main winners are "young, middle-class households with fixed-rate mortgage debt". We thus define

[17] While earnings are an imperfect approximating for labor supply responses, at least in the short-term most of the earnings responses should come via labor supply, since wages and salaries react with a delay.

three groups of households: 1) high net-worth (NW) households are aged 55-65 years white households with a male head in the household and no mortgage payments; 2) high leverage low NW households are aged 30-40 years-old white households with a male head in the household and mortgage payments representing more than 30% of their total expenses; 3) low leverage low NW households are the same as group 2 except their mortgage payments represent less than 30% of their total expenses but are positive.[18]

To characterize the effects of MP on earnings, we take two approaches. First, we use MP shocks identified in Romer and Romer (2004) in the updated and extended version by Coibion et al. (2017). Second, following Coibion et al. (2017, Section 5), we also use a narrower but more persistent measure of MP action: changes in the Federal Reserve's target rate of inflation. We use two estimates of this measure based on Coibion and Gorodnichenko (2011) and Ireland (2007).

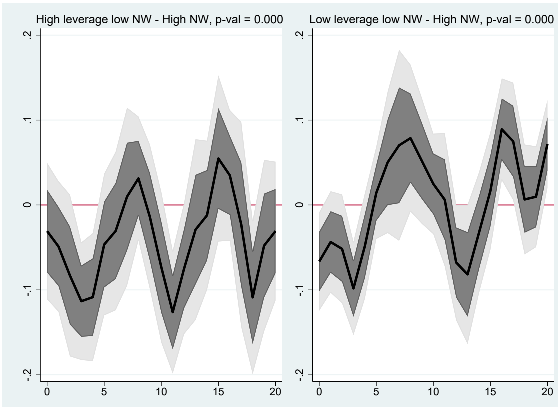
For each set of households, we compute mean (log) earnings and take the difference between different household groups. We then follow Jordà (2005) to estimate the responses to MP shocks at different time horizons h using the local projection methods over the period 1980q3—2008q4 exactly as in Coibion et al. (2017)

$$x_{t+h} - x_{t+h-1} = c^{(h)} + \sum_{j=1}^{J} \alpha_j^{(h)} \left(x_{t-j} - x_{t-j-1}\right) + \sum_{i=0}^{I} \beta_i^{(h)} e_{t-i} + \epsilon_{t+h}, \ \ \forall h = \{0, H\},$$

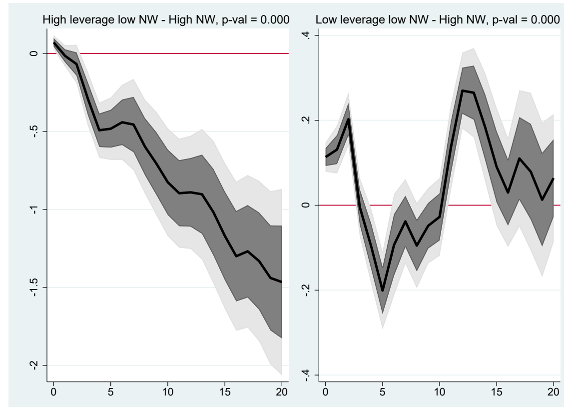
where x_{t+h} is difference in log mean earnings of specified groups of households, e_t are quarterly monetary policy innovations and $H = 20$, $J = 2$, $I = 20$.

The results, plotted in Figure 5, are consistent with the heterogeneous responses to the redistribution effect of MP shocks. In response to an *easing* Romer and Romer (2004) shock, high leverage low NW households reduce their earnings relative to high NW households, consistent with the theoretic implications of wealth redistribution from savers to borrowers (Panel (a) in Figure 5). The difference in earnings responses between the low leverage low

[18] Our groups differ from the ones in Coibion et al. (2017) by accounting for the relative size of mortgage payments. Coibion et al. (2017) have one group of low NW household who need to have simply positive mortgage payments. Unlike Coibion et al. (2017), we also do not condition on financial income to be positive or zero, since we consider this survey variable to be too coarse and merely limiting the number of households in the groups. But consistent with Coibion et al. (2017) low NW households need to have positive mortgage payments and we focus on white households. In Appendix E in Figure A-16 and in Figure A-17 we show that the results qualitatively hold for non-white households and for all households combined.



(a) Earnings response to 1 p.p. easing monetary policy shock



(b) Earnings response to 1 p.p. increase in inflation target

Figure 5: Difference in mean of log earnings responses between high leverage low net-worth households (low leverage low net-worth) and high net-worth households (respectively). Panel (a) uses Romer and Romer (2004) MP shocks and panel (b) uses inflation target shocks from Coibion and Gorodnichenko (2011). Horizontal axis is time in quarters. Dark and light grey areas represent confidence intervals of one and 1.65 standard deviations, respectively. Reported p-val are for the null hypothesis that the impulse response is zero for every quarter plotted.

NW and high NW households is significantly different from zero but the effects seem to be more short-lived with alternating signs. The fact that we find more evidence consistent with the wealth redistribution channel for high leverage low NW households can be explained by those seeing a bigger increase in wealth due to their larger debt positions relative to total expenses. Similarly, in response to an increase in the inflation target only the high leverage low NW households respond by consistently lowering their earnings relative to high NW households. This effect is highly significant and persistent (Panel (b) in Figure 5). The responses to target inflation shocks from Ireland (2007) are qualitatively similar to Coibion and Gorodnichenko (2011). We report them in Appendix E in Figure A-18.

7 Conclusion

Using a partial-equilibrium framework, we establish that heterogeneity in net nominal positions together with labor supply heterogeneity, especially retirement, implies that an unexpected increase in inflation lowers aggregate consumption and labor due to wealth redistribution from savers to borrowers. This insight is robust to the inclusion of binding borrowing constraints and carries over to an estimated heterogeneous agent DSGE model. In the general-equilibrium model, the wealth redistribution creates a trade-off for monetary policy: a short-term stimulus has medium-term output costs. This trade-off is smaller for less redistributive policy frameworks such as price-level targeting but bigger in economies with larger amounts of nominal debt and larger shares of wealth controlled by the retired population. This suggests that higher household indebtedness and population ageing would increase the relevance of the trade-off.

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Appendix

A Empirical evidence on persistent effects of shocks

While we are the first to highlight the endogenous labor force participation channel in a heterogeneous agent New Keynesian model, various microdata-based studies of household behavior have found persistent responses to unanticipated income shocks. Golosov et al. (2023) and Bulman et al. (2021) for the U.S., Imbens et al. (2001) for Massachusetts, Cesarini et al. (2017) for Sweden, and Picchio et al. (2018) for the Netherlands, analyze the consequences of (small) one-time lottery earnings using administrative data or survey data in the case of Imbens et al. (2001).[19] All studies document that households respond to an income shock by persistently reducing labor earnings with a constant or increasing effect over the whole studied period, which is 5 years in Golosov et al. (2023) and Bulman et al. (2021), 10 years in Cesarini et al. (2017) and 3 years in Picchio et al. (2018). Golosov et al. (2023) and Cesarini et al. (2017) also show that the effect is driven both by persistent adjustments of hours worked (intensive margin) and exits from the labor force participation especially for older households (extensive margin). These results are consistent with the smoothing of consumption and labor responses over the lifecycle, which is a feature of our model. There is some heterogeneity among these studies in terms of the size of earnings responses. We discuss this in Section C.3 on marginal propensities to earn (MPE), where we show that our model results are also quantitatively within the range implied by these studies.

There is further work on the impact of wealth changes on labor supply. Consistent with our mechanism, the general takeaway from these studies is that labor supply falls when wealth increases. Specifically, Algan et al. (2003) exploit panel data, Brown et al. (2010) and Kindermann et al. (2020) use data on inheritances, Benson and French (2011) and Daly et al. (2009) focus on changes in asset prices, with Disney and Gathergood (2018) exploring house price changes.

Also, related to our results, older Dutch households, according to Christelis et al. (2017), have a higher consumption response than younger ones, while Jappelli and Pistaferri (2014) find mixed results regarding age for Italy.

B Robustness checks

In this section, we assess key model features and how they influence the redistribution channel and its persistent medium-term implications. First, we evaluate the impact of restricting homeowners' access to credit. Second, we consider the importance of real asset price adjustments and, third, the importance of price and wage stickiness. Finally, we compare the model's medium-term implications to correlations obtained from cross-country data.

[19] Specificity of lottery winnings analyzed by Imbens et al. (2001) is that they are paid out over 20 years.

B.1 Binding refinancing constraints in general equilibrium

The benchmark GE model already includes borrowing constraints: renters cannot borrow, and homeowners have to satisfy the LTV constraint. However, conditional on satisfying the LTV constraint, households can access home equity freely, which would correspond to a generous availability of home equity lines of credit. This source of short-term liquidity is missing in some papers that stress the crucial role of borrowing constraints (e.g., Kaplan et al. 2018). Thus in this extension we analyze the effects of additional refinancing constraint. Using a PE setup in Section 3.2.3, we show that when the refinancing constraint is specified in nominal terms as mortgages typically are, then the response of constrained households to higher inflation, that lowers the real value of outstanding illiquid debt, is spread over time. In this case, nominal constraints limit how much of this windfall households can consume in any given period.

Here, we assess the impact of more stringent liquidity constraints in a GE setup. In particular, we limit the access to home equity by imposing a constraint on mortgage refinancing. Homeowners with high leverage, $-b_{i,t-1} > \underline{\theta} q_t^h$, are facing adjustment costs, if they keep the house and want to adjust their mortgage schedule, $\kappa^c(d_{i,t}, b_{i,t-1})$, where $d_{i,t}$ is the deviation from the mortgage schedule that is specified in nominal terms as mortgage contracts typically are. We calibrate the parameters of the adjustment costs to match (i) the share of wealthy hand-to-mouth (WHtM) households to 18% as reported for Canada in Kaplan et al. (2014) and (ii) their quarterly MPC of 30% out of transitory income, (Kaplan et al., 2014). See Appendix D.2 for detailed description of the additional constraints and their calibration. Figure A-13 in Appendix E shows the effect of additional frictions for the MPC out of transitory income for the affected households.

To prevent that higher average MPC increases the average MPE to unrealistically high levels, a challenge highlighted in Auclert et al. (2023), we introduce labor adjustment frictions in the form of sticky wages where a union sets wages on behalf of households and labor demand for a given wage is distributed among productive households in proportion to the labor contracts, which are predetermined one-period ahead. See Appendix D.2 for details. Predetermined contracts imply an average MPE of zero on impact despite a high average MPC as households cannot adjust labor supply instantaneously. But the MPE is positive albeit low for the subsequent periods.

Figure A-1 compares the impulse responses to a monetary policy easing shock, where the benchmark is the model in the main text augmented with sticky wages[20] and predetermined labor contracts. The alternative model differs by having additional constraints on mortgage refinancing. Intuitively due to tighter constraints, the immediate impact of rising rates on consumption of households in the labor force is larger, as some of them are constrained borrowers whose response is stronger to the resulting income effect. This implies a stronger immediate stimulation of the economy, which in turn increases inflation and wages more and thus leads to larger labor supply as well. Relatively high inflation leads to a faster reduction of monetary stimulus which results in a small temporary overshooting of output.

[20]In Section B.3, we show that the medium-term effects in the benchmark model with sticky wages and in the model with flexible wages are almost identical. As in Section B.3, setup with sticky wages means that a labor union sets the wage subject to Rotemberg-style adjustment costs. The union distributes the labor demand for a given wage across workers so that the marginal rate of substitution is equalized across them.

The medium-term effects on output are slightly larger in the more constrained economy. This is hard to see, since the economic impact is much stronger than before, leading to wider impulse response ranges. The larger medium-term effects partially stem from a stronger redistribution associated with higher inflation in the constrained economy. To make the impulse responses more comparable we scale down the size of the shock in the constrained economy to equalize the cumulative effect of inflation on the price level (see Figure A-14 in Appendix E). In this case the medium-term effects are almost identical in both cases. This is consistent with our finding that the majority of medium-term wealth effects that drive the output response are due to a persistently higher price level. This insight is analytically confirmed in a PE model (Section 3.2.3).

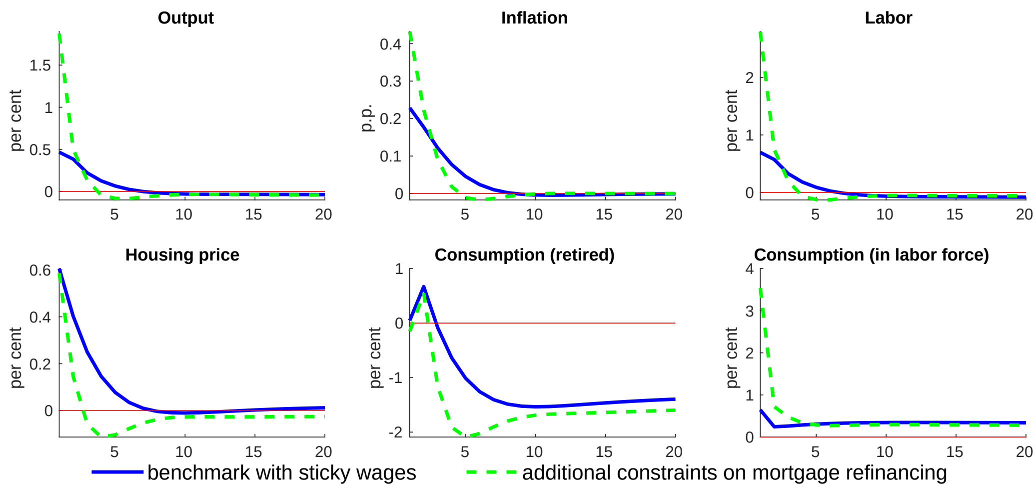


Figure A-1: The effect of additional constraints on mortgage refinancing. The effect of monetary policy easing is more pronounced on impact. The medium-term effects on output are marginally stronger.

B.2 Real asset prices in general equilibrium

A natural question is whether the redistributive impact on savers due to their holdings of nominal bonds might be partially mitigated by valuation effects on their positions in real assets. We investigate that idea by looking at the two real assets in our model: housing and capital. As expected, monetary policy easing reduces the value of nominal debt and increases the value of real assets in our model.

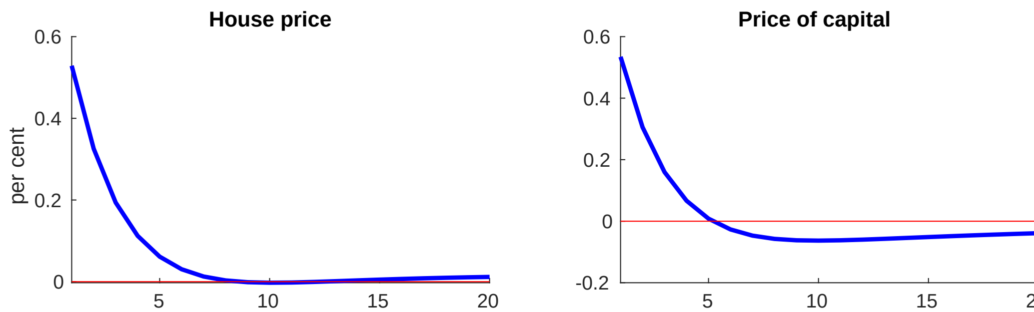


Figure A-2: Both house price and capital price increase only temporarily after monetary policy easing. The price of capital then remains persistently depressed.

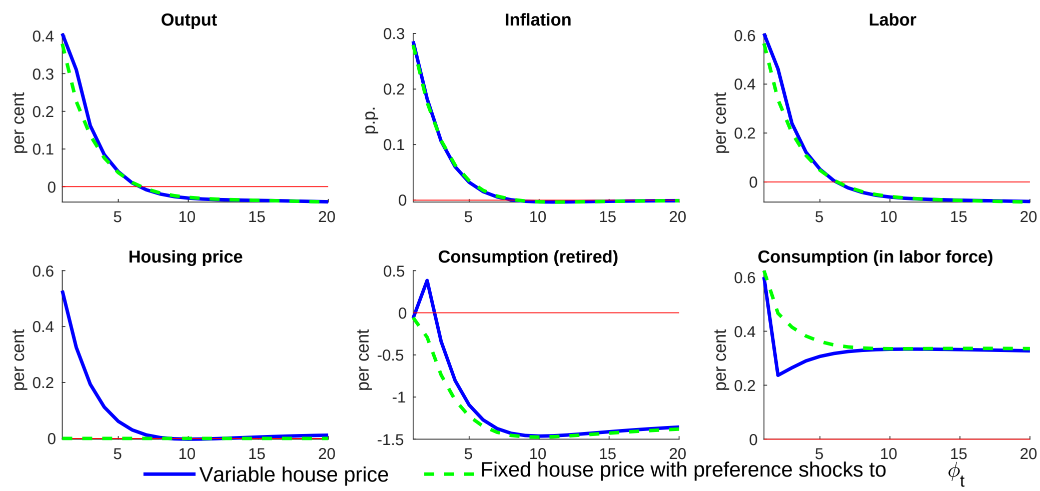


Figure A-3: Effect of a fixed house price. We keep the housing price at the steady-state value with a series of negative shocks to the utility of housing services ϕ_t. This does not have sizable medium-term effects. It only temporarily increases the consumption of households in the labor force, reduces their labor supply and output and depresses consumption of retired households.

On impact, we find a significant increase in real asset values. Both the price of houses (q_t^h) and capital (q_t^k) go up; see Figure A-2. However, this effect wears off quickly and does not offset the effects of a permanent devaluation of nominal debt over the medium term.[21]

House prices go up on impact, since lower mortgage rates increase the demand for housing. The marginal home buyers have relatively small nominal savings, and this endogenous group is relatively quickly replaced by new households who enter the labor market and are not directly affected by the easing shock. As a result, the distributional effects on the house price are limited and short lived. Indeed, the house price converges quickly back to the steady state. As a result, home buyers during the period of temporarily elevated house prices end up with slightly lower wealth following the return of the house price back to its steady-state value, right panel of Figure 2. Regarding the supply side, most homeowners

[21] Importantly, the price of capital is persistently reduced following period six, due to persistently lower output.

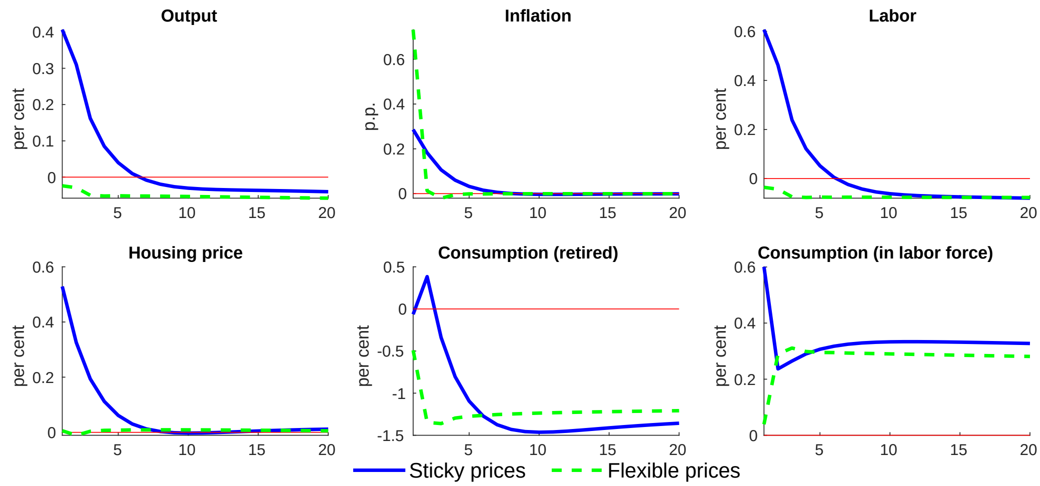


Figure A-4: Comparison of monetary policy easing effects in the benchmark model with sticky prices and in a model with flexible prices. The persistence is similar in both models, suggesting that output over the medium term is driven by lower potential.

stay in their house, so they do not benefit from the temporarily higher house price. There are two groups of house sellers. A small group of stressed sellers are indebted and cannot tap into their home equity due to the borrowing constraints. However, the majority of sales are associated with households that die. The resulting benefits of the temporarily higher house price are distributed among all existing homeowners (borrowers and savers) through the life-insurance mechanism. In conclusion, the temporary house price appreciation does not offset our medium-term effects. We confirm this point in Figure A-3, by showing that the persistent medium-term effects remain even if we neutralize the house price with a series of negative housing demand shocks e_t^ϕ, which affects the now time-varying utility from housing services, $\log(\phi_t) = \rho^\phi \phi_{t-1} + e_t^\phi$.

B.3 Price and wage stickiness

Our benchmark model features sticky prices and flexible wages. We evaluate alternative specifications of price and wage setting, namely flexible prices and sticky wages. Under flexible prices, prices fully adjust on impact, and the output does not increase in the short run. However, higher inflation has a similar implication for redistribution due to nominal debt contracts. Thus we find that the negative medium-term output effect of monetary policy easing is similar under both sticky and flexible prices, consistent with the finding that persistent wealth effects of monetary shocks are mostly driven by the inflation response, Figure A-4. Moreover, we find that even with flexible prices monetary easing under PLT has a smaller negative effect on output in the medium term than under IT because the effect on the price level is offset under PLT, Figure A-5.

Focusing on sticky wages, we confirm the persistent negative effect of monetary easing.[22]

[22]In the model version with sticky wages, a labor union sets the wage subject to Rotemberg-style adjustment costs. The union distributes the labor demand for a given wage across workers so that the marginal rate of substitution is equalized across them.

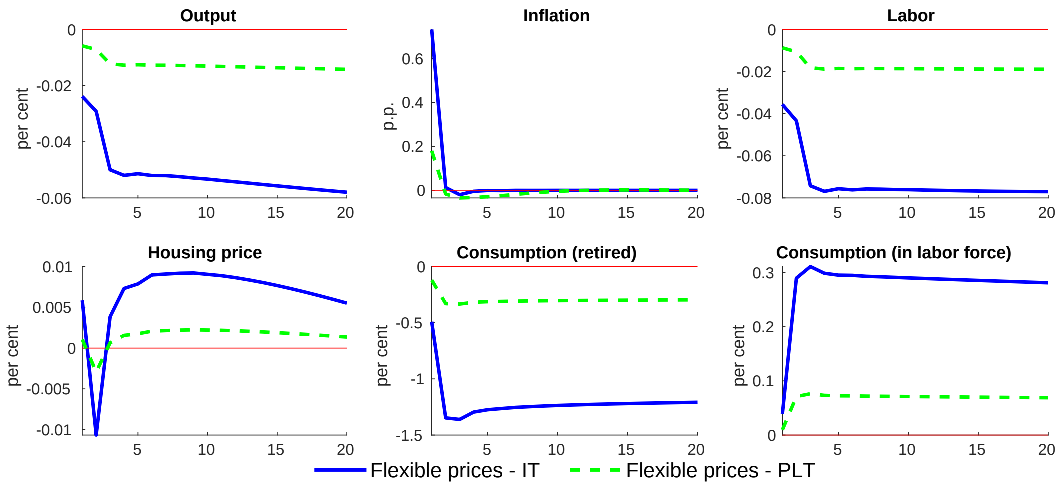


Figure A-5: Comparison of monetary policy easing under IT and PLT under flexible prices. The short-term monetary stimulus is absent, but PLT implies a stronger drop in output than IT, similar to the case with sticky prices.

However, the presence of wage stickiness reduces the response of wages on impact, resulting in a marginally smaller increase of inflation, a higher demand for labor and a stronger positive output response on impact. But there is no noticeable change over the medium term relative to the benchmark model, Figure A-6. This is consistent with the result that labor income changes have a relatively small impact on changes in the wealth distribution that drives the persistent effects of monetary policy shocks.

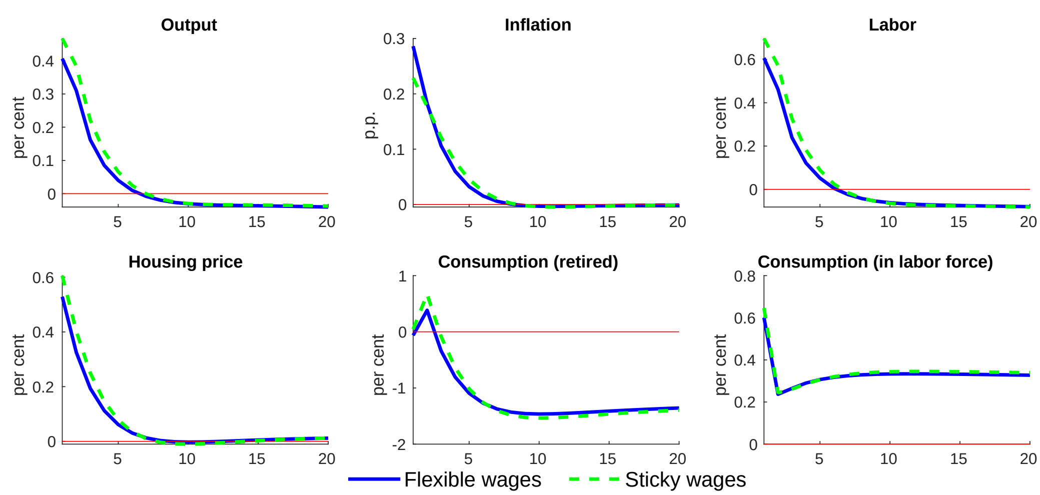


Figure A-6: Comparison of monetary policy easing under flexible and sticky wages. When wages are sticky, they do not increase as much, resulting in less inflation pressure, more demand for labor and higher output in the short run. However, the medium-term negative effects on output are unchanged.

B.4 Comparison of monetary policy regimes

In this section we further our analysis in Section 5.2.2 that compares distributive effects across various monetary policy frameworks. First, we highlight the role of expectations and GE setup in studying different impact of redistribution under IT and PLT. We also run simulations of our model with estimated demand and supply shocks under IT, AIT and PLT. And we show that because PLT better stabilizes inflation, it reduces redistribution and thus better stabilizes output too.

To highlight the importance of the firm-expectation channel in a GE setup, we do an inflation shock exercise based on Meh et al. (2010), who show in a PE that if inflation shocks are later reversed, as under PLT, they result in less redistribution. When we equalize inflation changes on impact under PLT and IT, to achieve comparability with Meh et al. (2010), we find that the responses of output and redistribution are larger under PLT, Figure A-7. While the return of the price level to target eliminates the persistent redistributive effects of inflation, we need larger monetary shocks in our model to produce the same endogenous response of inflation on impact under PLT. However, larger changes in nominal rates lead in our model to more redistribution under PLT. In contrast, nominal rates are constant in the PE setup of Meh et al. (2010). This experiment in combination with the insights from Figure 1 (Panel c) highlight the importance of the expectation channel and the benefits of a GE setup.

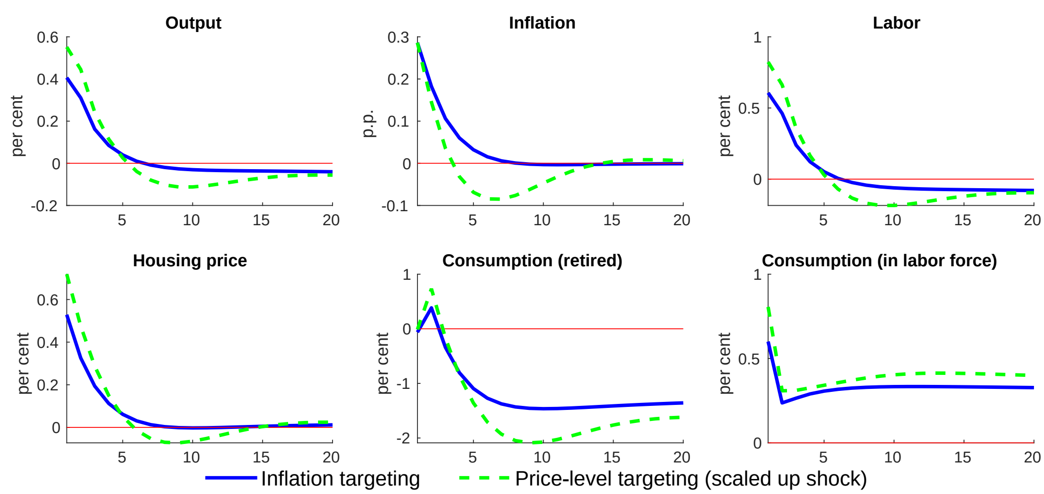


Figure A-7: Comparison of monetary policy regimes: impulse responses to monetary easing under IT and PLT, when the shock size is larger under PLT to equalize the inflation response between the two regimes.

So far, we have focused on monetary policy shocks. To complete the comparison of monetary policy regimes, we simulate the economy for various combinations of Taylor rule parameters, α^{π}, α^{y}, and three estimated shocks: total factor productivity shocks e_t^a, demand shocks e_t^{ν} and monetary shocks e_t^R. We limit values of Taylor rule parameters to the range considered by Schmitt-Grohe and Uribe (2007) as implementable in the face of communication challenges ($\alpha^{\pi} \leq 3, \alpha^{y} \leq 3$). We compare the following regimes: IT, PLT and AIT with four lags (AIT(4)) with a policy rule given by $R_t = R_{t-1}^{\rho^R} \left(R^* \left(\frac{\prod_{i=1}^{4} \pi_{t+i-1}}{(\pi^*)^4} \right)^{\alpha_\pi} \left(\frac{y_t}{y^*} \right)^{\alpha_y} \right)^{1-\rho^R} \exp(e_t^R)$.

Then we compare the stabilizing properties of the different regimes by plotting the variability of output and inflation under the three regimes, Figure A-8. The best outcome would be a stabilization of the economy at its steady-state level. The left panel of Figure A-8 features the usual trade-off between inflation and output stabilization for our benchmark economy. PLT dominates both AIT(4) and IT, since it achieves more stable inflation and output.

To highlight the importance of the redistribution channel, we obtain monetary policy possibility frontiers for an economy with real contracts as in Section 5.1.3, where the direct effect of inflation on the wealth distribution is eliminated; right panel of Figure A-8. Without the redistribution effects of inflation, it is easier to stabilize the economy for any monetary regime. PLT is still preferred when the central bank cares strongly about inflation volatility. However, AIT(4) or IT regimes can be preferred by a central bank that sufficiently values output stability.

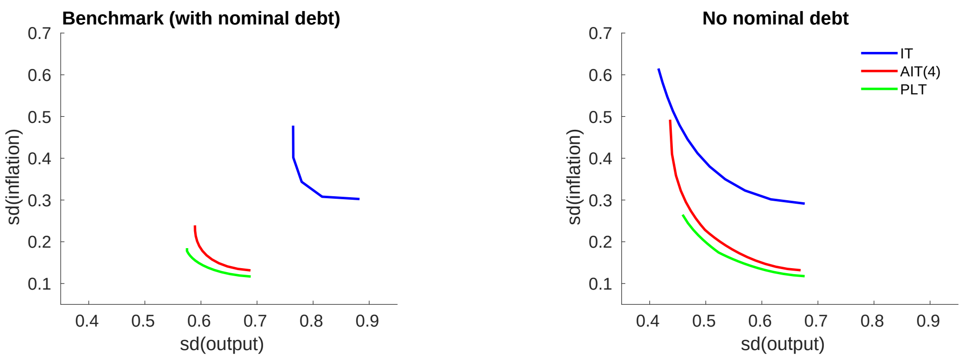


Figure A-8: Monetary policy possibility frontier when stabilizing the economy. The left panel shows the trade-off between inflation and output stabilization for the benchmark economy. The right panel shows the same trade-off in an economy where mortgages are specified in real terms and all capital is directly owned by households through equity.

B.5 Cross-country comparison

In an effort to shed light on the trade-off channel, we take a closer look at the period following the global financial crisis. The idea is that this period was marked by low interest rates for many countries and for extensive periods of time. In the context of our model, a larger monetary stimulus reduces the labor supply over the medium term. Consistent with this implication, countries that provided more monetary stimulus measured by the short-term interest rates in the five years following the financial crisis displayed slower growth for various measures of labor supply over the ten years following the crisis (see Figure A-19 in Appendix E).

In addition, a simple regression analysis suggests that the negative effect of the stimulus on the change in labor supply is more significant for the measures of the extensive margin of the labor supply. We also show that the size of private debt outstanding at the onset of the crisis (in 2007) tends to reduce the labor supply at the extensive margin (see Table A-1). This is consistent with our model-based result that a larger amount of nominal debt in the economy amplifies the medium-term effects on labor supply.

Table A-1. Regression results						
	Δ Labor participation		Δ Employment		Δ Hours p.c.	
Constant	5.48***	11.62***	5.69***	9.05***	1	2.2***
Monetary stimulus	−1.07***	−0.57	−1.58*	−1.22	−0.3	−0.1
Private debt in 2007		−3.66***		−1.93***		−0.8

C Calibration and estimation

C.1 Calibration of the stationary equilibrium

We solve the stationary equilibrium non-linearly using projection methods, specifically the endogenous gridpoints method (Carroll, 2006). To calibrate the stationary equilibrium relevant parameters, we proceed in two steps. First, we determine parameters either using standard statistics or by setting them to commonly used values from the literature. See Table 1 (Panel A) in Section 4 for these parameters and their values. The quarterly probability of dying is set to 0.44 per cent, which corresponds to a life expectancy of 57 years conditional on reaching the working-life age of 25. The elasticity of the substitution parameter among differentiated consumption goods, ε, is set to 10, which corresponds to a price markup of 10 per cent. Regarding the capital income share, we use a standard value in the literature of 0.33. Similarly, the capital depreciation parameter has the commonly used value of 2.5 per cent. Regarding the housing stock depreciation, we make use of the estimates by Kostenbauer (2001) for Canada. He finds an annual depreciation rate of 1.5 per cent, which we convert to quarterly values. Unemployment benefits are set to 55 per cent of the average annual wage income of a Canadian employee, and the funding tax is 3.9 per cent. Both values are taken from the Government of Canada webpage on the Employment Insurance. The minimum down payment requirement is set to 5 per cent in line with current mortgage requirements. We normalize the housing size of a renter to be 0.05. This normalization is possible, since all that matters for the house buying incentives is the relative utility from buying versus renting. We also introduce a housing transaction fee of 5 per cent. This corresponds to the commonly used real estate commission in Canada payed by the seller.[23] The interest rate spread between the borrowing and the savings interest rates is determined using the difference between the 5-year fixed conventional mortgage rate and the 5-year Guaranteed Investment Certificates (GIC) rate. To obtain a quarterly rate, we remove the term premium by taking out the difference between the 5-year GIC rate and the daily interest rate on large deposits. The resulting spread is 0.39 per cent.[24] The share of capital directly financed by households, i.e. via equity, is set to match the share of real positions (as opposed to nominal) in the portfolio of retired households (70 per cent in SFS 2005; see also Meh et al.

[23]There is no universally set commission, and the arrival of discount real estate brokers and sales-by-owner has had an impact over the last few decades. However, on average sellers pay 2.5 per cent to their real estate agent and 2.5 per cent to the buyer's real estate agent.

[24]We considered alternative interest rates regarding the savings rates and found a range for the spread from -5 to 40 basis points.

2010). Regarding the idiosyncratic earnings shock, we use a parsimonious setup with two possible states: employed and unemployed. The advantage is that the parameters guiding the 2-state Markov process, $M_{z',z}$, are easy to estimate from duration data. The focus on only two states comes at the cost of a less rich income distribution, but still captures the main income uncertainty in a working-age person's life. We take this approach mainly to keep the state space contained. From an average unemployment duration of 23 weeks over the period from 1993 to 2019, we determine that the probability of staying unemployed is 48 per cent per quarter. Similarly, from the average job tenure between 95 and 116 months, we determine that the average probability of staying in your job is 97 per cent per quarter.

With these parameters in hand, we proceed to our second step: a simulated method of moments exercise. The aim is to determine the parameters $\left(\beta, \psi, \phi, q^{h*}\right)$. These parameters have a significant impact on our results. The discount factor has a big impact on the amount of borrowing and lending in the model, which in turn is important for the redistribution mechanism. The disutility of labor influences the amount of labor supply heterogeneity. The utility from housing services together with the price of housing is critical for the amount of borrowing. To determine these parameters, we focus our attention on the stationary equilibrium and conduct a simulated method of moments exercise.[25]

We are targeting four moments: the mean LTV ratio in the 2016 Survey of Consumer Finance (SCF), 0.51; the average weekly hours worked by employed persons in Canada relative to 100, 38.5%; the share of debt to net worth, 0.2; and the share of wealth held by the population older than 65 years, 0.29. The last is matched with the share of wealth held by retired households in the model (households that choose not to supply labor for any possible idiosyncratic productivity levels).

The estimated parameter values are in Table 1 (Panel B), and the model's fit of the data moments can be found in Table 1 (Panel C) in Section 4. We successfully match the LTV ratio and the wealth share of retired households, which is critical given our redistribution mechanism. Regarding the other moments, we are very close but understate some of the moments. Our debt-to-net-worth ratio is 19 per cent instead of 20 per cent, and the average hours worked relative to 100 are 38.4% per week instead of 38.5%.

C.2 Estimating the aggregate shocks

To find the dynamic GE solution, we follow the approach of Reiter (2009). We use our stationary equilibrium, which includes a high-dimensional representation of the cross-sectional distribution of households, and obtain a first-order perturbation of the equilibrium. The implementation is done in Dynare (Adjemian et al., 2011), where we use macros to characterize the model with its large state space, including the high-dimensional household distribution and its dynamics.

Regarding the calibration of aggregate processes, we proceed in two steps. First, we determine a subset of dynamic parameters either using standard statistics or by setting them to commonly used values from the literature. Regarding monetary policy, we follow

[25]Normally, we would use the house price to clear the housing market. However, that would make our calibration very time consuming. So, we fix the house price and let housing supply adjust to clear the market. This is only done in the stationary model, while in the DSGE model house prices will vary to clear the market.

Alpanda et al. (2018), who postulate a 2 per cent inflation target and an inflation focused Taylor rule that has an inflation coefficient of 2.5 and no weight on the output gap. We also set the capital adjustment costs at 2.6 as in Alpanda et al. (2018). To capture the fact that the effective mortgage rate is adjusting only slowly, we introduce a persistence parameter that captures the speed of adjustment. Here we match the fact that the average mortgage term is 2.4 years and obtain a value of $\rho^b = 0.90$.[26]

Second, we use Bayesian estimation to find the persistence and standard deviation of the three aggregate shocks. The shock processes in the model affect total factor productivity, the demand for consumption goods and the effective monetary policy rate. The data we use in our estimation procedure are quarterly from 1993Q1–2019Q4: the overnight money market rate, real household consumption expenditures and total factor productivity. The latter is constructed as a residual using the time series for the capital stock, the gross domestic product, employment and hours worked. To remove trends, we use a one-sided Hodrick-Prescott filter with a parameter value of 1600. Our priors and posteriors are summarized in Table 1 (Panel D) in Section 4. The resulting numbers are broadly in line with the ones found in the standard New Keynesian literature, see Christiano et al. (2005), Smets and Wouters (2003) and Justiniano et al. (2011).

C.3 Marginal propensities to earn (MPE) and to consume (MPC)

The size and dynamics of the labor response to income shocks is crucial for our results. Therefore, we compute the MPE as defined by Auclert et al. (2023). MPEs are the negative of an earnings response to an unexpected one-time payment. Based on the empirical findings in Cesarini et al. (2017) and Imbens et al. (2001), Auclert et al. (2023) compute the average MPE in a given year in response to an income shock within the year, finding a value between 0 and 0.04. In the context of our model, the distribution of quarterly MPEs is reported in Figure A-9 and takes the average value of 0.011. Converted to an annual frequency, we find an average MPE of 0.022, which is well within the interval computed by Auclert et al. (2023).[27] This is also very close to the reaction of annual earnings after lottery winnings reported by Golosov et al. (2023), whereby earnings decrease by $0.023 in response to $1 dollar of lottery winnings. Golosov et al. (2023) also find that earnings reactions to smaller wins are larger (earnings decrease by $0.055 in response to a $1 win), which they explain by a limited response to larger winnings due to non-negative labor supply constraint. This suggests that the size of our MPEs could be conservative (on the low side) because the unconstrained responses would be more appropriate for responses to small monetary policy shocks.[28] Moreover, our earnings response to income is persistent, which is also consistent

[26] Even though most mortgages have a contract term no longer than 5 years, the initial amortization period in Canada is between 25 and 35 years.

[27] We compute the annual MPE assuming a uniform distribution of exogenous income shocks over the year. If the income shock takes place at the beginning of the year, the average MPE over the whole year is 0.032.

[28] Golosov et al. (2023) provide a comparison of their results to those in previous studies and argue that while other U.S. studies (Bulman et al. 2021 and Imbens et al. 2001) report lower earnings responses to lottery winnings, the results are similar when they use the same formula to calculate the MPE. They argue that results in previous U.S. studies are biased when they found lower earnings responses. The bias is due to a variety of reasons such as using pre-tax winnings as opposed to after-tax winnings.

with the findings in Golosov et al. (2023), Cesarini et al. (2017), Bulman et al. (2021) and Picchio et al. (2018).

The marginal propensities to consume are elevated for households close to the borrowing constraint given by Equation (4), which implies that renters cannot borrow and homeowners cannot exceed the LTV ratio. Households away from these constraints can freely utilize their savings and thus the average MPCs in the benchmark model are lower than those suggested in the recent literature (e.g. Kaplan and Violante 2014). In an extension B.1, we introduce mortgage refinancing frictions to match the share of wealthy hand-to-mouth households and the level of their MPCs. To keep the average MPE low despite higher MPCs (a challenge pointed out by Auclert et al. 2023), we also introduce labor adjustment frictions. Our medium-term results are largely unchanged in the presence of these changes.

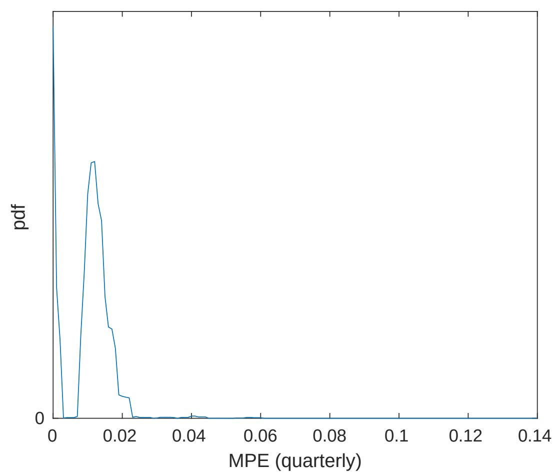


Figure A-9: Distribution of marginal propensity to earn (MPE) in the model. Quarterly MPEs are the negative of the response of earned income to a one-time, unexpected small payment in the same period. The mass point at zero corresponds to retired and unemployed households.

C.4 Data used for calibration

From Statistic Canada

- Job tenure by type of work (full or part time): Statistics Canada Table 14-10-0051-01 Job tenure by type of work (full and part time), annual
- Duration of unemployment: Statistics Canada Table 14-10-0057-01 Duration of unemployment, annual

Other sources

- LTV distribution: Bilyk et al. (2017) for 2014 and 2017; CMHC (2019) for 2019
- Mortgage insurance fees: CMHC; Genworth

- Life tables for Canada: Canadian Human Mortality Database, Life table Total 1x1, http://www.bdlc.umontreal.ca/CHMD/prov/can/can.htm
- Interest rates: Bank of Canada webpage
  - 5-year fixed rate conventional mortgage - V80691335
  - 5-year Guaranteed Investment Certificate - V80691341
  - 5-year personal fixed term - V80691336
  - Non-Chequable Savings Deposits - V80691338
  - Daily Interest Savings (balances over CAD 100,000) - V80691337

D Derivations and proofs

D.1 Optimality conditions for the general equilibrium model

Household optimality conditions FOCs with respect to $l_{i,t}$ and $b_{i,t}$

$$l_{i,t} = \max\left\{0, 1 - \frac{\psi}{(1-\tau_{soc})w_t z_{i,t-1}} c_{i,t}\right\} \quad \text{if} \quad z_{i,t-1} > 0, \quad \text{else } l_{i,t} = 0, \tag{A-1}$$

$$\frac{1}{c_{i,t}} = \beta E_t \frac{1}{c_{i,t+1}} \left(\frac{R_t^b + \zeta}{\pi_{t+1}} \mathbf{1}_{b_{i,t}<0} + r_{t+1}^s \mathbf{1}_{b_{i,t}>0} \right) + \lambda_{i,t}(R_t^b + \zeta), \tag{A-2}$$

where $\lambda_{i,t}$ is the Lagrange multiplier associated with the borrowing constraint of period t.

Indivisible housing Just as in reality, housing in our model is indivisible $h_{i,t} \in \{0,1\}$ and illiquid. This helps to generate a realistic debt distribution, since it motivates households with relatively little wealth to take on large debt positions that are repaid over their lifetime. To find the optimal solution to the discrete housing choice, we rewrite the household problem recursively (we drop the i subscripts and note that b, h, h', z denote $b_{i,t-1}, h_{i,t-1}, h_{i,t}, z_{i,t-1}$):

$$V(b,h,z) = E_\xi \max\left\{v(b,h,z,h'=h), v(b,h,z,h' \neq h) - \xi\right\},$$

where $V(b,h,z)$ is the value function of the household at the beginning of the period before the housing choice and the realization of the utility shock ξ and $v(b,h,z,h') = \max_{b',c,l} u(c,l,h') + \beta(1-\gamma)EV(b',h',z')$ is the continuation value conditional on the housing choice h'. Thus in any given period, when making their housing decisions, renters decide whether to buy a house and homeowners decide whether to sell their house by comparing the relevant continuation values.

There is a unique threshold for $\xi_{i,t}$ that makes a household indifferent between renting and owning over the next period for a potential buyer (current renter) and potential seller (current owner), respectively:

$$\begin{aligned} \tilde{\xi}^{buy}(b,z) &= v(b,h=0,z,h'=1) - v(b,h=0,z,h'=0), \\ \tilde{\xi}^{sell}(b,z) &= v(b,h=1,z,h'=0) - v(b,h=1,z,h'=1). \end{aligned}$$

Due to the bounds of the distribution of $\xi_{i,t} \sim \mathcal{U}(0, \bar{\xi})$, the fractions of households that buy and sell are given by $\hat{\xi}^{buy}(b,z) = \min\left\{1, \max\left\{\frac{\tilde{\xi}^{buy}(b,z)}{\bar{\xi}}, 0\right\}\right\}$ and $\hat{\xi}^{sell}(b,z) = \min\left\{1, \max\left\{\frac{\tilde{\xi}^{sell}(b,z)}{\bar{\xi}}, 0\right\}\right\}$, respectively.

This implies that value functions can be expressed as:

$$\begin{aligned} V(b, h=0, z) &= (1-\hat{\xi}^{buy}(b,z))v(b, h=0, z, h'=0) + \hat{\xi}^{buy}(b,z)\left(v(b, h=0, z, h'=1) - \frac{\min\{\bar{\xi}, \max\{\tilde{\xi}^{buy}(b,z), 0\}\}}{2}\right), \\ V(b, h=1, z) &= (1-\hat{\xi}^{sell}(b,z))v(b, h=1, z, h'=1) + \hat{\xi}^{sell}(b,z)\left(v(b, h=1, z, h'=0) - \frac{\min\{\bar{\xi}, \max\{\tilde{\xi}^{sell}(b,z), 0\}\}}{2}\right). \end{aligned}$$

This shows how the shock to the utility costs of buying or selling a house, $\xi_{i,t}$, smooths the related kink in the value functions.

Mutual fund The FOC w.r.t. k_t gives the condition for the indifference between investing in nominal bonds and capital:

$$E_t \frac{R_t^b}{\pi_{t+1}} = E_t \frac{r_{t+1}^k + (1-\delta^k) q_{t+1}^k}{q_t^k}. \tag{A-3}$$

Goods production There is a unit measure of monopolistically competitive firms indexed by j. Each firm produces intermediate goods according to

$$y_{j,t} = a_t k_{j,t-1}^{\alpha} n_{j,t}^{1-\alpha}, \tag{A-4}$$

where $y_{j,t}, k_{j,t}, n_{j,t}$ are the firm j's levels of output, capital and labor.

Intermediate goods are aggregated into a homogeneous final good by perfectly competitive final goods producers:

$$Y_t = \left(\int y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where ε is the elasticity of substitution between goods. Cost minimizing final goods producers have a demand for intermediate goods given by:

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} y_t, \text{ where } P_t = \left(\int P_{j,t}^{1-\varepsilon} dj\right)^{\frac{1}{1-\varepsilon}}. \tag{A-5}$$

The intermediate producer j maximizes the stream of profits:

$$\max_{\{n_{j,t}, k_{j,t-1}, P_{j,t}\}} \sum_{t=0}^{\infty} E_t \, \Lambda_{0,t} \frac{\Pi_{j,t}^P}{P_t}, \tag{A-6}$$

subject to (A-4) and (A-5), where $\Lambda_{0,t}$ is the aggregate stochastic discount factor. Profits are distributed to households in a lump-sum fashion $\Gamma_t^P = \int \Pi_{j,t}^P / P_t dj$. We use the expected real interest rate as the discount factor, i.e.:

$$\Lambda_{0,t} = \prod_{s=0}^{t} \frac{\pi_{s+1}}{R_s^b}. \tag{A-7}$$

This profit maximization problem can be rewritten as the following Lagrangian

$$\mathcal{L} = \sum_{t=0}^{\infty} E_t \, \Lambda_{0,t} \left\{ \frac{P_{j,t}}{P_t} y_{j,t} - w_t n_{j,t} - r_t^k k_{j,t-1} - \frac{\kappa}{2} \left(\frac{P_{j,t}}{\pi^* P_{j,t-1}} - 1 \right)^2 y_t + m_{j,t} \left(a_t k_{j,t-1}^{\alpha} n_{j,t}^{1-\alpha} - y_{j,t} \right) \right\}, \tag{A-8}$$

where $y_{j,t}$ can be substituted using (A-5). The price stickiness is due to quadratic adjustment costs of deviations of price growth from steady-state inflation (inflation target π^*). The Lagrange multiplier of the production function $m_{j,t}$ can be interpreted as real marginal costs. The FOCs w.r.t. $n_{j,t}, k_{j,t-1}$ are

$$\begin{aligned} w_t &= (1-\alpha) \, m_{j,t} \frac{y_{j,t}}{n_{j,t}}, \\ r_t^k &= \alpha m_{j,t} \frac{y_{j,t}}{k_{j,t-1}}, \end{aligned}$$

which gives

$$m_{j,t} = \frac{1}{a_t} \left(\frac{r_t^k}{\alpha} \right)^{\alpha} \left(\frac{w_t}{1-\alpha} \right)^{1-\alpha}. \tag{A-9}$$

Note that marginal costs are equal across firms so we can drop j subscript, m_t.

The FOC w.r.t. $P_{j,t}$ is given by:

$$\begin{aligned} \Lambda_{0,t} \left[(1-\varepsilon) \left(\frac{P_{j,t}}{P_t} \right)^{-\varepsilon} \frac{y_t}{P_t} - \kappa \left(\frac{P_{j,t}}{\pi^* P_{j,t-1}} - 1 \right) \frac{y_t}{P_{j,t-1} \pi^*} + m_t \varepsilon \left(\frac{P_{j,t}}{P_t} \right)^{-\varepsilon-1} \frac{y_t}{P_t} \right] & \\ + E_t \Lambda_{0,t+1} \kappa \left(\frac{P_{j,t+1}}{\pi^* P_{j,t}} - 1 \right) \frac{y_{t+1} P_{j,t+1}}{P_{j,t}^2 \pi^*} &= 0. \end{aligned}$$

Since goods producers are facing a symmetric problem, in equilibrium, there is no price dispersion. Imposing $P_{j,t} = P_t$ in the above FOC, we can rewrite it to get the New Keynesian Phillips curve:

$$\left(\frac{\pi_t}{\pi^*} - 1 \right) \frac{\pi_t}{\pi^*} = E_t \frac{\Lambda_{0,t+1}}{\Lambda_{0,t}} \left(\frac{\pi_{t+1}}{\pi^*} - 1 \right) \frac{\pi_{t+1}}{\pi^*} \frac{y_{t+1}}{y_t} + \frac{\varepsilon}{\kappa} \left(m_t - m^* \right), \tag{A-10}$$

where $m^* = \frac{\varepsilon - 1}{\varepsilon}$ and $E_t \frac{\Lambda_{0,t+1}}{\Lambda_{0,t}} = E_t \frac{\pi_{t+1}}{R_t^b}$.

The profit of goods producers is distributed lump-sum to all households:

$$\Gamma_t^P = (1 - m_t) y_t - \frac{\kappa}{2} \left(\frac{\pi_t}{\pi^*} - 1 \right)^2 y_t. \tag{A-11}$$

Capital producers Capital producers purchase goods from the final goods producers, and they convert them into investment goods x_t, which are sold at price q_t^k. The production of new capital is subject to a quadratic adjustment costs in investment κ^k and takes place in a perfectly competitive market. Thus, they maximize the discounted stream of profits

$$\max_{\{x_t\}} E_t \sum_{\tau=0}^{\infty} \Lambda_{0,\tau} q^k_\tau \left(k_\tau - (1-\delta^k)k_{\tau-1}\right) - x_t, \tag{A-12}$$

subject to the law of motion for capital

$$k_t - (1-\delta^k)k_{t-1} = x_t \left(1 - \frac{\kappa^k}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2\right). \tag{A-13}$$

The FOC w.r.t. i_t is given by:

$$q^k_t = 1 + q^k_t \kappa^k \left[\frac{1}{2}\left(\frac{x_t}{x_{t-1}} - 1\right)^2 + \frac{x_t}{x_{t-1}}\left(\frac{x_t}{x_{t-1}} - 1\right)\right] + q^k_{t+1}\frac{\pi_{t+1}}{R^b_t}\left(\frac{x_{t+1}}{x_t}\right)^2 \kappa^k \left(\frac{x_{t+1}}{x_t} - 1\right). \tag{A-14}$$

D.2 Refinancing constraints in Section B.1 and their calibration

Refinancing constraints. Employed homeowners with high leverage, $-b_{i,t-1} > \underline{\theta} q^h_t$, are facing adjustment costs, if they keep the house and want to adjust their mortgage schedule, $\kappa^c(d_{i,t}, b_{i,t-1})$, where $d_{i,t}$ is the deviation from the mortgage schedule that is specified in nominal terms as mortgage contracts typically are. For simplicity and in order to limit the effect of the constraint on the steady state wealth distribution, the nominal mortgage schedule is set to the optimal mortgage repayment in the absence of aggregate shocks where inflation is at the steady-state level π^*. Since in the steady state only the growth of the price level is pinned down, we write the schedule as $b^{i\prime *}\left(b/\pi^*, h=1, h'=1, z=1\right)$ (for simplicity we henceforth drop the preset arguments that restrict the constraint to productive homeowners who do not sell their house: $h=1, h'=1, z=1$). Thus the deviation from the mortgage schedule is $d^{i\prime}(b) = b^{i\prime}\left(b/\pi\right) - b^{i\prime *}\left(b/\pi^*\right)$. Moreover, to match the higher MPC of unemployed households, these households face a tighter constraint that allows them to access only a small fraction of home equity: $-b_{i,t} \leq \varphi^G(-b_{i,t-1})$, if $h_{i,t} = 1$ and $z_{i,t-1} = 0$ and $-b_{i,t-1} > \underline{\theta} q^h_t$, where $\varphi^G = 1.01$.

Calibration of refinancing constraints. We calibrate the refinancing constraints in Section B.1 to match the share of WHtM households in the population and their MPC and to have limited effect on the distribution of steady-state wealth, which would imply that the difference in impulse responses to the benchmark model can be attributed to the difference in the response of constraint households to aggregate shocks.

The adjustment costs are given by

$$\kappa^c(d', b) = \kappa^c_1|d'| + \kappa^c_2\left|\frac{d'}{b} + \kappa^c_0\right|^{\kappa^c_3}|b| + \kappa^c_4|b|,\ \forall - b_{i,t-1} > \underline{\theta} q^h_t, \tag{A-15}$$

where $\underline{\theta} = 0.49$ matches the share of WHtM households of 18% as reported for Canada in

Kaplan et al. (2014). Following Kaplan et al. (2018) we set $\kappa_2^c = 0.956$ and $\kappa_3^c = 1.402$. We set $\kappa_0^c = 0.002$ to match the average quarterly MPC of wealthy hand-to-mouth households to 0.3 as reported by Kaplan et al. (2014). The remaining parameters κ_1^c and κ_4^c are set such that the steady-state adjustment costs and their first derivative are zero in the steady state, $\kappa^c(0, b) = 0$ and $\partial\kappa^c/\partial d' \mid_{d'=0} = 0$, and thus do not affect the steady-state wealth distribution. This implies that $\kappa_4^c = -\kappa_2^c(\kappa_0^c)^{\kappa_3^c}$ and $\kappa_1^c = -\kappa_2^c\kappa_3^c(\kappa_0^c)^{(\kappa_3^c-1)}$.

Labor frictions. Households propose their preferred work hours in the next period $l_{i,t}^C(z_{i,t})$ conditional on the future realization of $z_{i,t}$ and reflecting their idiosyncratic preferences,

$$l_{i,t}^C(z_{i,t}) = E_t \max\left\{0, 1 - \frac{\psi}{w_{t+1}z_{i,t}}c_{i,t+1}(z_{i,t})\right\}. \tag{A-16}$$

Then the labor union chooses the wage to maximize workers utility. The demanded hours for a given wage are supplied by productive households, $l_t^D(w_t) = L_t^{scale}\sum_i l_{i,t-1}^C(z_{i,t-1})z_{i,t-1}$. The distribution of hours among workers is proportional to the predetermined labor contracts of households $l_{i,t} = L_t^{scale} l_{i,t-1}^C(z_{i,t-1})\ \forall i$.[29]

D.3 Derivations for Section 3.2.1 and proof of Lemma 1

First, we derive the optimal individual consumption of households. We replace $b_t\ \forall t \geq 0$ sequentially from the budget constraint to obtain the present value budget constraint:

$$c_{i,0}+\frac{1-\gamma}{R^*}c_{i,1}+\left(\frac{1-\gamma}{R^*}\right)^2 c_{i,2}\cdots = b_{i,-1}\frac{1}{1-\gamma}\frac{R^*}{\pi_0}+w^*l_{i,0}+\frac{1-\gamma}{R^*}w^*l_{i,1}+\left(\frac{1-\gamma}{R^*}\right)^2 w^*l_{i,2}\cdots, \tag{A-17}$$

where after substituting Equation (10) with $\lambda_{i,t} = 0\ \forall i,t$, $l_{i,t} = 1\ \forall i,t$ and transversality condition $\lim_{t\to\infty}\left(\frac{(1-\gamma)}{R^*}\right)^{t-1} b_{i,t} = 0$, the aggregating infinite sums become: $c_{i,0}\frac{1}{1-(1-\gamma)\beta} = \frac{R^*}{1-\gamma}\frac{b_{i,-1}}{\pi_0} + w^*\frac{1}{1-\frac{1-\gamma}{R^*}}$. Thus in equilibrium households consume an optimal fraction of their initial wealth $\Psi_{i,0} = \frac{R^*}{1-\gamma}\frac{b_{i,t-1}}{\pi_0}$ and of human capital measured by the discounted lifetime labor income. Rearranging this condition yields

$$c_{i,0} = MPC_{i,0}\left[\underbrace{\frac{R^*}{1-\gamma}\frac{b_{i,t-1}}{\pi_0}}_{\text{initial wealth } \Psi_{i,0}} + \underbrace{w^*\frac{1}{1-\frac{1-\gamma}{R^*}}}_{\text{human capital}}\right].$$

Since optimal consumption grows at the rate βR^* (from Equation 10), we obtain the intertemporal MPC out of changes in initial wealth:

[29] To avoid a strategic manipulation of labor contract sizes in an environment with sticky wages, we assume that the labor union can observe households characteristics and thus detect and penalize any strategic misrepresentation of their preferences to work.

$$MPC_{i,t} \equiv \frac{\partial c_{i,t}}{\partial \Psi_{i,0}} = (1-(1-\gamma)\beta)\left(\beta R^*\right)^t < 1, \tag{A-18}$$

which also grows at the rate βR^*.

Aggregating individual consumption responses to the inflation shock, we obtain the change in aggregate consumption

$$\begin{aligned} dC_t &= (1-\gamma)^t \int dc_{i,t} di = (1-\gamma)^t \int MPC_{i,t} d\Psi_{i,0} di = (1-\gamma)^t ds \int MPC_{i,t} NNP_{i,-1} di \\ &= (1-\gamma)^t ds \left(\int MPC_{i,t} di \underbrace{\int NNP_{i,-1} di}_{=0} + \underbrace{Cov(MPC_{i,t}, NNP_{i,-1})}_{=0} \right) = 0. \end{aligned}$$

D.4 Derivations for Section 3.2.2 and proof of Proposition 1

We start with the intertemporal budget constraint of a household that retires at $T_i \gg 0$, such that T_i satisfies $1 - \frac{\psi}{w^*} c_{i,T_i} < 0$ and $1 - \frac{\psi}{w^*} c_{i,T_i - 1} > 0$ (also using Equations 10 and 9 for substitutions):

$$\begin{aligned} c_{i,0} \frac{1}{1-(1-\gamma)\beta} &= b_{i,-1} \frac{1}{1-\gamma} \frac{R^*}{\pi_0} + w^* \left(1 - \frac{\psi}{w^*} c_{i,0}\right) + \frac{1-\gamma}{R^*} w^* \left(1 - \frac{\psi}{w^*} c_{i,0} \beta R^*\right) \cdots \\ & \cdots + \left(\frac{1-\gamma}{R^*}\right)^{T_i - 1} w^* \left(1 - \frac{\psi}{w^*} \underbrace{c_{i,0} (\beta R^*)^{T_i - 1}}_{c_{i,T_i - 1}}\right). \end{aligned}$$

Summing the finite sums from period 0 until $T_i - 1$ yields

$$c_{i,0} \left(\frac{1}{1-(1-\gamma)\beta} + \psi \frac{1-((1-\gamma)\beta)^{T_i}}{1-(1-\gamma)\beta} \right) = b_{i,-1} \frac{1}{1-\gamma} \frac{R^*}{\pi_0} + w^* \frac{1 - \left(\frac{1-\gamma}{R^*}\right)^{T_i}}{1 - \frac{1-\gamma}{R^*}},$$

or equivalently we can decompose the distribution of wealth in present-value terms

$$\underbrace{c_{i,0} \frac{1}{1-(1-\gamma)\beta}}_{\text{consumption}} + \underbrace{c_{i,0} \psi \frac{1-((1-\gamma)\beta)^{T_i}}{1-(1-\gamma)\beta}}_{\text{leisure before retirement}} + \underbrace{w^* \frac{\left(\frac{1-\gamma}{R^*}\right)^{T_i}}{1 - \frac{1-\gamma}{R^*}}}_{\text{leisure in retirement}} = \underbrace{b_{i,-1} \frac{1}{1-\gamma} \frac{R^*}{\pi_0}}_{\text{initial wealth } \Psi_{i,0}} + \underbrace{w^* \frac{1}{1 - \frac{1-\gamma}{R^*}}}_{\text{human capital}}. \tag{A-19}$$

A generic version of (A-19) for any T_i, thus even for already retired households, is:

$$\underbrace{c_{i,0} \frac{1}{1-(1-\gamma)\beta}}_{\text{consumption}} + \underbrace{c_{i,0} \psi \frac{1-((1-\gamma)\beta)^{\max\{0,T_i\}}}{1-(1-\gamma)\beta}}_{\text{leisure before retirement}} + \underbrace{w^* \frac{\left(\frac{1-\gamma}{R^*}\right)^{\max\{0,T_i\}}}{1 - \frac{1-\gamma}{R^*}}}_{\text{leisure in retirement}} = \underbrace{\frac{R^*}{1-\gamma} \frac{b_{i,t-1}}{\pi_0}}_{\text{initial wealth } \Psi_{i,0}} + \underbrace{w^* \frac{1}{1 - \frac{1-\gamma}{R^*}}}_{\text{human capital}}. \tag{A-20}$$

Thus, households now use their wealth and human capital (maximum possible lifetime labor income) for consumption and leisure. Rearranging (A-20) by expressing consumption on the LHS and taking into account that optimal consumption grows at the rate βR^* (from FOC 10) gives the expression for the MPC in (11). From Equation (9) we then get the MPE: $MPE_{i,t} = \mathbf{1}_{T_i>t}\psi MPC_{i,t}$.

Aggregate labor. Individual labor elasticities are given by $\partial l_{i,t}/\partial \Psi_{i,0} = -1/w^* MPE_{i,t}$ (from MPE definition). Integrating labor responses to shocks over the population, we get the aggregate labor response:

$$\begin{aligned} dl_t &= (1-\gamma)^t \int -\frac{MPE_{i,t}}{w^*} d\Psi_{i,0} di = -\frac{(1-\gamma)^t}{w^*} ds \left(\int MPE_{i,t} di \underbrace{\int NNP_{i,-1} di}_{=0} + Cov(MPE_{i,t}, NNP_{i,-1}) \right) \\ &= -\frac{(1-\gamma)^t}{w^*} \underbrace{ds}_{<0} Cov(MPE_{i,t}, NNP_{i,-1}). \end{aligned}$$

Since we know that the MPEs of retired households are zero, we can express dl_t while focusing on means and covariances for households in the labor force ($T_i > t$):

$$dl_t = -\frac{(1-\gamma)^t}{w^*} \underbrace{ds}_{<0} \left(\int \mathbf{1}_{T_i>t} MPE_{i,t} di \int \mathbf{1}_{T_i>t} NNP_{i,-1} di + Cov(\mathbf{1}_{T_i>t} MPE_{i,t}, \mathbf{1}_{T_i>t} NNP_{i,-1}) \right).$$

We can use the above expression to rewrite the condition $dl_t < 0$ as follows:

$$\int \mathbf{1}_{T_i \le t} NNP_{i,-1} di > \frac{Cov(\mathbf{1}_{T_i>t} MPE_{i,t}, \mathbf{1}_{T_i>t} NNP_{i,-1})}{\int \mathbf{1}_{T_i>t} MPE_{i,t} di},$$

where we used the fact that $ds < 0$ and that there is zero net supply of nominal bonds in the economy at $t = -1$: $\int \mathbf{1}_{T_i>t} NNP_{i,-1} di + \int \mathbf{1}_{T_i \le t} NNP_{i,-1} di = 0$.

Aggregate consumption. We aggregate individual consumption responses to obtain aggregate consumption

$$dc_t = (1-\gamma)^t \int dc_{i,t} di = (1-\gamma)^t \underbrace{ds}_{<0} \underbrace{Cov(MPC_{i,t}, NNP_{i,-1})}_{>0} < 0$$

The above result relies on $Cov(MPC_{i,t}, NNP_{i,-1}) > 0$ which is true since $Cov(T_i, NNP_{i,-1}) < 0$ and $MPC_{i,t}$ is decreasing in T_i.

D.5 Derivations for Section 3.2.3, proofs of Propositions 2 and 3

Constant labor supply. A constrained household cannot achieve its optimal consumption path due to a binding borrowing constraint:

$$c_{i,t} < (1-(1-\gamma)\beta) \left[\frac{R^*}{1-\gamma} \frac{b_{i,t-1}}{\pi_t} + w^* \frac{1}{1-\frac{1-\gamma}{R^*}} \right]. \quad \text{(A-21)}$$

Instead the consumption of constrained households is determined by their current cash-flows. Substituting binding borrowing constraint $b_{i,t} = \varphi \frac{b_{i,t-1}}{\pi_t}$ into the budget constraint, we get Equation (13). Combining the above inequality with the maximum consumption given by a binding constraint (13), we can show that households consumption is lower than optimal if

$$w^* + \left(1 - \varphi \frac{1-\gamma}{R^*}\right) \frac{R^*}{1-\gamma} \frac{b_{i,t-1}}{\pi_t} < (1 - (1-\gamma)\beta) \left[\frac{R^*}{1-\gamma} \frac{b_{i,t-1}}{\pi_t} + w^* \frac{1}{1 - \frac{1-\gamma}{R^*}} \right], \qquad \text{(A-22)}$$

which implies that households are constrained when they are poorer, $\frac{b_{i,t-1}}{\pi_t} < \tilde{b}$, where

$$\tilde{b} \equiv -w^*(1-\gamma) \frac{\beta R^* - 1}{\left(R^* - (1-\gamma)\right)\left(\beta R^* - \varphi\right)}$$

is the level of bonds that satisfies the condition (A-22) with equality. Since we want the constraint to apply only to borrowers, $\tilde{b} < 0$, we focus on the parameter subspace $\varphi < \beta R^*$, where the constraint requires debt repayment. Intuitively, all households have the same human capital and differ in their wealth. When their current low level of wealth is too low to allow them to consume an optimal fraction of their human capital (and wealth), they are constrained.

Using Equation (13), we can show that a change in the initial wealth implies the effect on consumption of constrained borrowers $dc_{i,0} = MPC_{i,0}\, ds\, b_{i,-1}$ and on their debt $d(-b_{i,0}) = \varphi \frac{b_{i,-1}}{\pi_0} \frac{d\pi_0}{\pi_0} < 0$, where the impact MPC of constrained borrowers out of illiquid wealth is $MPC_{i,0} \mid_{\frac{b_{i,-1}}{\pi_0} < \tilde{b}} = 1 - \varphi \frac{1-\gamma}{R^*}$. If households remain constrained their intertemporal MPC evolves at the rate φ (see Equation 14). To see that, we combine the budget constraint (13) with the above expression for $d(-b_{i,0})$ and the evolution of bonds over time $b_{i_t} = \varphi b_{i,t-1}\ \forall t > 0$, where we substituted in $\pi_t = 1\ \forall t > 0$.

Since $\varphi < \beta R^*$, the MPC of constrained households is higher in the early periods as described in the main text. The aggregate consumption response is again given by the expression $dc_t = (1-\gamma)^t \int dc_{i,t} di = (1-\gamma)^t\, ds\, Cov(MPC_{i,t}, NNP_{i,-1})$. Since constrained households are poorer ($\frac{b_{i,t-1}}{\pi_t} < \tilde{b}$) and have higher MPCs for $t < \tilde{t}$, $Cov(MPC_{i,t}, NNP_{i,-1}) < 0$ for $t < \tilde{t}$. The MPCs of constrained households grow at a smaller rate than the MPC of unconstrained households (or declines), since $\varphi < \beta R^*$. Thus for $t > \tilde{t}$ it will be lower than the MPC of unconstrained households implying $Cov(MPC_{i,t}, NNP_{i,-1}) > 0$. The time threshold $\tilde{t}$ is given by the equality of the MPCs of constrained and unconstrained:

$$\left(1 - \varphi \frac{1-\gamma}{R^*}\right) \varphi^{\tilde{t}} = (1 - (1-\gamma)\beta)(\beta R^*)^{\tilde{t}},$$

and thus $\tilde{t} \equiv {}^{\log}\left(\frac{1-\varphi(1-\gamma)/R^*}{1-\beta(1-\gamma)}\right) / {}_{\log}\left(\frac{\beta R^*}{\varphi}\right)$.

Heterogeneous labor supply. Constrained households, $\frac{b_{i,t-1}}{\pi_t} < \tilde{b}'$, in the labor force, $t < T_i$, use the maximum current household income not only for consumption $c_{i,t}$ but also for leisure $\psi c_{i,t}$: $c_{i,t} + \psi c_{i,t} = w^* + \left(1 - \varphi \frac{(1-\gamma)}{R^*}\right) \frac{R^*}{1-\gamma} \frac{b_{i,t-1}}{\pi_t}$, and thus their MPC out of illiquid wealth is lower than in the case with constant labor (Equation 14):

$$MPC_{i,t} \mid_{\frac{b_{i,t-1}}{\pi_t}<\tilde{b}'} = \frac{1-\varphi\frac{1-\gamma}{R^*}}{1+\psi}\varphi^t. \tag{A-23}$$

The MPC of unconstrained households is given by Equation (11). The MPC of constrained households in the labor force is higher than the MPC of unconstrained households for $t < \tilde{t}'(T_i)$ and lower later, where

$$\tilde{t}'(T_i) \equiv \frac{\log\left(\frac{1-\varphi(1-\gamma)/R^*}{1-\beta(1-\gamma)}\frac{1+\psi\left(1-((1-\gamma)\beta)^{\max\{0,T_i\}}\right)}{1+\psi}\right)}{\log\left(\frac{\beta R^*}{\varphi}\right)}.$$

When both heterogeneous labor supply and borrowing constraints are present, the reaction of consumption on impact is not unequivocal. The reason is that constrained borrowers react more in the short term than unconstrained households. At the same time, retirees who are net savers also react more on impact than unconstrained households. Thus, the aggregate response would depend on the NNPs of constrained households and the NNPs of retired households. In practice, a realistic calibration implies that the response of constrained households would dominate on impact, as we show in Section B.1.

But when it comes to the aggregate consumption in the medium term, the two effects amplify each other. Retirees who are net savers react more to the shock. And constrained borrowers react less. As a result, the aggregate consumption decreases more.

Aggregate labor supply decreases in the short run since households in the labor force are net borrowers who increase their consumption (more in the case of constrained households). Higher wealth and consumption of households in the labor force leads to lower labor supply.

However, there are two offsetting effects on aggregate labor supply in the medium-term. Constrained borrowers adjust their labor supply less over the medium term. At the same time the largest savers, who are retired, do not adjust their labor supply at all. The overall effect thus depends on the NNPs of constrained and unconstrained households in the labor force.

D.6 Decomposition formula for standard and distribution effects

To isolate the effects of redistribution, we decompose variable responses into two components. Consider for instance the relative deviation of aggregate labor supply from its steady state, $\frac{\hat{l}_t}{l^*}$, where the asterisk (hat) denotes the *steady-state level* (level deviation from the steady-state), thus $\hat{l}_t \equiv l_t - l^*$. We can decompose it as follows while using the transformed distribution $\tilde{\mu}_t(\Psi(b,h),h,z)$ that reflects the effect of prices at t on wealth $\Psi_{i,t}$:[30]

$$\frac{\hat{l}_t}{l^*} \approx \underbrace{\frac{\int\int\int \hat{l}_t^i(\Psi(b,h),h,z)\tilde{\mu}^*(\Psi^*(b,h),h,z)db\,dh\,dz}{l^*}}_{\text{Standard effect}} + \underbrace{\frac{\int\int\int l^{i*}(\Psi^*(b,h),h,z)\hat{\tilde{\mu}}_t(\Psi(b,h),h,z)db\,dh\,dz}{l^*}}_{\text{Distribution effect}}. \tag{A-24}$$

[30] At the first-order approximation, this decomposition is exact.

Fixing the steady-state distribution, the first component captures the deviation of the labor supply choice from its steady state. We obtain it by aggregating the individual labor deviations from the steady state in levels conditional on their individual state, $\hat{l}_t^i(\Psi(b,h),h,z)$, across all households over the steady-state distribution of households, $\tilde{\mu}^*(\Psi^*(b,h),h,z)$, scaled by the steady state labor supply $l^* = \int\int\int l^{i*}(\Psi^*(b,h),h,z)\tilde{\mu}^*(\Psi^*(b,h),h,z)db\,dh\,dz$. We refer to this component as the standard effect, since it captures channels present in RANK models, such as the effect of wages or the intertemporal substitution effect. Fixing the labor choices at the steady-state level, the second component isolates the distribution effect. It captures the part of the labor deviation driven by endogenous changes in the distribution and is computed by aggregating individual steady-state labor choices of households conditional on their individual state, $l^{i*}(\Psi^*(b,h),h,z)$, over the deviations of the distribution from the steady state in levels $\hat{\tilde{\mu}}_t(\Psi(b,h),h,z)$, again scaled by aggregate steady-state labor supply l^*. We do a similar decomposition for the consumption of the two households groups.

D.7 Extension of partial-equilibrium model with bequests

Consider the simplified model from Section 3, only now households care about bequests. We introduce a warm-glow value of assets that are left behind to other households in the case of a household's death $\vartheta(b_{i,t})$ s.t. $\vartheta'(\cdot) > 0$, $\vartheta''(\cdot) < 0$. After the initial shock to inflation, the only source of uncertainty is mortality risk. The household problem becomes

$$\max_{\{b_{i,t},l_{i,t}\}} E\left(\sum_{t=0}^{\infty}\beta^t(1-\gamma)^t\left(\log(c_{i,t})+\psi\log(1-l_{i,t})\right)+\sum_{t=1}^{\infty}\beta^t\gamma(1-\gamma)^{t-1}\vartheta(b_{i,t})\right),$$

subject to $l_{i,t} \geq 0$ and the budget constraint for surviving households $b_{i,t} + c_{i,t} \leq w_t l_{i,t} + \frac{1}{1-\gamma}\frac{R_{t-1}}{\pi_t}b_{i,t-1}$. Households do not face binding borrowing constraints, $\psi \to \infty$. First-order conditions (FOCs) with respect to labor $l_{i,t}$ and bond holdings $b_{i,t}$ are

$$l_{i,t} = \max\left\{0, 1-\frac{\psi}{w_t}c_{i,t}\right\}, \tag{A-25}$$

$$\frac{1}{c_{i,t}} = \beta\frac{1}{c_{i,t+1}}\frac{R_t}{\pi_{t+1}} + \beta\gamma\vartheta'(b_{i,t}), \tag{A-26}$$

Note that the FOC with respect to labor (A-25) is not affected by bequests and thus we again get the same relationship between MPE and MPC: $MPE_{i,t} = \mathbf{1}_{T_i>t}\psi MPC_{i,t}$. The bequest motive increases the benefits from saving and thus affect the FOC (A-26), which can be rewritten as:

$$\frac{c_{i,t+1}}{c_{i,t}} = \beta\frac{R_t}{\pi_{t+1}} + \beta\gamma\frac{c_{i,t+1}}{b_{i,t}}\eta(b_{i,t}),$$

where $\eta(b_{i,t}) = b_{i,t}\vartheta'(b_{i,t})$. Mian et al. (2021) show that if preferences are homothetic, in our case $\vartheta(b_{i,t}) = \log(b_{i,t})$, the marginal utility of consumption and the marginal utility of bequests are proportional and $\eta(b_{i,t}) = 1$ is a constant. However, when $\eta(b_{i,t})$ is increasing, preferences are non-homothetic and wealthier households have higher incentives to save. Thus their MPC out of wealth is lower than the MPC of poorer households.

When $\eta(b_{i,t})$ is sufficiently increasing, it can offset the effect of heterogeneous labor supply responses and generate a negative covariance between MPC and initial NNP, $Cov(MPC_{i,t}, NNP_{i,-1}) < 0\ \forall t$. This in turn implies that an unexpected inflation shock $d\pi_0 > 0$ considered in Section 3 would increase aggregate consumption $dc_t > 0\ \forall t \geq 0$.

However the negative effect of the inflation shock on aggregate labor supply would be reinforced. For an inflation-induced redistribution to have negative effects on aggregate labor $dl_t < 0$ we need $Cov(MPE_{i,t}, NNP_{i,-1}) < 0$. Recall that $MPE_{i,t} = \mathbf{1}_{T_i>t}\psi MPC_{i,t}$. As shown in Proposition 1 when $Cov(MPC_{i,t}, NNP_{i,-1}) > 0$, aggregate labor declines $dl_t < 0$ only if the retirees (with $MPE_{i,t} = 0$) have enough wealth to offset the positive $Cov(\mathbf{1}_{T_i>t}MPE_{i,t}, \mathbf{1}_{T_i>t}NNP_{i,-1}) > 0$ of households in the labor force ($T_i > t$). When bequest motives imply $Cov(MPC_{i,t}, NNP_{i,-1}) < 0$, the covariance $Cov(MPE_{i,t}, NNP_{i,-1}) < 0$ is negative even in the absence of retirement. Therefore an unexpected increase in inflation still implies persistently lower labor supply $dl_t < 0\ \forall t \geq 0$.

E Additional figures

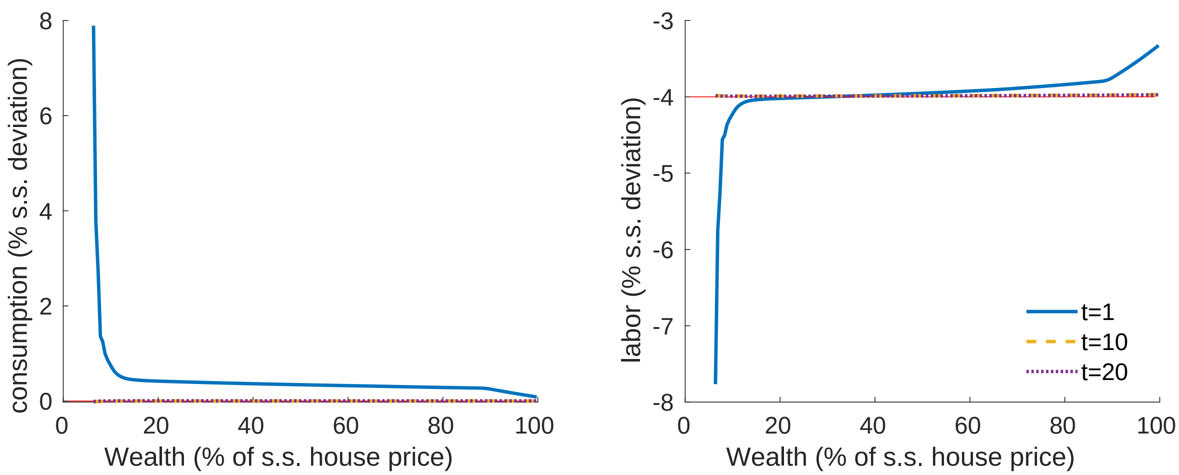


Figure A-10: Consumption and labor supply responses conditional on wealth dissipate quickly. We report the deviations of consumption and labor supply from their steady state level $\hat{c}^i_t(\Psi(b, h = 1), h = 1, z = 1)$ across employed borrowers conditional on their wealth level (borrowers have to have collateral thus $h_{i,t-1} = 1$; also $z_{i,t-1} = 1$, and the remaining state variable $b_{i,t-1}$ can be mapped to wealth $\Psi_{i,t}(b_{i,t-1}, h_{i,t-1} = 1)$. On impact all borrowers increase consumption. This is especially true for borrowers close to the borrowing constraint, who also lower their labor supply. Wealthier borrowers increase their labor supply despite higher consumption due to higher wages. In periods 10 and 20 there is no significant deviation of conditional consumption and labor supply from steady-state for any wealth level.

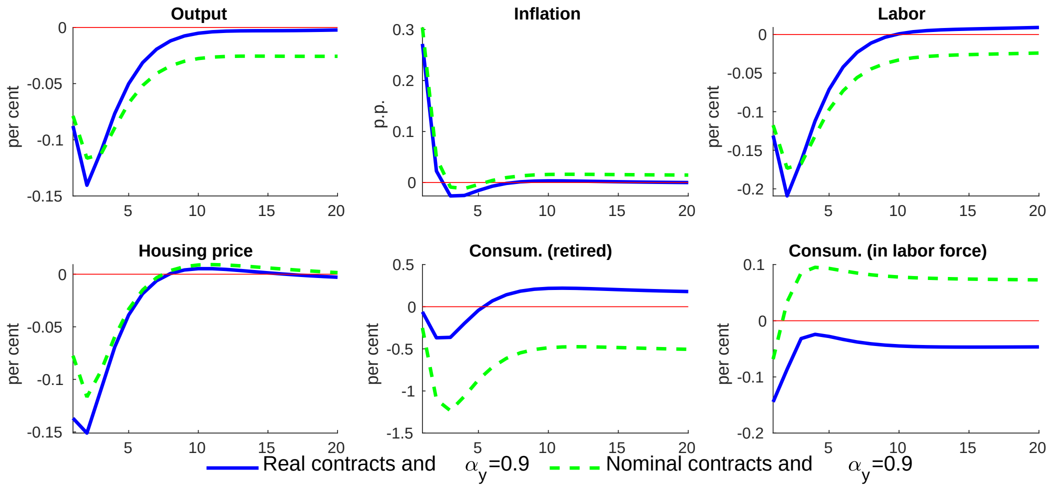


Figure A-11: Comparison of markup shocks in an economy where monetary policy tradeoffs inflation and output stabilization ($\alpha_y = 0.9$): in an economy with real contracts the redistribution is significantly weaker and output and inflation converge back to the steady state.

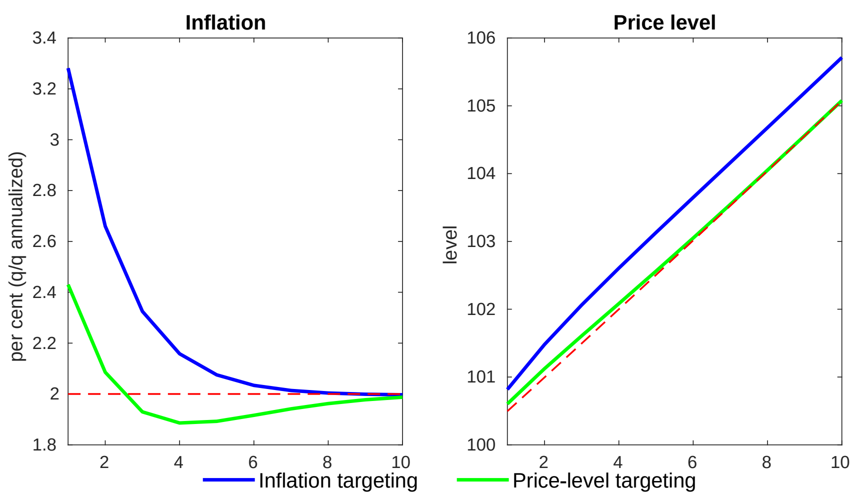


Figure A-12: Illustration of the difference between PLT and IT (responses to scaled-up monetary shock). PLT offsets the initial increase of inflation following a monetary policy shock in order to return to the targeted trend in the price level.

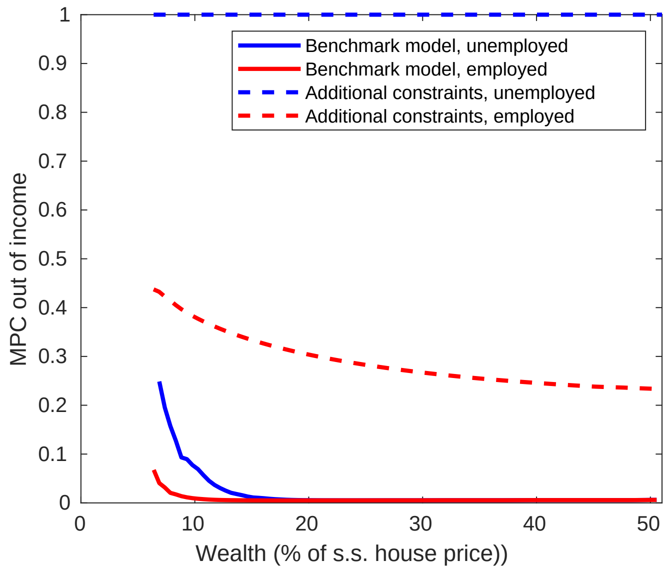


Figure A-13: The effect of additional mortgage refinancing constraints on the marginal propensity of consume (MPC) out of transitory income. We report MPCs for employed and unemployed households that are affected by additional constraints (i.e. households with large leverage $-b_{i,t-1} > \underline{\theta} q_t^h$). We compare these to the MPCs in the benchmark model.

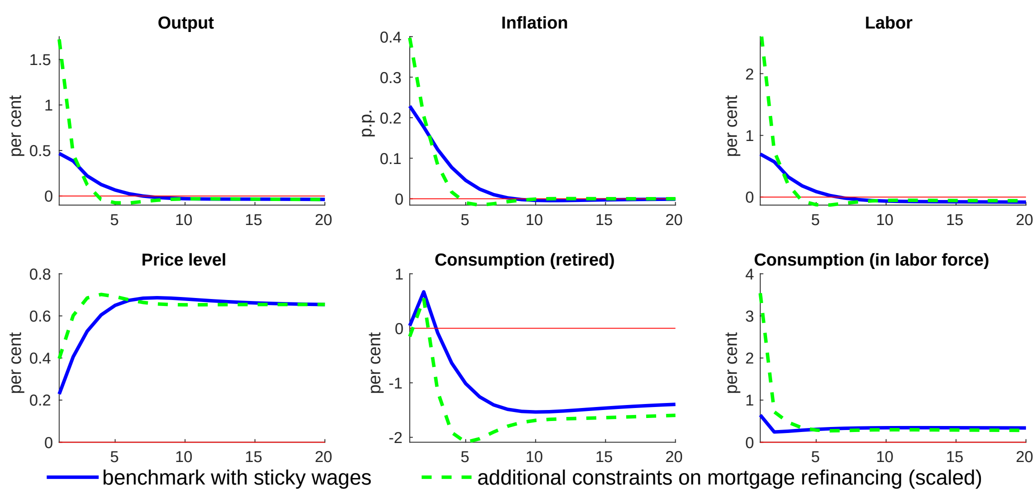


Figure A-14: The effect of additional mortgage refinancing constraints when the cumulative effect on the price level is matched (the shock affecting the constrained economy is scaled down). The effect of monetary policy easing is more pronounced on impact. The medium-term effects on output are unchanged.

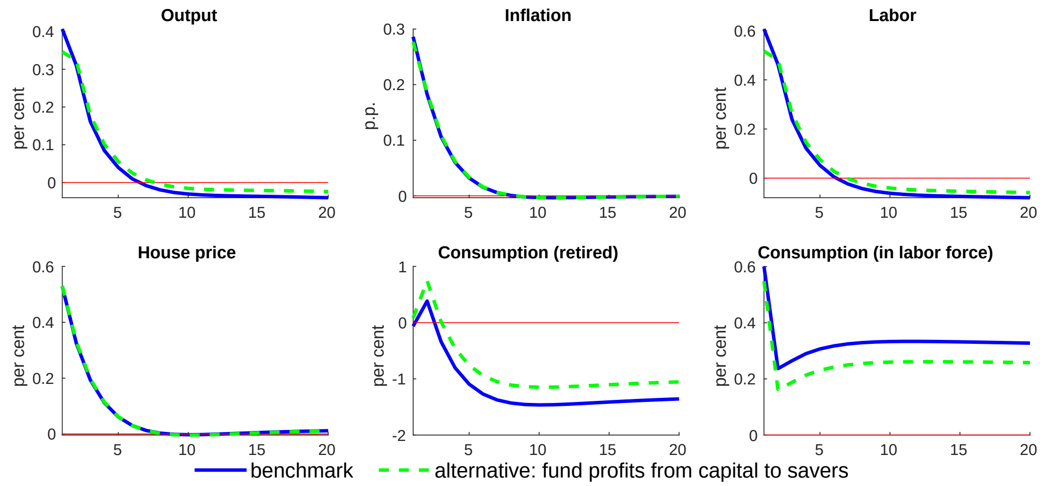
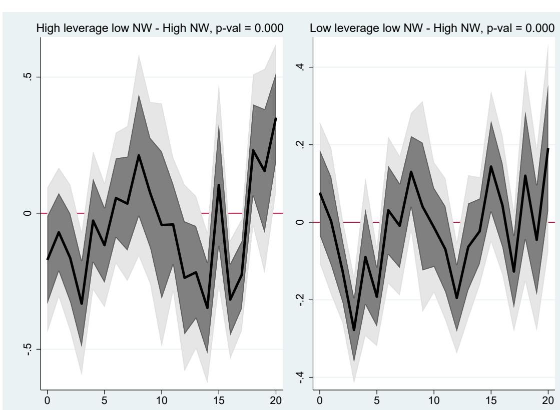
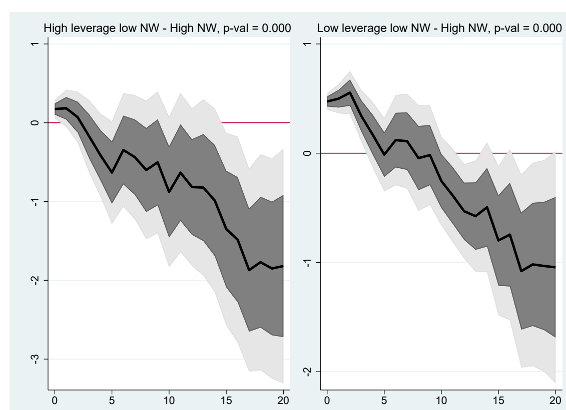


Figure A-15: Impulse responses to monetary easing in the benchmark model where part of fund's purchases of capital are financed by issuance of long-term bonds bought by households and in the alternative where saving households get all profit from the fund's purchases and capital rents (as if households held capital directly). Since this reduces the net nominal position of saving households who now hold more real assets, the redistribution effects and the related medium-term effects are reduced.

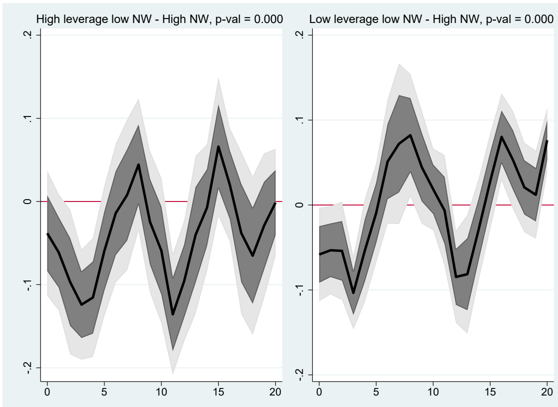


(a) Earnings response to 1 p.p. easing monetary policy shock

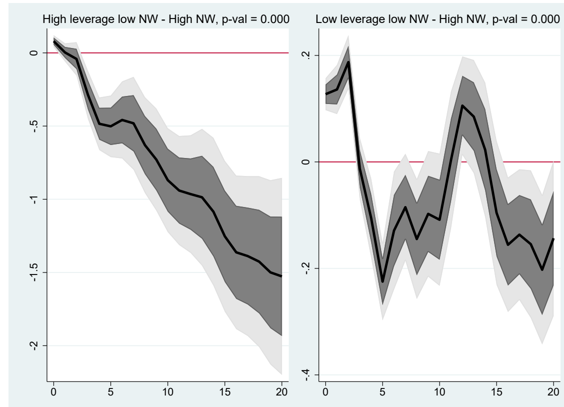


(b) Earnings response to 1 p.p. increase in inflation target

Figure A-16: Case of non-white households: Difference in mean of log earnings responses between high leverage low net-worth households (low leverage low net-worth) and high net-worth households (respectively). Panel (a) uses Romer and Romer (2004) MP shocks and panel (b) uses inflation target shocks from Coibion and Gorodnichenko (2011). Horizontal axis is time in quarters. Dark and light grey areas represent confidence intervals of one and 1.65 standard deviations, respectively. Reported p-val are for the null hypothesis that the impulse response is zero for every quarter plotted.



(a) Earnings response to 1 p.p. easing monetary policy shock



(b) Earnings response to 1 p.p. increase in inflation target

Figure A-17: Case with all households (white and non-white) combined: Difference in mean of log earnings responses between high leverage low net-worth households (low leverage low net-worth) and high net-worth households (respectively). Panel (a) uses Romer and Romer (2004) MP shocks and panel (b) uses inflation target shocks from Coibion and Gorodnichenko (2011). Horizontal axis is time in quarters. Dark and light grey areas represent confidence intervals of one and 1.65 standard deviations, respectively. Reported p-val are for the null hypothesis that the impulse response is zero for every quarter plotted.

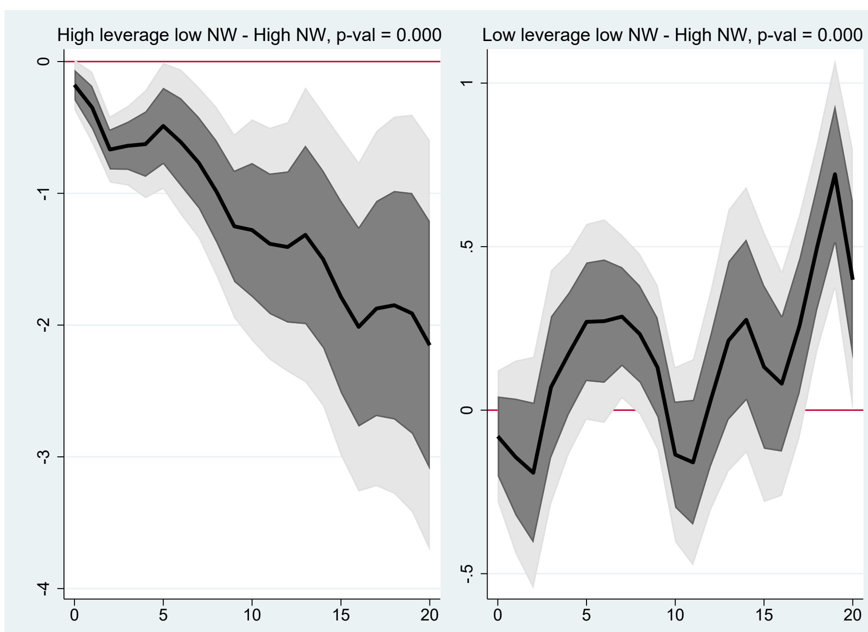


Figure A-18: Difference in mean of log earnings responses between high leverage low net-worth households (low leverage low net-worth) and high net-worth households (respectively) to 1 p.p. increase in inflation target using Ireland (2007) shocks. Horizontal axis is time in quarters. Dark and light grey areas represent confidence intervals of one and 1.65 standard deviations, respectively. Reported p-val are for the null hypothesis that the impulse response is zero for every quarter plotted.

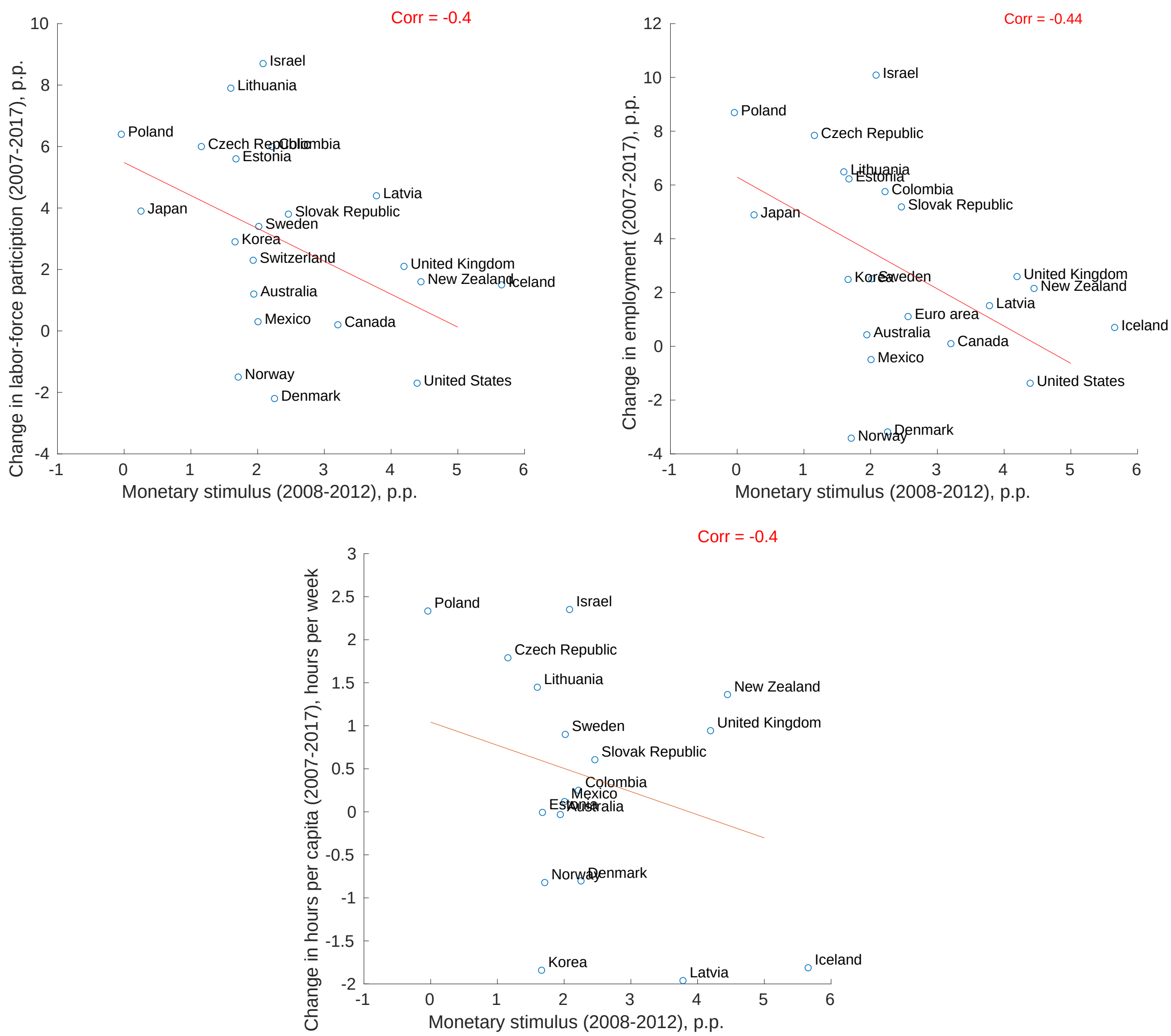


Figure A-19: Monetary stimulus after the crisis is negatively correlated with labor supply. We report the correlation coefficient, and the red line represents the regression. Monetary stimulus is measured as the average short-term nominal rate over 2008-2012 relative to the average level in 2007. The labor supply change is measured as the level at the end of 2017 relative to the level at the end of 2007. We report the change in the labor participation rate, employment rate and the hours per person in the age group 25 to 65 years of age. We include all countries available in the database of the Organisation for Economic Co-operation and Development (OECD) while excluding member countries of the euro area in 2007 as these by definition receive the same stimulus. Data source: OECD.