Distributional Imbalances, Monetary Policy, and the U.S. Business Cycle

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Abstract

Cyclical changes in U.S. income and wealth inequality during 1954-2009 affect the macroeconomy through persistent shifts in aggregate demand, have limited influence on output cycles (4-7%), explain a sizable part of debt fluctuations (35-45%) but do not account for the debt pileup prior to the Great Recession which is explained by credit relaxation based on a proposed and estimated with Bayesian mixed-frequency techniques DSGE model featuring ten sources of stochastic variation. Monetary policy surprises trigger negligible pro-(counter-)cyclical swings in income (wealth) inequality over time. An aggressive stance against inflation stabilizes the economy in response to swings in inequality, while a policy response to inequality entails small gains for the inflation-output gap variability trade-off.

Keywords: Distributional Imbalances, Aggregate Demand, DSGE, Bayesian Estimation

JEL classification: E32, E52

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1 Introduction

Despite rising interest in U.S. inequality, still little is known about its macroeconomic implications. A relatively older literature finds mixed evidence about the implications of inequality for long-term growth [Alesina and Rodrik, 1994; Persson and Tabellini, 1994; Alesina and Perotti, 1996; Banerjee and Duflo, 2003; Barro, 2000], while recent studies show that the origins of soaring U.S. household debt can be found on the coincidently rising top income share [Kumhof et al., 2015] and volatility of earnings [Iacoviello, 2008] since the 1980s. Such findings urge the study of the financial markets and inequality nexus [Stiglitz 2014, 2015].

Nevertheless, the above studies adopt a long-run perspective on the macroeconomic implications of inequality leaving unexplored their short- to medium-run effects. The present paper fills this void by examining the implications of changes in income and wealth inequality for macroeconomic cycles, aggregate demand gyrations, debt swings, and monetary policy. More specifically, the present work quantitatively evaluates a long-time-held view suggesting that distributional shifts do not influence the business cycle, and identifies the response of aggregate demand that is missing from the above studies. Studying the implications for debt swings sheds light on the portfolio adjustments of households in the face of fluctuations in inequality. Jointly examining monetary policy and inequality allows to address concerns about the policy effectiveness in the presence of inequality [Greenspan, 1998; Bullard, 2014; Bernanke, 2015; Coeuré, 2012; Mersch, 2014; Panetta, 2015; Draghi, 2016].

The present work, therefore, identifies the business cycle implications of inequality by studying the evolution of income and wealth inequality, household debt, and macroeconomic conditions jointly over a period of five decades (1954-2009) in U.S. through structural lenses. It introduces heterogeneous agents and imbalances in a medium-scale model building on the workhorse model for policy analysis [Christiano et al. 2005; Smets and Wouters 2007], and estimates it. Agent heterogeneity is projected in two fixed groups – the top and the middle class. The two dimensions sufficiently approximate reality where a disconnect between the top and the rest of the distribution is well-documented\(^1\). The imbalances pertain to two facts. First, at each point in time, the model features distributional imbalances – an unequal distribution of income and wealth – which differ from the equitable distribution of the representative agent (RA) model. Second, due to inequality, macroeconomic conditions in

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\(^1\)As argued by Kumhof et al. (2015), the stable or slightly declining income mobility in the U.S. since the 1950s [Kopczuk et al., 2010] provides some support to the consideration of two agent groups.
response to aggregate shocks can potentially differ from those implied by the same shocks in the RA model. The sources of imbalances entail an exogenous and an endogenous component.

The exogenous component pertains to three “distributional” shocks generating dispersion in wages, wealth, and credit availability between the top and the middle class. Wage polarization shocks introduce time-varying incomplete wage insurance, and build on Walsh (2017) who introduces a similar, albeit deterministic, scheme. In a similar spirit, Lansing and Markiewicz (2018) consider shocks in a labor aggregator reflecting changes in the skill premium. Wealth shocks, modeled as disturbances in preferences for wealth, are similar to those considered in [Fisher, 2015; Krishnamurthy and Vissing-Jorgensen, 2012; Iacoviello and Neri, 2010; Iacoviello, 2005]. The interaction of wealth shocks with heterogeneous preferences for wealth, however, leads to heterogeneous shock influence reflecting unequal investment opportunities and returns. The latter are documented by Fagereng et al. (2018) using tax records, while Lee (2012) models partial insurance of returns. Credit supply shocks are modeled as stochastic variations in the borrowing limit [Justiniano et al., 2015].

The endogenous component of imbalances pertains to the heterogeneous household responses spurred by all shocks that are filtered through the channels of imperfect financial insurance and heterogeneous marginal propensities to consume (MPC). Intra-family loans provide partial insurance since the borrowing middle class (due to a lower discount factor than the top) can renge on its obligations as in Kiyotaki and Moore (1997) and Iacoviello (2005). As a result, lenders ask for collaterals that are met by the assets of the middle class (firm ownership), and distributional shocks are rendered relevant for equilibrium dynamics. Moreover, heterogeneous preferences over wealth, encapsulating Carroll (2000)’s argument that wealth confers social status, amplify the MPC differentials.

Through a full-information Bayesian approach, the model explains the U.S. top income and wealth deciles, household debt, and seven aggregate series jointly over a period of five decades. Parameters are estimated, and both aggregate and distributional shocks are extracted within the model. Since the inequality series are in annual terms whereas all other data are available in a quarterly frequency, mixed frequency estimation is conducted. Multiple series for debt and a latent factor approach strengthen identification. To deal with the large state space dimensionality, I borrow an efficient treatment of it from the econometrics literature and operationalize it in a DSGE and mixed frequency context.

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2 See Alichi et al. (2016), Phillippon and Reshef (2012), and Heathcote et al. (2010) for empirical evidence.
1.1 FINDINGS.

The findings corroborate the view that changes in income and wealth inequality have limited effect on output cycles. The combined effect of distributional shocks, which explains the majority of the swings in income and wealth inequality, accounts for about 10/6% of output cycles in the short/medium run: polarization, wealth, and credit shocks account for 3/2%, 4/2%, and 3/2% of those cycles, respectively. Moreover, that influence does not have a time-varying size, is robust across a battery of checks, and operates through shifts in aggregate demand: when distributional shocks hit the households’ optimization, they trigger persistent consumption responses across the population that do not net out entirely to zero.

The distributional shocks, however, explain a sizable part of the swings in household indebtedness: 75/52% in the short/medium run\(^3\). Inequality swings and fluctuations in household debt positions are, therefore, connected as in Kumhof et al. (2015) and Iacoviello (2008). Contrary to Kumhof et al. (2015), however, rising income inequality weakens the collateral channel and, hence, does not suffice to explain the debt pileup prior to the Great Recession. Neither does rising wealth inequality accounted for to a large extent by wealth shocks that generate a negative correlation between wealth inequality and debt. The heterogeneous dynamics induced by the triplet of distributional shocks, therefore, render credit supply shocks a major force behind the debt pileup during the decades prior to the Great Recession. Credit relaxation, thus, has a pronounced role in debt accumulation in line with Mian and Sufi (2018), but limited implications for output in line with Justiniano et al. (2015).

As for the transmission of distributional shocks, wage polarization shocks entail a positive output elasticity reflecting the pro-cyclicality of the top income decile in the data. They contract middle-class consumption, and lead to pro-cyclical responses in both income and wealth inequality. Since they drastically alter the distribution of assets and, thereby, the ability of middle class to post collaterals, the collateral channel worsens their impact. Put differently, access to credit is harder when inequality rises. Both wealth and credit supply shocks yield positive elasticities for output and the top income decile (since they increase the debt burden of the middle class). Although credit shocks lead to a positive correlation between wealth inequality and debt, wealth shocks lead to a negative correlation. The reason

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\(^3\)In modeling debt, I follow the mainstream approach of Iacoviello (2005). Debt is amortized within a quarter which according to Gelain et al. (2018b, 2018a), renders debt sensitive to (aggregate) shocks. The estimation may partially resolve the tension between the adopted modeling and the low-frequency observed debt dynamics in the likelihood construction by boosting the influence of distributional shocks on debt.
is that after credit shocks asset prices, and thereby the top’s-bonds-to-economy-wide-wealth ratio, do not respond as much as they do after wealth shocks.

The present paper quantifies the effect of erratic and unpredictable fluctuations in the policy instrument on the path of income and wealth inequality, and shows that it has been negligible throughout the sample. Expansionary fluctuations, in fact, raise income inequality because profits are unequally distributed, and decrease wealth inequality because low lending costs help the middle class acquire assets. As for the systematic part of monetary policy, the findings suggest that the policy transmission channel is not broken in the presence of inequality. An aggressive stance towards inflation stabilizes the economy even when the economy wide fluctuations emanate from distributional shocks because inflation and aggregate demand are pro-cyclical in response to these shocks. Nonetheless, reacting to either income, or wealth, or consumption inequality directly and not only through general equilibrium effects, entails small gains in the variability of the output gap that is linked to the variability of aggregate demand, in exchange of inflation volatility.

Comparing the results from the RA model to those of this paper reveals that, in the former, the persistence in aggregate consumption is captured by endogenous sources of persistence and, in particular, habit formation whereas, in the latter, the importance of habit is attenuated (from 0.77 to 0.51) and replaced by persistent changes in income and wealth inequality. Heterogeneous preferences and imperfect insurance, in contrast, amplify the volatility of aggregate demand. In general, the findings suggest a dichotomy in identification: parameters associated with the model’s aggregate dimension are identified mainly by aggregate data, whereas inequality data are informative for the parameters associated with distributional imbalances. Moreover, in the present model, risk premium and investment shocks obtain a tad more elevated (ephemeral) role in output (consumption) cycles compared to the RA model, suggesting that with distributional shocks incorporated demand shocks contribute less to the output–consumption correlation. Furthermore, the analysis pins down the direction and size of the impact of aggregate shocks on inequality; for example, these shocks explain 39/10% of the swings in short/medium-run wealth inequality.

The literature review follows below. Section 2 outlines the structural model. Section 3 elaborates on the estimation strategy. Section 4 presents the results. Section 5 concludes.
1.2 Related Literature.

In tackling inequality and debt, the present paper relates to Iacoviello (2008) and Kumhof et al. (2015). Both of these papers feature exogenous production and, thereby, preclude a recurrent impact of changes in inequality on output. In contrast, in the present work, endogenous production enables the emergence of an aggregate demand channel. As in Kumhof et al. (2015), I consider two agent groups. These authors consider the top and the rest of the distribution, where the latter involves borrowers with no assets holdings. In this paper, however, I consider middle-class households who hold both liabilities and assets in their portfolio allowing for a broad view on the balance sheet of households outside of the top.

This perspective on the portfolio of agents also distinguishes this work from Cairó and Sim (2018) who endogenize production in the framework of Kumhof et al. (2015). These authors assume that workers only receive wages whereas shareholders own capital and firms but do not supply labor. The present paper’s framework, though, allows to match income and wealth inequality simultaneously for both agent groups. In addition, the present approach to the middle-class portfolio along with the extraction of distributional shocks from the data within a structural setup contributes in the strand of two-agent NK models featuring a fraction of agents excluded from financial markets, and abstracting from including information found in inequality series [Debortoli and Galí, 2018; Walsh, 2017; Eggertsson and Krugman, 2012; Lee, 2012; Curdia and Woodford, 2010; Iacoviello, 2005].

As argued by Christiano et al. (2018), a developing research strand involves Heterogeneous Agent New Keynesian (HANK) models along the lines of Kaplan et al. (2018). Studies in that strand feature idiosyncratic risk and investigate how inequality influences demand [Werning, 2015], as well as the various channels of monetary or fiscal policy transmission to inequality [Gornemann et al., 2014; Doepke et al., 2015; Sterk and Tenreyro, 2015; Kaplan and Violante, 2014; Auclert, 2015]. Similarly to those papers, I consider a small set of assets and a fraction of financially constrained agents. Contrary to them, I consider fixed rather than endogenously formed agent groups. Although this choice does not allow the study of precautionary savings, it helps with model tractability and is consistent with the observed changes in inequality suggesting a disconnect between the top and the rest of the distribution as well as with the equilibrium formation of two groups derived in HANK models.

Another distinguishing feature of the present work is that I include seven aggregate
and three distributional shocks in total that exceed the number of shocks often considered in HANK models (two aggregate and one idiosyncratic). Moreover, contrary to HANK models involving either perfect competition or search frictions in labor markets, I consider staggered wage setting which is used in the workhorse monetary policy models. Furthermore, HANK models involve partial information approaches, namely moment matching and data treatment outside of the model. The present paper, though, adopts a full-information approach that allows to examine the joint historical evolution of U.S. inequality and macroeconomic series.

Delving into the interaction of monetary policy and inequality from a structural perspective complements a branch of the literature involving reduced-form models and examining whether various inequality series (i) are affected by policy and inflation [Lenza and Slacalek, 2018; Muntaz and Theophilopoulou, 2017; Guerello, 2017; Coibion et al., 2016; Adam and Zhu, 2015; Casiraghi et al., 2016; Furceri et al., 2016; McKinsey Global Institute, 2013; Doepke and Schneider, 2006; Romer and Romer, 1998]; (ii) are associated with credit conditions [Coibion et al., 2014; Paul, 2017]; (iii) exhibit cyclicality [De Giorgi and Gambetti, 2017]. Worth pointing out is that extracting a latent factor from multiple debt measures strengthens identification and builds on the use of multiple observables in Boivin and Giannoni (2006) and wages in Gali et al. (2012a, 2012b) and Justiniano et al. (2013).

The heterogeneity in preferences for wealth is aligned with that considered in Kumhof et al. (2015), Carroll et al. (2015), Tokuoka (2012), and Francis (2009). More generally, this formulation shares similarities with Sidrauski (1967) who introduces utility from money balances – an approach followed by Michaillat and Saez (2015) in order to study economic slack and by Zou (1998) who argues that it reflects Weber’s spirit of capitalism; with Kurz (1968) who examines non-linearities stemming from utility yielding capital in a growth model; and with Iacoviello (2005) who introduces utility from housing services.

2 Full-Fledged Model

The model builds on the medium-scale DSGE environment of Christiano et al. (2005) and Smets and Wouters (2007), and shares similarities with Iacoviello and Neri (2010) and Justiniano et al. (2015). Two families populate the economy. \( \tau \) indexes the top family and \( \mu \) indexes the middle-class family, populated by measures of \( n^\tau \) and \( n^\mu = 1 - n^\tau \) identical house-
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holds, respectively. The families differ in terms of their wealth preferences and discounting. Perfect consumption insurance holds within families. Households participate in intra-family borrowing, and trade firms’ ownership shares. Each household consists of a continuum of agents with different labor types. The differentiated labor is uniformly distributed, supplied along the intensive margin, priced in a staggered fashion by monopolistically competitive unions, aggregated and sold to monopolistically competitive intermediate good producers who rent capital from capital producers and choose prices in a staggered fashion.

2.0.1 Households. Household \(i\), with \(i \in \{\mu, \tau\}\), chooses a sequence of consumption, loans, and shares, \(\{C^i_t, B^i_t, \Omega^i_t\}\), to maximize the present discounted value of future utility:

\[
E_t \sum_{s=0}^{+\infty} (\beta^i)^s \left[ \ln \left( C^i_{t+s} - \eta C^i_{t+s-1} \right) - \theta \int_0^1 \frac{[L^i_{t+s}(j)]^{1+\chi}}{1+\chi} dj + \phi^j v^\omega t_s \ln (\Omega^i_{t+s}) \right] \tag{2.1}
\]

Preferences are log-separable, and depend on consumption, on labor disutility across \(j\) labor types, and on the ownership of firms’ shares that confers social status. \(\eta\) mirrors external habit formation, \(\chi\) is the inverse Frisch elasticity, and \(\phi^j\) captures the strength of preferences over wealth (shares) which differs across families: \(\phi^\mu \neq \phi^\tau\). \(\beta^\mu < \beta^\tau\) renders middle-class families more impatient than the top in a way analogous to that in Iacoviello (2005). \(v^\omega t_s\) stands for the wealth shock affecting wealth preferences. The combination of that shock and heterogeneous \(\phi^j\) creates wealth dispersion, and potentially captures unequal access to investment opportunities. \(\ln(v^\omega t_s)\) follows an AR(1) process with parameters \(\{\rho_\omega, \sigma_\omega\}\).

The budget constraint for a middle-class household is given by

\[
C^i_t + Q_t \left[ \Omega^i_t - (1 - S_{\omega}(\Omega^i_t/\Omega^i_{t-1})) \Omega^i_{t-1} \right] + T^i_t/P_t = Y^i_t \tag{2.2}
\]

\[
Y^i_t \equiv \int W^{i,h,r}_t(j) L^i_t(j) dj + F^\mu_t + \left[ B^i_t/(e^{v^\mu t_t} R_t P_t) - B^i_{t-1}/(P_t-1) \right] + \Omega^i_t V_t \tag{2.3}
\]

The budget constraint of a top household is symmetric to the above, bonds enter with the opposite sign though. \(Y^i_t\) is the pre-tax income. \(v^\beta_t\) is a risk premium shock following an AR(1) process with parameters \(\{\rho_\beta, \sigma_\beta\}\). \(S_{\omega}(\cdot)\), with \(S_{\omega}(1) = S_{\omega}(1)' = 0\) and \(S''_{\omega}(1) \equiv S_{\omega} > 0\), stands for portfolio adjustment costs. \(Q_t\) is the shares’ price in terms of the final good. \(\Pi_t\) stands for price inflation. \(V_t\) denotes economy wide profits. \(T^i_t\) stands for nominal taxes. \(W^{i,h,r}_t(j)\) is the real wage of labor type \(j\) in household \(i\) that would prevail in the absence of rigidities, and is equal to the marginal labor disutility expressed in consumption terms:

\[6\] \(\eta, \theta, \chi\) are common across agents. This assumption, albeit stylized, ensures that the steady state of economy wide aggregates is the same as that in the representative agent model; that region is a natural starting point. Identifying heterogeneous \(\eta, \theta, \chi\) would require heterogenous consumption and labor data.
where $\Xi^i_t$ is the multiplier associated with the budget constraint. The second equality in (2.4) holds in equilibrium, and uses the fact that type-$j$ labor is determined by the labor union’s problem independently of the household identity.

Contrary to Smets and Wouters (2007) who consider an equal distribution of labor income ($W^t L_t$), but along the lines of Walsh (2017) and Lee (2012) who consider partial, albeit deterministic, income insurance, aggregate income is distributed to households via an imperfect wage insurance scheme. Household members supply labor, pool together wages across unions, but when the wage bill is allocated, they only receive a fraction of what would be allocated under perfect insurance. Thus, transfers $F^i_t$ from the unions read as

$$F^\mu_t = s_t W^t L_t / n^\mu - \int W^{i,h,r}_t(j) L^i_t(j) dj$$

for the middle class and, symmetrically, as $F^\tau_t = (1-s_t) W^t L_t / n^\tau - \int W^{i,h,r}_t(j) L^i_t(j) dj$ for the top. $s_t$ stands for the time-varying wage share of the middle class; it is a wage polarization shock generating wage dispersion between the top and the middle class. For $s_t = n^\mu$, the scheme boils down to an equitable wage distribution. $\tilde{s}_t \equiv \ln(s_t / \bar{s})$ follows an AR(1) process with associated parameters $\{\rho_s, \sigma_s\}$ and steady state $\bar{s}$.

Along the lines of Kiyotaki and Moore (1997) and Iacoviello (2005), middle-class borrowers can default, in which case lenders receive a fraction $m_t$, with steady state $m$, of the posted collateral. $\ln(m_t)$ follows an AR(1) process with parameters $\{\rho_m, \sigma_m\}$. The shares serve as collateral and have no impact on the production function as in Gelain et al. (2018b, 2018a). Thus, borrowing $B^i_t / (e^{v^t R_t} P_t)$ is up to a period-t limit determined by:

$$B^i_t / [e^{v^t R_t} P_t] \leq m_t E_t \left( Q_{t+1} \Omega_t^{\mu} \Pi_{t+1} / [e^{v^t R_t}] \right)$$

Two remarks are in order. First, modeling the polarization shock through (2.5) allows that shock to enter in the budget constraint that becomes relevant for equilibrium dynamics because of the financial market imperfection. In contrast, under perfect insurance, shocks in polarization and the debt limit would play no role, while wealth shocks would lose interpretation. Thus, hurdles in perfect insurance play a catalytic role for distributional shocks to have an impact. Second, the wage shock does not affect the marginal labor disutility. If it did, it would appear in the wage Philips curve and be convoluted with wage markup shocks.
2.0.2 Capital. As in Chen et al. (2012), a representative capital producer invests $I_t$ in raw capital, $K_t$, subject to adjustment costs $S(I_t/I_{t-1})$. It chooses the utilization rate $u_t$ that determines the effective capital, $K_t = u_tK_{t-1}$, subject to utilization costs that are proportional to the last period’s raw capital $(a(u_t)K_{t-1})$. The rental rate of capital is denoted by $R_t^k$. The firm maximizes the present discounted value of future dividends,

$$E_t\sum_{s=0}^{\infty} \left[ (\Xi^{avg}_{t+s}P_t)/(\Xi^{avg}_{t}P_{t+s}) \right] \left[ R_{t+s}K_{t+s} - P_{t+s}a(u_{t+s})K_{t+s-1} - P_{t+s}I_{t+s} - Z_{t+s}P_{t+s}\Phi_k \right]$$

subject to the law of capital accumulation: $\dot{K}_t = (1 - \delta)K_{t-1} + v_t^i(1 - S(I_t/I_{t-1}))I_t$. The steady state full utilization is associated with zero cost: $a(1) = 0$. As in Smets and Wouters (2007), the properties of the cost functions are defined so that $a(1)/a(1) = \psi/(1 - \psi)$, $S(e^\gamma) = S(e^\gamma)' = 0$, and $S(e^\gamma)'' \equiv S > 0$. $\gamma$ is the growth rate of aggregates along the balanced growth path, and $Z_t = e^\gamma Z_{t-1}$ reflects trend growth. $\delta$ is the depreciation rate. Fixed costs ($\Phi_k$) ensure zero steady state dividends. $v_t^i$ is an investment disturbance; $ln(v_t^i)$ follows an AR(1) process with associated parameters $\{\rho_i, \sigma_i\}$. $\Xi^{avg}_{t+s}/\Xi^{avg}_{t}$ stands for the average discounting between $t + s$ and $t$, defined as: $(\beta^r)^s[n^o\Xi^{t+s}_t + n^o\Xi^{t+s}_t]/[n^o\Xi^t_t + n^o\Xi^t_t]^7$.

2.0.3 Final Good. A perfectly competitive final good producer purchases and aggregates intermediate goods $Y_t(i), \forall i \in [0,1]$, to output $Y_t$ according to technology $Y_t = \int_0^1 Y_t(i)^{(\lambda_{p,t} - 1)/(\lambda_{p,t} - 1)}\lambda_{p,t}/(\lambda_{p,t} - 1)$. $\lambda_{p,t}$ is the time varying elasticity of substitution across product varieties, with the gross markup, $\lambda_{p,t}/(\lambda_{p,t} - 1)$, following an AR(1) process with parameters $\{\rho_p, \sigma_p\}$. The associated demand for good $i$ and the aggregate price index are

$$Y_t(i) = [P_t(i)/P_t]^{-\lambda_{p,t}Y_t} \quad \text{and} \quad P_t = [f P_t(i)^{-\lambda_{p,t}d_i}]^{1/(1-\lambda_{p,t})} \quad (2.8)$$

2.0.4 Intermediate Good. Monopolistically competitive intermediate good producers, indexed by “i” and situated in the unit interval, hire labor $L_t(i)$ from a labor aggregator defined below, and capital $K_t(i)$ from the capital producing sector while taking as given factor prices $(W_t, R_t^c)$, in order to produce output $Y_t(i)$ according to the production function:

$$Y_t(i) = e^{\tilde{z}_i}K_t(i)^{\alpha} (Z_tL_t(i))^{1-\alpha} - Z_t\Phi_y \quad (2.9)$$

$\tilde{z}_i$ is the technology shock following an AR(1) process with associated parameters $\{\rho_z, \sigma_z\}$. Fixed production costs, $\Phi_y$, guarantee zero steady state profits. Cost minimization

\[\footnote{This definition simplifies a discount factor that would take into account the time-varying ownership of firms and severely complicate the equations governing capital and investment and their associated steady state expressions – the chosen definition keeps them isomorphic to their representative agent analogues.}
yields the optimal capital-labor ratio, \( K_t(i)/L_t(i) = [\alpha/(1 - \alpha)](W_t/R_t^k) \), and marginal cost, 
\[
MC_t = (\alpha)^{-\alpha}(1 - \alpha)^{-(1-\alpha)}(W_t)^{(1-\alpha)}(R_t^k)^{\alpha}Z_t^{-(1-\alpha)}e^{-\hat{\xi}_t} \tag{2.10}
\]

Each firm chooses price \( P_t^o(i) \) with probability \( \zeta_p \). In periods in which the price cannot be optimally chosen, it is updated according to a convex combination of lagged and steady-state (gross) inflation based on the indexation parameter \( \tau_p \). Thus, the period-\((t + s)\) price of a firm that last chose its price in period \( t \) is given by 
\[
P_{t+s|t}(i) = P_{t+s}(i)X_{t+s}^p, \text{ where } X_{t+s}^p \equiv \prod_{i=1}^{s} r_{t+s} \Pi_{t+1}^{1-\tau_p} \text{ for } s > 0 \text{ and } 1 \text{ for } s = 0.
\]
The firm maximizes the present discounted value of current and expected future profits subject to output demand \( (2.8) \),
\[
E_t \sum_{s=0}^{+\infty} (\zeta_p)^s \left[ \left( \Xi_{t+s}^{avg}(P_t) / \Xi_{t+s}^{avg}(P_{t+s}) \right) \right] \left[ P_{t+s|t}(i) - MC_{t+s} \right] Y_{t+s|t}(i) \tag{2.11}
\]

2.0.5 Labor Demand. Individuals of the same labor type \( j \) form a union that operates in a monopolistically competitive environment and sets wages in a staggered fashion. The unions sell differentiated labor to a labor agency that aggregates it according to technology
\[
L_t = [\int L_t(j)λ_{w,t-1}/λ_{w,t}dj]λ_{w,t}/(λ_{w,t}-1).
\]
\( \lambda_{w,t} \) is the time varying elasticity of substitution across labor varieties, with the gross markup, \( \lambda_{w,t}/(\lambda_{w,t} - 1) \), following an AR(1) process with parameters \( \{ρ_w, σ_w\} \). The associated demand for type \( j \) and the aggregate wage are
\[
L_t(j) = [W_t(j)/W_t]^{-λ_{w,t}} L_t \quad \text{and} \quad W_t = [\int W_t(j)^{1-λ_{w,t}}dj]^{1/(1-λ_{w,t})} \tag{2.12}
\]

The type-\( j \) labor union, in turn, takes into account labor demand \( (2.12) \) and chooses wage \( W_t^o(j) \) in a staggered way à la Calvo-Yun and Erceg et al. (2000), in order to maximize the present discounted value of expected future wages net of the economy wide average type-\( j \) labor disutility expressed in terms of the final good. Given equation \( (2.4) \) and the uniform distribution of labor types within each household, the latter is given by:
\[
W_t^h(j) = n^\mu W_t^{\mu,h,\tau}(j) + n^\tau W_t^{\tau,h,\tau}(j) = θL_t(j)^{λ}[n^\mu/\Xi_t^\mu + n^\tau/\Xi_t^\tau] \tag{2.13}
\]

When wages are not reset, they are updated according to lagged and steady-state price inflation based on the indexation parameter \( \tau_w \): 
\[
W_{t+s|t}(j) = W_{t+s}(j)X_{t+s}^w, \text{ where } X_{t+s}^w = \prod_{i=1}^{s} (e^{\gammaΠ_{t+s-1}})^{w} (e^{\gammaΠ})^{1-\tau_w} \text{ for } s > 0 \text{ and } 1 \text{ for } s = 0.
\]
The objective function of a union is:
\[
E_t \sum_{s=0}^{+\infty} (ζ_w)^s \left[ \left( \Xi_{t+s}^{avg}(P_t) / \Xi_{t+s}^{avg}(P_{t+s}) \right) \right] \left[ W_{t+s|t}(j) - W_{t+s}^h(j)P_{t+s} \right] L_{t+s}(j) \tag{2.14}
\]

2.0.6 Policy. Monetary policy follows a Taylor rule with interest rate smoothing.
\[ \frac{R_t}{R_t} = (R_{t-1}/R)^{\rho_f} [(\Pi_t/\Pi)^{\psi_c} (Y_t/Y_t^f)^{\psi_y} [(Y_t/Y_{t-1})/(Y_{t-1}^f/Y_{t-1})]^\psi_{\Delta_y}]^{1-\rho_f} e^{v_{t}^{mp}} \]  

\[ v_{t}^{mp} \sim N(0, \sigma_{mp}^2) \]  

is a white noise disturbance. \( Y_t^f \) denotes output under flexible prices and wages and perfect insurance. Fiscal policy follows a balanced budget: \( P_t G_t = T_t \), where \( \ln(G_t/Z_t) = \rho_g \ln(G_{t-1}/Z_{t-1}) + \rho_g \epsilon_t^g + \epsilon_t^g \), with \( \epsilon_t^g \sim N(0, \sigma_g^2) \). To avoid additional complications, the tax burden is equally distributed across households: \( T_t^{\iota} = T_t^{\mu} = T_t^\gamma = T_t^8 \).

2.0.7 Aggregation. Consumption is the weighted sum of family-specific consumption profiles: \( C_t = n^\tau C_t^\tau + n^\mu C_t^\mu \). After using (2.9) and the capital-labor ratio, the aggregate production function reads as: \( Y_t = e^{z_t} K_t^\alpha (L_t Z_t)^{1-\alpha} - Z_t \Phi_y \). Market clearing dictates \( n^\tau B_t^\tau = n^\mu B_t^\mu \) in the debt market, and \( n^\tau \Omega_t^\tau + n^\mu \Omega_t^\mu = \Omega_t \equiv 1 \) in the market for shares – the sum of shares is normalized to unity. Profits in the intermediate good sector are: \( \Pi_t^{int} = Y_t - W_t^r L_t - R_t^{k,r} K_t \). The dividends from capital production are given by \( Div_t = R_t^{k,r} K_t - a(u_t) \bar{K}_{t-1} - I_t - Z_t \Phi_k \). Thus, the economy wide profits distributed to households according to their shares are: \( V_t = \Pi_t^{int} + Div_t \). Combining the household (2.3) and government budget constraints, financial market clearing, and profits, yields the resource constraint

\[ C_t + I_t + G_t + AC_t + \Phi_k Z_t = Y_t \]  

(2.16) featuring adjustment costs: \( AC_t = a(u_t) \bar{K}_{t-1} + Q_t [n^\mu \Omega_t^\mu S_{\omega} (\Omega_t^\mu/\Omega_{t-1}^\mu) + n^\tau \Omega_t^\tau S_{\omega} (\Omega_t^\tau/\Omega_{t-1}^\tau)] \).

2.0.8 Equilibrium. The stationary model, the steady state, and the log-linearized equilibrium are reported in Appendix A. The steady state of aggregate variables is the same as that of the representative agent economy. The interest rate is given by \( R = \Pi e^{\gamma} / \beta^r \). Moreover, the steady state features heterogeneous consumption, debt, and shares, as well as a binding constraint (2.6) since \( \beta^r > \beta^\mu \). I examine equilibria in which the constraint binds.

The model features 10 structural shocks. The 7 aggregate shocks are those considered in the representative agent model [Smets and Wouters, 2007]: risk premium, technology, wage and price markups, government spending, investment, and monetary policy shocks. To the above set of shocks, wage polarization, wealth, and credit supply shocks are added.

---

8 In the canonical model, the way in which government spending is financed, be it taxation or one-period bonds, is irrelevant in the log-linearized equilibrium. With heterogeneous households and financial frictions, this no longer is the case. Justiniano et al. (2015) consider some degree of heterogeneous taxation.
3 Estimation

I conduct mixed-frequency estimation over quarterly and annual data series starting in 1954Q3 and stopping in 2009Q4 to avoid getting further into the zero lower bound period. I discuss below the data, the measurement equations, and how I apply the state space approach of Chan and Jeliazkov (2009), along the lines of Charalampidis (2018), that leads to computational gains by exploiting the sparse and block-banded nature of precision matrices.

3.1 Data And Observation Equations.

\[ t = \{1, 2, \ldots, n_q\} \mapsto \{1964Q1, \ldots, 2007Q4\} \text{ and } T = \{1, 2, \ldots, n_T\} \mapsto \{1964, \ldots, 2007\} \]

denote the quarterly and annual time spans of the sample, respectively. Ten \( o_q \) quarterly series are used. Per capita real growth of output, consumption, and investment, along with labor hours, the Federal Funds Rate, the GDP deflator, and the growth rate of the compensation index are obtained from the sources described in Smets and Wouters (2007)\(^9\).

Two quarterly measures of real per capita household debt, loaded with measurement error, aim to discipline the evolution of debt. Home mortgages \((HM_t)\) and consumer credit debt \((CC_t)\) are obtained from Fred. The second series is loaded with a factor \( \Psi_b \). The observation equations are reported below, where \( dlnX_t \equiv 100(lnX_t - lnX_{t-1}) \).

\[
\begin{bmatrix}
  dlnHM_t \\
  dlnCC_t
\end{bmatrix} = \begin{bmatrix}
  100\gamma_{hm} \\
  100\gamma_{cc}
\end{bmatrix} + \begin{bmatrix}
  1 \\
  \Psi_b
\end{bmatrix} \begin{bmatrix}
  \hat{\mu}_t \\
  \hat{\mu}_{t-1}
\end{bmatrix} + \begin{bmatrix}
  \epsilon_{hm}^t \\
  \epsilon_{cc}^t
\end{bmatrix},
\begin{bmatrix}
  \epsilon_{hm}^t \\
  \epsilon_{cc}^t
\end{bmatrix} \sim N\left(\begin{bmatrix}
  0 \\
  0
\end{bmatrix}, \begin{bmatrix}
  \mu_{hm}^2 \\
  \mu_{cc}^2
\end{bmatrix}\right)
\]

(3.1)

Debt detrending is data driven and captures the fact that the sample average growth rates of home mortgage and consumer credit debt (1% and 0.7%, respectively) are well above the growth rate of output (measured at 0.4% within the sample)\(^{10}\).

Moreover, I introduce observables for the annual top 10% income and wealth shares obtained from the World Inequality Database and the work of Piketty and Saez (2003) and Saez and Zucman (2016). Table (1) gives inklings of the correlation of income and wealth inequality with macroeconomic and debt series. Income inequality is strongly procyclical, whereas wealth inequality exhibits a small degree of counter-cyclicality. Moreover, the correlation of both income and wealth inequality with output are stronger in the post-

---

\(^9\)The observation equations for that block of observables are similar to those in Smets and Wouters (2007), with the inclusion of measurement error, \( \epsilon_{b}^t \sim N(0, \mu_b^2) \), for each generic \( j \) series being the difference.

\(^{10}\)Imposing the balanced growth path trend on debt series would yield persistent and volatile measurement errors in (3.1); see earlier versions of this paper.
84 period than in the pre-84 period. Furthermore, income inequality is positively correlated with the multiple measures of household debt. Although wealth inequality does not commove with debt across the entire sample, it is actually positively correlated with debt in the years before 1984 but becomes negatively correlated after 1984.

<table>
<thead>
<tr>
<th>Year</th>
<th>TIS</th>
<th>TWS</th>
<th>Y</th>
<th>π</th>
<th>HM</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954-2009</td>
<td>1.64</td>
<td>0.30</td>
<td>0.49</td>
<td>-0.16</td>
<td>0.34</td>
<td>0.32</td>
</tr>
<tr>
<td>1954-1983</td>
<td>1.50</td>
<td>0.32</td>
<td>0.43</td>
<td>-0.19</td>
<td>0.37</td>
<td>0.43</td>
</tr>
<tr>
<td>1984-2009</td>
<td>1.69</td>
<td>0.15</td>
<td>0.68</td>
<td>0.37</td>
<td>0.23</td>
<td>0.19</td>
</tr>
</tbody>
</table>


The model-implied pre-tax top income share that is consistent with the observed series \(TIS_T\) encompasses wages, profits (entrepreneurial income), and interest (capital income) over aggregate pre-tax income, and is pinned down by:

\[
TIS_T = \frac{\sum_{j=0}^{3} (n^\tau Y^\tau_{t-j})}{\sum_{j=0}^{3} (n^\tau Y^\tau_{t-j} + n^\mu Y^\mu_{t-j})} 
\approx \overline{tis} + \sum_{j=0}^{3} (\nu_j \cdot \widehat{tis}_{t-j}) + (1 \cdot \kappa_{tis} \cdot t) + \epsilon^{tis}_{T} \tag{3.2}
\]

where \(\hat{tis}_t = \hat{tis}^{ea}_t + \hat{tis}^{b}_t + \hat{tis}^{pr}_t\). The approximation (3.2) is obtained in equilibrium, after converting the ratio in terms of stationary variables, and taking a Taylor expansion (Appx. D). The steady state top income share is given by \(\overline{tis} = (1 - s) + \overline{tis}_b\); 1 – s is the top 10% wage share, and \(\overline{tis}_b \equiv n^\tau b^\gamma (R - e^\gamma \Pi)/(e^\gamma \Pi w^r LR)\) stands for bond income flowing to the top. Steady state profits are zero. \(\hat{tis}_t\) stands for the cyclical component of the top income share; its weight is given by \(\nu_j \equiv e^{(3-j)\gamma}/[e^{3\gamma} + e^{2\gamma} + e^{\gamma} + 1]\). Measurement error, \(\epsilon^{tis}_T \sim N(0, \mu_{tis}^2)\), is included. \(\kappa_{tis} \cdot t\) approximates higher-order terms in the expansion, and aims at capturing the non-stationary evolution of \(TIS_T\) after the mid-80s; consequently, the indicator function, \(1\), is non-zero only during that period. \(\{\hat{tis}^{ea}_t, \hat{tis}^{b}_t, \hat{tis}^{pr}_t\}\) drive the swings of the top income share; they stand for earnings, bond income, and profits, respectively. They are given by:

According to (3.3–3.5), the top income share falls below its steady state if there is an
Table 2: Cyclical Swings, Top Income Share

<table>
<thead>
<tr>
<th>Channel</th>
<th>Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earnings channel</td>
<td>( \tilde{t}is_t^a = -\bar{s} \cdot \tilde{s}_t + (\tilde{w}_t + \tilde{L}_t) \cdot \tilde{t}is_b ) (3.3)</td>
</tr>
</tbody>
</table>
| Bond income channel    | \( \tilde{t}is_t^b = (\hat{b}_{t-1} - \hat{\pi}_t) \left[ n^\tau b^\tau / (e^{\tau} \Pi \omega^\tau L) \right] 
- (\hat{b}_t - \hat{\tau}_t - \hat{\omega}_t) \left[ n^\tau b^\tau / (w^\tau LR) \right] \) (3.4) |
| Profits channel        | \( \tilde{t}is_t^{pr} = \hat{v}_t \left[ (y/w^\tau L) \left( n^\tau \omega^\tau - \tilde{t}is \right) \right] \) (3.5) |

In contrast, increases in the bottom borrowing and in profits (\( \hat{\nu}_t \)) boost capital income flowing to the top and, in turn, the top income share.

The model-implied top wealth share that is consistent with the observed series (\( TWS_T \)) is given by the sum of shares and assets over the value of all shares (\( n^\tau \Omega_t Q_t + n^\mu \Omega_t^{\mu} Q_t = Q_t \)) since family debt positions net out to zero:

\[
TWS_T = \sum_{j=0}^{3} n^\tau \left[ Q_{t-j} \Omega_t^{\tau-j} + \frac{B_{t-j}
}{e^{\nu_t-j} R_{t-j}} \right] / \sum_{j=0}^{3} Q_{t-j} 
\approx \tilde{t}ws + \sum_{j=0}^{3} (\nu_j \cdot \tilde{t}ws_{t-j}) + (\kappa_{tws} \cdot t) + \epsilon_{tws}^{tws} \quad (3.6)
\]

where \( \tilde{t}ws_t^{\tau} = \tilde{t}ws_t^\omega + \tilde{t}ws_t^b + \tilde{t}ws_t^q \). The approximation (3.6) is obtained after converting the ratio in terms of stationary variables, and taking a Taylor expansion. (Appx. D). The steady state top wealth share is given by \( \tilde{t}ws = n^\tau \omega^\tau + \tilde{t}ws_b \): \( n^\tau \omega^\tau \) is the top profit share, and \( \tilde{t}ws_b \) is the top’s outstanding assets to the value of shares in terms of the final good. \( \tilde{t}ws_{t-j} \) stands for the cyclical component of the top wealth share. Measurement error, \( \epsilon_{tws}^{tws} \sim N(0, \mu_{tws}^2) \), is included. \( \kappa_{tws} \cdot t \) approximates higher-order terms in the expansion, and aims at capturing the fact that \( TWS_T \) exhibits a small positive sample growth rate. The terms \( \{ \tilde{t}ws_t^\omega, \tilde{t}ws_t^b, \tilde{t}ws_t^q \} \) drive the fluctuations of the top wealth share; they stand for shares, bonds, and asset price gains/losses, respectively. They are given by:

According to (3.7–3.9), the top wealth share overshoots its steady state when the profit shares or the intra-household assets of the top increase. It undershoots it, however, when the interest rate, or the risk premium shock, or the asset price (\( \hat{q}_t \)) increase since all those changes decrease the contribution of outstanding bonds to the top wealth share.
Table 3: Cyclical Swings, Top Wealth Share

<table>
<thead>
<tr>
<th>Channel</th>
<th>Equation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real assets (shares) channel</td>
<td>$\tilde{\text{tws}}<em>{\omega t} = \tilde{\omega}</em>{t}^\tau (n^\tau \omega^\tau)$</td>
<td>(3.7)</td>
</tr>
<tr>
<td>Bonds channel</td>
<td>$\tilde{\text{tws}}<em>{\omega t}^{b} = (\tilde{b}</em>{t}^\prime - \tilde{r}<em>{t} - \tilde{\nu}</em>{t}^b) \tilde{\text{tws}}_{b}$</td>
<td>(3.8)</td>
</tr>
<tr>
<td>Asset price gains/losses channel</td>
<td>$\tilde{\text{tws}}<em>{\omega t}^{q} = -\tilde{\varrho}</em>{t} \tilde{\text{tws}}_{b}$</td>
<td>(3.9)</td>
</tr>
</tbody>
</table>

Few assumptions underlie equations (3.1, 3.2, 3.6). (3.1) implies that the observed debt pertains to the bottom 90% of the income distribution. This mapping is supported by data from the Survey of Consumer Finance [Ravenna and Vincent, 2014], while including multiple debt indicators with measurement error helps extract their part that is relevant for the model. In addition, measurement error in both top shares (3.2 and 3.6) mitigates potential inconsistencies from assuming that the top of the income and wealth distributions coincide. Consistently with the model’s foundations, there is no feedback from inequality to the growth rate along the balanced growth path that is determined by technology.

### 3.2 State Space And Likelihood.

I stack the measurement equations for aggregates series and (3.1) vertically to obtain:

$$\Upsilon_t = \Gamma_q + H_0 \zeta_t + H_1 \zeta_{t-1} + M_t, \quad M_t \sim N(0, \Sigma_q)$$  \hspace{1cm} (3.10)

where $\Upsilon_t$ and $\Gamma_q$ are $(o_q \times 1)$ vectors of quarterly observed series and intercepts, respectively. $M_t$ collects the associated measurement errors. $\Sigma_q$ is the diagonal covariance matrix. \{\$H_0, H_1\$\} denote the $(o_q \times n_\zeta)$ selection matrices and include the slope coefficients. $\zeta_t$ is the period-t $(n_\zeta \times 1)$ state vector. Stacking (3.2) and (3.6) vertically yields:

$$\Upsilon_T = \Gamma_a + H_{30} \zeta_T + H_{31} \zeta_{T-1} + H_{32} \zeta_{T-2} + H_{33} \zeta_{T-3} + H_{34} \zeta_{T-4} + M_T, \quad M_T \sim N(0, \Sigma_a)$$  \hspace{1cm} (3.11)

where $\Upsilon_T \equiv [TIS_T, TWST]'$ and $\Gamma_a$ are $(o_a \times 1)$ vectors $(o_a = 2)$ of annually observed series and intercepts, respectively. $M_T \equiv [\varepsilon^{tis}_T, \varepsilon^{twst}_T]'$ collects the measurement errors; $\Sigma_a$ is the associated diagonal covariance matrix. \{\$H_{30}, H_{31}, H_{32}, H_{33}, H_{34}\$\} denote the $(o_a \times n_\zeta)$ selection matrices that include the slope coefficients of (3.2) and (3.6).

Eq.(3.10) appears for four consecutive quarters until the end of a year when the inequality series are observed and linked to the model via (3.11). Stacking over time yields:

---

11 Kumhof et al. (2015) and Cairo and Sim (2018) map debt to the bottom 95%.
The matrix representation of (3.12) is given by

\[
\begin{bmatrix}
\Gamma_1 \\
\Gamma_2 \\
\Gamma_3 \\
\vdots \\
\end{bmatrix}
+ \begin{bmatrix}
\zeta_1 \\
\zeta_2 \\
\zeta_3 \\
\vdots \\
\end{bmatrix}
= \begin{bmatrix}
M_1 \\
M_2 \\
M_3 \\
\vdots \\
\end{bmatrix}
\]

(3.12)

where \( o = [(4 o_q + o_n) n_T] \times 1 \). \( \Upsilon \equiv [\Upsilon'_1, \Upsilon'_2, \Upsilon'_3, \Upsilon'_4, \Upsilon'_{T-1}, \ldots]' \) is the observation vector. \( \Gamma \equiv [\Gamma_q', \Gamma_q', \Gamma_q', \Gamma_q', \ldots]' \) is a vector of intercepts. \( \zeta \equiv [\zeta'_1, \zeta'_2, \zeta'_3, \zeta'_4, \ldots]' \) is the \((n_{\zeta} n_q) \times 1 \) state vector. \( M \equiv [M'_1, M'_2, M'_3, M'_4, M'_{T-1}, \ldots]' \) collects the measurement errors. \( H \) is a sparse and block-banded matrix. According to (3.13), the likelihood of the data given the parameter vector \( \Theta \) and the states \( \zeta \) is \( P(\Upsilon - \Gamma|\Theta, \zeta) \), where \( (\Upsilon - \Gamma)|\Theta, \zeta \sim N(H \zeta, \Sigma_M) \).

The log-linearized equilibrium conditions are casted in the form: \( \Gamma_0(\Theta) \zeta_t = \Gamma_1(\Theta) \zeta_{t-1} + \Psi(\Theta) \epsilon_t + \Pi \eta_t \), where the system matrices \( \{\Gamma_0, \Gamma_1, \Psi\} \) are functions of the parameter vector \( \Theta \), and \( \eta_t \) collects the expectational errors. The structural shocks are grouped in the \((n_e \times 1)\) vector \( \epsilon_t \), and are fewer than the number of observables \((n_e < o_q + o_n)\). (3.14) gives the VAR(1) representation of the rational expectations solution of Sims (2002).

\[
\zeta_t = \Phi_1(\Theta) \zeta_{t-1} + \Phi_2(\Theta) \epsilon_t , \quad \epsilon_t \sim N(0_{n_e}, I_{n_e}), \quad \forall t \geq 2
\]

(3.14)

\( \{\Phi_1, \Phi_2\} \) are non-linear functions of \( \Theta \). \( \zeta_1 \) is initialized with covariance \( D \) being the steady state covariance of the state vector evaluated at the prior mean of \( \Theta \). Defining the reduced-form errors, \( \tilde{\epsilon}_t = \Phi_2 \epsilon_t \) for \( t > 1 \) and \( \tilde{\epsilon}_1 = \epsilon_1 \), and stacking (3.14) across time yields:

\[
\begin{bmatrix}
I_{n_\zeta} \\
-\Phi_1 \\
\vdots \\
-\Phi_1 \\
\end{bmatrix}
\begin{bmatrix}
\zeta_1 \\
\zeta_2 \\
\zeta_T \\
\end{bmatrix}
= \begin{bmatrix}
\epsilon_1 \\
\epsilon_2 \\
\tilde{\epsilon}_T \\
\end{bmatrix}
\sim N\left(0_{n_\zeta n_q}, \begin{bmatrix} D & \ldots \\
\vdots & \Omega \otimes I_{T-1} \end{bmatrix} \right)
\]

(3.15)
where $\Omega \equiv \Phi_2 \Phi_2'$. In matrix notation, the above equation reads as

$$Z\zeta = \tilde{\epsilon} , \quad \tilde{\epsilon} \sim N(0_{n_\zeta n_\eta}, K_\tilde{\epsilon}^{-1})$$

(3.16)

$\tilde{\epsilon} \equiv [\tilde{\epsilon}_1', \tilde{\epsilon}_2', \ldots, \tilde{\epsilon}_T']'$ is the $(n_\zeta n_\eta) \times 1$ vector of errors, and $K_\tilde{\epsilon}$ is its sparse and block-banded precision. A change of variable transformation yields the prior state distribution, $P(\zeta|\Theta)$, with $\zeta|\Theta \sim N(\tilde{\zeta}, K^{-1}_\tilde{\epsilon})$ and $\tilde{\zeta} = 0_{n_\zeta n_\eta}$. The precision $K = Z'K_\tilde{\epsilon}Z$ is sparse and block-banded [Chan and Jeliazkov, 2009]. Bayes rule, $P(\zeta|\Upsilon, \Theta) \propto P(\Upsilon|\Theta, \zeta)P(\zeta|\Theta)$, yields the block-banded posterior precision: $P = K + H'\Sigma_M^{-1}H$. The posterior mean state ($\hat{\zeta}$) is computed from (3.17) below based on the efficient simulation of Chan and Jeliazkov (2009).

$$\hat{P}_\zeta = K\tilde{\zeta} + H'\Sigma_M^{-1}(\Upsilon - \Gamma)$$

(3.17)

The integrated log-likelihood (given the parameters but marginally of the states) is evaluated at a high density point along the lines of Chib (1995) and, in particular, at the posterior mean of the hidden states: $\log P(\Upsilon|\Theta) = +\log P(\Upsilon|\Theta, \hat{\zeta}) + \log P(\hat{\zeta}|\Theta) - \log P(\hat{\zeta}|\Upsilon, \Theta)$.

3.3 Priors.

The Random Walk Metropolis-Hastings algorithm is used to simulate draws from the non-tractable posterior. The RA version is obtained for $n^\tau = 1$ and $\phi^\tau = 0$. The priors for the parameters appearing in both the present and the RA models are conventional\(^\text{12}\) and reported in Table (4). Additionally, the fraction of top agents ($n^\tau$) is 10% in accordance with the observed series. $\beta^\tau$ is set to 0.99, and $\beta^\mu$ is fixed at 0.985 as in Gelain et al. (2018b). The loan-to-value ratio ($m$) is fixed at 0.55 as in Iacoviello (2005). The top wage share, $1 - \bar{s}$, is calibrated at 0.32 – a value a tad below the sample average top income share (0.35) before the mid-80s since wages are less unequally distributed than overall income that includes capital income. The strength of preferences over wealth for the top ($\phi^\tau$) is sampled from Beta centered at 0.1 (0.03 standard deviation, “std”) often considered in the literature. $\phi^\mu$ is drawn from Beta too with a tad higher mean (0.15) that attenuates inequality in the distribution of shares which, when combined with the bonds-to-income ratio (influenced by $m$), yields a prior top wealth share of about 0.67 that is aligned with the data. The prior std for wage, wealth, and credit shocks is aligned with that of all other shocks; their prior persistence is a tad higher (0.7) though. Portfolio adjustment costs ($S_\omega$) are small (0.1).

\(^{12}\) The std of all measurement errors is drawn from the Inverse Gamma centered at 0.15 (1 std) for the debt series and at 0.01 (0.001 std) for series matched to a single observable – these estimates are shown in the Appendix. $\delta$ and $g$ are set to the values chosen in Smets and Wouters (2007).
4 Findings

The parameter estimates are presented first. The economy wide effects of cyclical changes in inequality and the interplay between inequality and monetary policy are then assessed. The subsequent section delves into the distributional implications of aggregate shocks. A battery of robustness checks closes the analysis.

4.1 Posterior Estimates.

The parameter estimates across the RA and the present model are displayed in Table (4). Zooming in on the parameters associated with the economy’s aggregate dimension, habit ($\eta$) falls considerably from 0.77 in the RA model to 0.51. The inverse Frisch elasticity ($\chi$) is a tad higher in the present model than in the RA model. Both price ($\iota_p$) and wage ($\iota_w$) indexation are a tad elevated compared to their RA estimates, whereas price ($\zeta_p$) and wage ($\zeta_w$) stickiness are a tad dampened down. Wage markup shocks become more volatile and persistent, and price markup shocks gain volatility but lose persistence. Risk premium shocks obtain a stronger low-frequency impact compared to the RA model (their persistence rises from 0.80 to 0.91, and their volatility falls from 0.12 to 0.1). In the investment side, investment shocks obtain a more profound impact ($\rho_i$ rises from 0.85 to 0.99, and $\sigma_i$ increases from 0.30 to 0.53). The latter along with the increased elasticity of utilization costs ($\psi$) compared to the RA model compensate for lower investment adjustment costs ($S$) in the former (2.48) compared to the latter (6.74). The policy reaction coefficient to inflation ($\psi_\pi$) rises from 1.88 in the RA model to 2.17 in the present model. Overall, the small differences in the parameter estimates across the two configurations imply a dichotomy in identification: parameters associated with the economy’s aggregate dimension are mainly identified by aggregate data included in the estimation of both models rather than by the inclusion of inequality and debt series.

As for the parameters associated with the distributional dimension of the model, the strength of preferences over wealth ($\phi^\mu, \phi^\tau$) is heterogeneous across households, 0.37 for the middle class and 0.15 for the top, and implies that the homogeneity often postulated in models might be restrictive\textsuperscript{13}. Polarization, wealth, and credit shocks are all persistent. Credit and wage shocks are more volatile than wealth shocks. The debt series are loaded with volatile measurement errors suggesting that the model picks a slow-evolving component from them. Home mortgage debt is favored over consumer credit debt ($\Psi_d = 0.77$). The trends

\textsuperscript{13}Justiniano et al. (2015) consider such heterogeneous parameters in their robustness checks.
in debt and the top shares are situated around their data averages. This set of parameters jointly with a subset of aggregate parameters yield tight posteriors for the top income (37%) and wealth (68%) shares around their sample averages (38% and 67%). Inequality and debt data are, hence, informative for this set of parameters.

4.2 Economy Wide Implications of Inequality.

4.2.1 Economy Wide Effect. I quantify the autonomous effect of distributional shocks on the U.S. business cycle in Table (5) which displays the forecast error variance decompo-

<table>
<thead>
<tr>
<th>Prior</th>
<th>Posterior Mean [5-95%]</th>
<th>Prior</th>
<th>Posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>α</td>
<td>N(0.30, 0.05) 0.21 [0.19, 0.24] 0.25 [0.23, 0.27]</td>
<td>φµ</td>
<td>B(0.15, 0.03) 0.37 [0.32, 0.42]</td>
</tr>
<tr>
<td>η</td>
<td>B(0.70, 0.10) 0.77 [0.71, 0.82] 0.51 [0.46, 0.55]</td>
<td>φr</td>
<td>B(0.10, 0.03) 0.15 [0.13, 0.17]</td>
</tr>
<tr>
<td>χ</td>
<td>N(2.00, 1.00) 4.14 [2.94, 5.39] 5.14 [4.01, 6.35]</td>
<td>µ</td>
<td>B(0.70, 0.20) 0.99 [0.99, 0.99]</td>
</tr>
<tr>
<td>ψ</td>
<td>B(0.50, 0.10) 0.37 [0.24, 0.56] 0.59 [0.47, 0.72]</td>
<td>σx</td>
<td>IG(0.15, 1.00) 2.77 [2.16, 3.49]</td>
</tr>
<tr>
<td>S</td>
<td>N(4.00, 1.00) 6.74 [5.45, 8.01] 2.48 [1.92, 3.13]</td>
<td>ρw</td>
<td>B(0.70, 0.20) 1.00 [0.99, 1.00]</td>
</tr>
<tr>
<td>ζw</td>
<td>B(0.60, 0.10) 0.90 [0.84, 0.95] 0.77 [0.73, 0.80]</td>
<td>σw</td>
<td>IG(0.15, 1.00) 0.27 [0.21, 0.38]</td>
</tr>
<tr>
<td>ζp</td>
<td>B(0.60, 0.10) 0.91 [0.87, 0.92] 0.90 [0.87, 0.99]</td>
<td>ρm</td>
<td>B(0.70, 0.20) 0.99 [0.99, 1.00]</td>
</tr>
<tr>
<td>τp</td>
<td>B(0.50, 0.15) 0.07 [0.03, 0.12] 0.09 [0.04, 0.16]</td>
<td>σm</td>
<td>IG(0.15, 1.00) 1.55 [1.38, 1.72]</td>
</tr>
<tr>
<td>ρw</td>
<td>B(0.50, 0.15) 0.75 [0.61, 0.87] 0.80 [0.67, 0.91]</td>
<td>Ψd</td>
<td>N(1.00, 0.50) 0.77 [0.63, 0.90]</td>
</tr>
<tr>
<td>ρz</td>
<td>B(0.75, 0.10) 0.90 [0.88, 0.92] 0.85 [0.83, 0.87]</td>
<td>µhm</td>
<td>IG(0.15, 1.00) 0.70 [0.49, 0.88]</td>
</tr>
<tr>
<td>ψπ</td>
<td>N(1.70, 0.25) 1.88 [1.55, 2.22] 2.17 [1.89, 2.46]</td>
<td>µcc</td>
<td>IG(0.15, 1.00) 1.12 [0.99, 1.24]</td>
</tr>
<tr>
<td>ψy</td>
<td>N(0.12, 0.05) 0.20 [0.13, 0.26] 0.17 [0.12, 0.23]</td>
<td>γhm</td>
<td>N(1.00, 0.04) 1.04 [0.95, 1.07]</td>
</tr>
<tr>
<td>ψΔy</td>
<td>N(0.12, 0.05) 0.23 [0.14, 0.31] 0.33 [0.25, 0.41]</td>
<td>γcc</td>
<td>N(0.70, 0.04) 0.70 [0.64, 0.76]</td>
</tr>
<tr>
<td>ρb</td>
<td>B(0.60, 0.20) 0.80 [0.71, 0.88] 0.91 [0.88, 0.93]</td>
<td>κtis</td>
<td>N(0.32, 0.03) 0.30 [0.24, 0.35]</td>
</tr>
<tr>
<td>σb</td>
<td>IG(0.15, 1.00) 0.12 [0.09, 0.15] 0.10 [0.08, 0.12]</td>
<td>κtws</td>
<td>N(0.00, 0.03) 0.03 [-0.02, 0.07]</td>
</tr>
<tr>
<td>ρz</td>
<td>B(0.60, 0.20) 0.99 [0.98, 0.99] 0.96 [0.94, 0.97]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>σz</td>
<td>IG(0.15, 1.00) 0.55 [0.51, 0.60] 0.57 [0.52, 0.61]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ρi</td>
<td>B(0.60, 0.20) 0.85 [0.75, 0.98] 0.99 [0.99, 1.00]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>σi</td>
<td>IG(0.15, 1.00) 0.30 [0.25, 0.36] 0.53 [0.44, 0.64]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ρp</td>
<td>B(0.60, 0.20) 0.81 [0.74, 0.87] 0.71 [0.65, 0.78]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>σp</td>
<td>IG(0.15, 1.00) 0.07 [0.05, 0.08] 0.10 [0.08, 0.11]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ρw</td>
<td>B(0.60, 0.20) 0.13 [0.05, 0.22] 0.25 [0.14, 0.38]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>σw</td>
<td>IG(0.15, 1.00) 0.60 [0.54, 0.67] 0.63 [0.54, 0.72]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>σmp</td>
<td>IG(0.15, 1.00) 0.24 [0.22, 0.26] 0.26 [0.23, 0.28]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ρg</td>
<td>B(0.60, 0.20) 0.97 [0.95, 0.99] 0.94 [0.91, 0.96]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>σg</td>
<td>IG(0.15, 1.00) 0.46 [0.42, 0.50] 0.45 [0.41, 0.49]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ρgz</td>
<td>B(0.50, 0.20) 0.32 [0.26, 0.38] 0.34 [0.29, 0.40]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>γ</td>
<td>N(0.40, 0.03) 0.39 [0.35, 0.43] 0.41 [0.38, 0.44]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>π</td>
<td>N(0.80, 0.03) 0.83 [0.78, 0.87] 0.88 [0.83, 0.93]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ωw</td>
<td>N(0.50, 0.03) 0.50 [0.45, 0.54] 0.50 [0.45, 0.55]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>ωp</td>
<td>N(0.30, 0.03) 0.34 [0.29, 0.38] 0.27 [0.22, 0.31]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
<tr>
<td>l</td>
<td>N(0.00, 0.10) 0.03 [-0.12, 0.20] 0.17 [0.03, 0.31]</td>
<td>(, )</td>
<td>(, )</td>
</tr>
</tbody>
</table>

logL -1433 -2764

sition of several variables two/ten years ahead. The combined effect of wage, wealth, and credit shocks explains less than 10% of output fluctuations at any horizon. More precisely, wage polarization shocks have a small impact (3/2%) on output cycles. Wealth shocks explain 4/2% of output cycles. That influence is aligned with the findings of Iacoviello and Neri (2010), according to which a similar shock affecting the preferences over housing exerts about the same influence on output. Credit supply shocks, too, explain a small fraction (3/2%) of output cycles. The limited macroeconomic impact of credit shocks, is consistent with the findings of Justiniano et al. (2015). The small influence of the above triplet of shocks is confirmed in the cases of inflation and of the interest rate.

Despite its aforementioned limited influence, the above triplet of shocks has a profound impact on household indebtedness. It explains 75% and 52% of household debt swings at short and long horizons, respectively. Polarization shocks account for 8% of long-run debt swings. The influence of wealth shocks on debt (44/27%) is about 1.5 times higher than the influence of credit supply shocks on debt (30/17%) at any horizon. The sizable influence of the above shocks on household debt empirically corroborates the dynamics described in Kumhof et al. (2015) and Stiglitz (2014), according to which households outside of the top leverage their portfolios in response to swings in inequality.

Table 5: Business Cycles and Distributional Shocks

<table>
<thead>
<tr>
<th>variable</th>
<th>shock</th>
<th>yt</th>
<th>it</th>
<th>rt</th>
<th>bτ</th>
<th>tis</th>
<th>tWs</th>
<th>cτ</th>
<th>cµ</th>
</tr>
</thead>
<tbody>
<tr>
<td>wage polariz.</td>
<td>3/2</td>
<td>0/1</td>
<td>2/5</td>
<td>1/8</td>
<td>99/100</td>
<td>13/61</td>
<td>91/95</td>
<td>69/85</td>
<td></td>
</tr>
<tr>
<td>wealth pref.</td>
<td>4/2</td>
<td>1/1</td>
<td>5/5</td>
<td>44/27</td>
<td>0/0</td>
<td>40/9</td>
<td>2/1</td>
<td>3/1</td>
<td></td>
</tr>
<tr>
<td>credit supply</td>
<td>3/2</td>
<td>0/1</td>
<td>3/3</td>
<td>30/17</td>
<td>0/0</td>
<td>8/20</td>
<td>1/0</td>
<td>2/0</td>
<td></td>
</tr>
<tr>
<td>distributional</td>
<td>10/6</td>
<td>1/3</td>
<td>11/13</td>
<td>75/52</td>
<td>100/100</td>
<td>61/90</td>
<td>93/96</td>
<td>74/86</td>
<td></td>
</tr>
<tr>
<td>technology</td>
<td>32/28</td>
<td>1/2</td>
<td>0/0</td>
<td>15/7</td>
<td>0/0</td>
<td>16/3</td>
<td>0/1</td>
<td>6/3</td>
<td></td>
</tr>
<tr>
<td>price markup</td>
<td>10/5</td>
<td>68/60</td>
<td>16/8</td>
<td>2/1</td>
<td>0/0</td>
<td>6/1</td>
<td>0/0</td>
<td>1/0</td>
<td></td>
</tr>
<tr>
<td>wage markup</td>
<td>2/2</td>
<td>8/8</td>
<td>1/1</td>
<td>5/1</td>
<td>0/0</td>
<td>6/1</td>
<td>0/0</td>
<td>1/0</td>
<td></td>
</tr>
<tr>
<td>supply side</td>
<td>44/35</td>
<td>77/70</td>
<td>18/9</td>
<td>22/9</td>
<td>0/0</td>
<td>28/5</td>
<td>1/1</td>
<td>9/4</td>
<td></td>
</tr>
<tr>
<td>risk premium</td>
<td>28/14</td>
<td>12/13</td>
<td>49/46</td>
<td>1/2</td>
<td>0/0</td>
<td>5/2</td>
<td>0/0</td>
<td>9/3</td>
<td></td>
</tr>
<tr>
<td>investment</td>
<td>5/39</td>
<td>7/12</td>
<td>6/24</td>
<td>1/35</td>
<td>0/0</td>
<td>2/1</td>
<td>6/3</td>
<td>1/6</td>
<td></td>
</tr>
<tr>
<td>gov. spending</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>0/0</td>
<td>0/1</td>
<td>0/0</td>
<td>2/1</td>
<td></td>
</tr>
<tr>
<td>mon. policy</td>
<td>13/6</td>
<td>2/2</td>
<td>16/8</td>
<td>1/1</td>
<td>0/0</td>
<td>4/2</td>
<td>0/0</td>
<td>5/1</td>
<td></td>
</tr>
<tr>
<td>demand side</td>
<td>46/59</td>
<td>22/27</td>
<td>72/78</td>
<td>3/39</td>
<td>0/0</td>
<td>11/5</td>
<td>6/3</td>
<td>17/11</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Forecast Error Variance Decomposition 8/40 quarters ahead, computed at the posterior mean. Mnemonics: \{\hat{y}_t, \hat{π}_t, \hat{r}_t, \hat{b}_τ, \hat{t}_{is}, \hat{t}_{Ws}, \hat{c}_τ, \hat{c}_µ\} stand for output, inflation, the interest rate, lending/borrowing, top income share, top wealth share, top and middle-class consumption (% deviation from steady state).
It is worthwhile to elaborate on the labeling of polarization, wealth, and credit shocks as “distributional” shocks. Polarization shocks account for the entire cyclical fluctuations of income inequality and have a sizable impact on wealth (13/61%) and consumption inequality as well (91/95% and 69/85% of the cycles in the consumption of the top and the middle class, respectively). Wealth shocks, too, have a sizable influence on the fluctuations of wealth inequality (40/9%). Credit supply shocks have a sizable impact on middle-class’ indebtedness and the top wealth share (8%/20%) – they are, thus, viewed as a distributional disturbance in this paper. Altogether, the findings suggest that a moderate fraction of wealth inequality (39%/10%) is accounted for by aggregate shocks, and that the fluctuations in polarization, wealth, and credit shocks capture cyclical swings in income and wealth inequality as well as in debt. Their economy wide effect, therefore, reflects the effect of changes in inequality.

4.2.2 Diffusion. Figures (1) and (2) display the effect of shocks in wages, wealth, and credit on economic aggregates and on the top income and wealth deciles, respectively. They suggest that distributional shocks operate through an aggregate demand channel. The latter hinges on the heterogeneous consumption responses across the population, reflecting the heterogeneity in marginal propensities to consume. Moreover, the effect on the evolution of inequality and debt is highly persistent compared to the effect on aggregate variables, and mirrors the low-frequency shifts in the observed debt and inequality series.

In response to wage polarization, top consumption rises whereas middle-class consumption falls. The two changes do net out to zero, and result in a gradual economy wide consumption increase – an aggregate demand stimulus – that eventually raises production, employment, and wages, and generates pro-cyclical, albeit small in magnitude, inflation and interest rate responses. Therefore, the adjustment is stronger in quantities than in prices. The positive output elasticity mirrors the observed pro-cyclicality of the top income share (0.49 in Table 1). The workings of a demand channel are corroborated by the fact that the output and consumption increases are about coequal on impact.

In addition, wage polarization leads to pro-cyclical responses in both income and wealth inequality. More specifically, it results in a higher share of earnings flowing to the top ($tis^e$). The top families leverage their income to increase consumption ($c^t$) and raise their shares ($tws^ω$). Interest payments from bond holdings ($tis^b$) boost income inequality ($tis$) further. Due to the increased demand for ownership shares, their price goes up and negatively
feedbacks to the top wealth share \((tws^q)\) since part of the assets of the top is in terms of bonds. It is worth pointing out that the collateral channel amplifies the effect of these shocks: although middle-class households are borrow after the shock, the combination of a fixed supply of shares and of an increasing fraction of them going to the top \((tws^\omega\) rises) leaves middle-class households with less collaterals to post. As a result, the middle class borrows \((tws^b\) falls) and consumes less. Thus, access to credit is harder when income inequality rises.

Figure 1: Economy Wide Implications of Wage Polarization Shocks

Notes: impulse response functions, % deviation from steady state. 3rd row:: top income share \((tis)\): earnings \((tis^{ea})\), bond income \((tis^b)\), and profits \((tis^{pr})\) channels, with \(tis = tis^{ea} + tis^b + tis^{pr}\). 4th row:: top wealth share \((tws)\): shares \((tws^\omega)\), bonds \((tws^b)\), and asset price \((tws^q)\) channels, with \(tws = tws^\omega + tws^b + tws^q\).

The effects of changes in the desire for wealth accumulation and in the borrowing capacity of the middle class are similar [Fig.2]. Both shocks trigger positive output and aggregate demand elasticities because they lead to an expansion fueled by the consumption expansion of the middle class. The consumption of top households exhibits a small drop. Inflation, the interest rate, and the real wage all follow a small pro-cyclical response.

Both credit and wealth shocks quickly elevate income inequality; \(tis^b\) falls on impact
Distributional Imbalances, Monetary Policy, and the U.S. Business Cycle

and immediately rises (the reduction stems from the fact that, on impact, lending rises but payments start in the second period). Over time, the economic expansion leads to profits for the top ($tis^{pr}$) that shape the increase in income inequality ($tis$) since the response of the earnings channel ($tis^{ea}$) is negligible. Both shocks lead to an expansion in the bonds held by the top ($tws^{b}$): middle-class families borrow in order to increase their ownership shares ($tws^{ω}$ decreases). The high demand for shares raises their price which, in turn, negatively affects the top wealth share ($tws^{q}$). It is worth pointing out that despite the fact that both wealth and credit shocks lead to changes of the same sign, the former shocks drive down wealth inequality whereas the latter raise it. This difference happens because credit shocks do not generate an increase in the asset price (reflected in $tws^{q}$) as large as that observed after wealth shocks. Thus, wealth shocks lead to a negative correlation between debt and wealth inequality, whereas credit shocks to a positive correlation.

Figure 2: Economy Wide Implications of Wealth and Credit Shocks

Notes: impulse response functions, % deviation from steady state. 3rd row:: top income share ($tis$): earnings ($tis^{ea}$), bond income ($tis^{b}$), and profits ($tis^{pr}$) channels, with $tis = tis^{ea} + tis^{b} + tis^{pr}$. 4th row:: top wealth share ($tws$): shares ($tws^{ω}$), bonds ($tws^{b}$), and asset price ($tws^{q}$) channels, with $tws = tws^{ω} + tws^{b} + tws^{q}$. 

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4.2.3 Debt Pileup and Output Cycles. Although the findings of Table (5) suggest that distributional shocks explain about 50-70% of household debt fluctuations, they remain silent about the influence of those shocks during the debt buildup of the decades prior to the Great Recession. In other words, is the historical effect of distributional shocks on debt and output growth time-varying over the 1954-2009 period? Fig.(3) tackles this question.

The top panel displays the structural forces behind the average debt growth during 1954-1982 and 1983-2009. It demonstrates that there is a debt buildup over the business cycle: debt growth is larger during the 1983-2009 period (0.3) than during the 1954-1982 period (-0.2). Both credit and supply shocks contribute to the debt buildup. The contribution of credit shocks, in particular, is sizable. Their effect accounts for about half of the average debt growth. This evidence, hence, casts support on Mian and Sufi (2018), and citations therein, who argue that the U.S. credit expansion was one of the main factors behind the phenomenon of debt buildup, but goes against Justiniano et al. (2015) who find that a taste shock for housing (the analogous of the present wealth shock but differently identified) accounts for the observed leveraging, despite the fact that the present limited influence of credit shocks on output cycles is compatible with Justiniano et al. (2015) according to whom credit shocks do not suffice to account for the severity of the Great Recession and have limited economic influence. What is, though, behind that difference?

Two factors explain that difference: (i) the weakening of the collateral channel due to rising income inequality, and (ii) the negative correlation of wealth inequality and debt in response to wealth shocks. The cyclical rise of income inequality after the 1980s (see Appx.) is reflected in wage polarization shocks. The latter trigger an increase in the ownership of shares of top households as shown in Fig.(1). As a result, middle-class families have fewer shares available to use as collateral and, thus, borrow less. Rising income inequality, hence, cannot trigger an increase in borrowing. A downward influence on debt accumulation is also triggered by wealth shocks after the 1980s. Negative wealth shocks explain a large part of the cyclical rise in wealth inequality during that period (see Appx.), and trigger a decrease in household debt according to the negative correlation shown in Fig.(2). Therefore, against both polarization and wealth shocks pushing towards a reduction in borrowing, credit supply shocks obtain an influential role in explaining the observed increase in debt.

The bottom panel of Fig.(3) corroborates that distributional shocks have limited impact on output cycles. Wealth shocks are more influential during the cycles before the 1980s than
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after that period. Polarization shocks exert a small influence throughout time. Credit relaxation consistently boosts output growth during the cycles from 1982 to 2009.

Figure 3: Debt Pileup and Output Cycles


4.2.4 Endogenous and Exogenous Imbalances. This section disentangles the influence of exogenous distributional imbalances (distributional shocks) from the influence of mechanisms (heterogeneous $\phi$’s and imperfect insurance) that endogenously generate distributional imbalances. Table (6) reports the properties of aggregate demand across various alternative scenarios pertaining to imbalances. Removing the impact of distributional shocks while keeping in the model the mechanisms of endogenous imbalances, results in an aggregate demand that is more volatile than (0.85 vs 0.74), less persistent than (-0.07 vs 0.26), and considerably different from (0.19) the observed series of aggregate demand. Therefore, a sizable part of the persistent evolution of aggregate demand and, thereby, of the economy hinges on distributional shocks which, in turn, account for a large part of inequality and
debt. Put differently, a large part of the economy’s persistence is attributed to the low-frequency dynamics of inequality and debt. This result is mirrored in the lower habit \( (\eta) \) that is obtained in the present model compared to the RA model (0.51 vs 0.77).

Removing distributional shocks and assuming homogeneous preferences over wealth across households results in an aggregate demand that remains more volatile than (0.81 vs 0.74) and largely deviates from (0.31) the observed series. Nevertheless, this series is less volatile than the series with heterogeneous \( \phi \)’s (0.81 vs 0.85). The heterogeneity in wealth preferences, therefore, amplifies the heterogeneity in the consumption responses and, thereby, the effect of aggregate shocks compared to an environment with homogeneous preferences.

As a final step, I impose perfect insurance. The model collapses to the RA specification and, therein (i.e. with the RA parameter estimates), I consider the propagation of aggregate shocks extracted from the present model. The fact that the volatility of the resulting aggregate demand is not dampened down implies that the estimated standard deviation of disturbances in the RA model is about the same with that in the present model. Nevertheless, the resulting series is far more persistent (0.59) than the observed and counterfactual series above. The RA estimation, therefore, yields higher endogenous persistence than the present model reflected in the deep parameter of habit (see Appx. for a graphical depiction).

Table 6: Measuring Endogenous and Exogenous Distributional Imbalances

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Volatility</th>
<th>Persistence</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aggregate Demand</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed (minus measur. error)</td>
<td>0.48</td>
<td>0.74</td>
<td>0.26</td>
<td>0.00</td>
</tr>
<tr>
<td>No Exogenous Imbalances</td>
<td>0.49</td>
<td>0.85</td>
<td>-0.07</td>
<td>0.19</td>
</tr>
<tr>
<td>No Exog. Imbalances &amp; ( \phi^\mu = \phi^\tau )</td>
<td>0.49</td>
<td>0.81</td>
<td>-0.09</td>
<td>0.31</td>
</tr>
<tr>
<td>No Exog. &amp; Endog. Imbalances</td>
<td>0.47</td>
<td>0.85</td>
<td>0.59</td>
<td>0.31</td>
</tr>
<tr>
<td><strong>Inflation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observed (minus measur. error)</td>
<td>0.85</td>
<td>0.58</td>
<td>0.86</td>
<td>0.00</td>
</tr>
<tr>
<td>No Exogenous Imbalances</td>
<td>0.84</td>
<td>0.58</td>
<td>0.86</td>
<td>0.00</td>
</tr>
<tr>
<td>No Exog. Imbalances &amp; ( \phi^\mu = \phi^\tau )</td>
<td>0.83</td>
<td>0.58</td>
<td>0.86</td>
<td>0.00</td>
</tr>
<tr>
<td>No Exog. &amp; Endog. Imbalances</td>
<td>0.80</td>
<td>0.71</td>
<td>0.91</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Notes: Observed and simulated series. Quarterly % changes in aggregate demand (consumption) and inflation. “Deviation” refers to the quarterly average squared deviation from the observed series.

The bottom part of Table (6) entails another important result. Both exogenous distributional shocks and heterogeneous \( \phi \)’s have limited direct effects on the volatility and persistence of inflation: after gradually removing them, following the steps described above,
inflation remains close to the data. The reason behind this result is that the inclusion of inequality and debt entails an indirect implication for inflation, namely the attenuation of general equilibrium effects on it. This attenuation is reflected on the resulting inflation series deviating from the observed ones (0.05) when the aggregate shocks from the present model are fed to the RA model, since the RA parameters of Table (4) [low price indexation (0.07 vs 0.09) and volatility of price markup shocks (0.07 vs 0.10), as well as high price stickiness (0.91 vs 0.90) and persistence of price markup shocks (0.81 vs 0.71) – all compared to the present model] do not dampen the volatile aggregate shocks of the present model.

4.2.5 The Nature of Aggregate Shocks. Is the transmission of aggregate shocks to economy wide variables in the model with distributional imbalances (DI) different from that implied by the RA model due to keeping track of additional facets of the U.S. economy? Table (7) reports the five-year cumulative effect of aggregate shocks in the DI and RA models. Matching inequality and debt alters aspects of these shocks. Compared to the RA model, technology and price markup shocks in the DI model obtain a tad less influential role in the fluctuations of all variables. In contrast, wage markup shocks are more prominent in explaining output and consumption in the DI model than in the RA model. Risk premium and investment shocks exert a pronounced effect on the economy when inequality is considered. Interestingly, along with the habit reduction, the influence of risk premium shocks on consumption declines in the DI model compared to the RA model. The influence of government spending shocks is more temporary in the DI than in the RA economy.\textsuperscript{14}

Table 7: Total Effect of Aggregate Shocks across Model Specifications

<table>
<thead>
<tr>
<th></th>
<th>(y_t)</th>
<th>(\pi_t)</th>
<th>(r_t)</th>
<th>(c_t)</th>
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<tr>
<td></td>
<td>RA</td>
<td>DI</td>
<td>RA</td>
<td>DI</td>
</tr>
<tr>
<td>technology</td>
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<td>15.7</td>
<td>-0.7</td>
<td>-0.2</td>
</tr>
<tr>
<td>price markup</td>
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<td>-6.0</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>wage markup</td>
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<td>-4.3</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>premium</td>
<td>8.1</td>
<td>10.5</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>investment</td>
<td>8.6</td>
<td>10.7</td>
<td>-0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>spending</td>
<td>2.7</td>
<td>0.5</td>
<td>0.1</td>
<td>-0.0</td>
</tr>
<tr>
<td>policy</td>
<td>6.1</td>
<td>6.4</td>
<td>0.1</td>
<td>0.2</td>
</tr>
</tbody>
</table>

\textit{Notes:} Cumulative \% deviation from steady state after twenty quarters. RA: Representative Agent model. DI: Distributional Imbalances model.

\textsuperscript{14}In the Appx., I compare the FEVD and IRFs across the DI and RA specifications, and show that including the top deciles and debt in the estimation has minor implications for the path of the output gap.
4.3 Monetary Policy and Inequality.

I examine three aspects of the monetary policy and inequality nexus: (i) the propagation of unpredictable changes in the policy instrument to inequality; (ii) the role of the policy stance against inflation in the transmission of distributional shocks; (iii) the inflation–output gap variability trade-off from a direct interest rate response to distributional imbalances.

Figure 4: Monetary Policy Disturbances

Notes: impulse response functions (posterior mean). All variables in % deviation from steady state. 1st and 2nd row: aggregate variables. 3rd row:: top income share (tis): earnings (tis^{ea}), bond income (tis^{b}), and profits (tis^{pr}) channels, with tis = tis^{ea} + tis^{b} + tis^{pr}. 4th row:: top wealth share (tws): shares (tws^{ω}), bonds (tws^{b}), and asset price gains/losses (tws^{q}) channels, with tws = tws^{ω} + tws^{b} + tws^{q}.

4.3.1 Unpredictable Policy over Half a Century. Fig.(4) pins down the effect of an unexpected expansionary change in the interest rate. The latter stimulates the consumption of both top and middle-class households. Aggregate demand shifts outwards and production adjusts to it. Low lending costs favor middle-class borrowing (tws^{b}) which leads to interest payments to the top (tis^{b}). The latter along with the unequally disturbed profits (tis^{pr}) stemming from the economic expansion lead to a positive (pro-cyclical) elasticity of income.
inequality. In contrast, the elasticity of wealth inequality is negative (counter-cyclical) because the middle class uses the borrowed funds to raise its asset holdings ($tw^ω$ falls). The latter along with the asset price rise ($tw^q$ falls) that accompanies low interest rates, spur downward pressures to wealth inequality that dominate top’s increased bond assets.

Figure 5: Monetary Policy Surprises and Inequality Swings

Notes: Counterfactual top 10% income and wealth shares for zero monetary policy surprises.

The present paper allows to quantify the effect of interest rate changes not explained by fundamentals (i.e. the policy “surprises”) on inequality during the entire 1954-2009 period. To that end, Fig.(5) displays how the U.S. income and wealth inequality would have looked like, had monetary policy been characterized by zero surprises during the above period. According to the findings, there are some differences of small magnitude (about 1-3% points) between the observed and the counterfactual series. In terms of wealth inequality, between 1955 and 1981 as well as between 2000 and 2009 the initially formed differences between the actual and the counterfactual series persist and remain rather constant. From the mid-80s and up to about 2000, the counterfactual series converges to the actual one from above
implying that zero policy surprises are more expansionary than the actual surprises of that period. In terms of income inequality, the picture is a tad different: in the absence of policy surprises the counterfactual income inequality becomes more noisy and volatile than the actual series is. The counterfactual series fluctuates around the actual series, demonstrating a sensitivity of the top income share to the policy interest rate.

4.3.2 Monetary Policy Stance. I shed light on how the propagation of swings in inequality depends on the monetary policy stance. According to Fig. (6), the policy regime towards inflation \( (\psi_\pi) \) influences the amplitude of the output elasticity to wage polarization and wealth shocks: the more non-accommodative the policy, the smaller the output elasticity. The reason behind this result is that those shocks generate pro-cyclical changes in aggregate demand and, thereby, in inflation. As a result, monetary policy faces no trade off in stabilizing the economy.

Figure 6: Monetary Policy Stance and the Transmission of Distributional Imbalances

Notes: Transmission of polarization and wealth shocks across different policy regimes towards inflation.

As described in Fig. (1), polarization shocks weaken the collateral channel and force the
middle class to bring down its debt obligations, while inflation and output, driven by the consumption of the top, increase and result in an interest rate rise. Therefore, the stronger the policy reaction to inflation, the higher the interest rate rise and, thereby, the heavier the debt burden on the middle class and, in turn, the reduction in its debt obligations. Furthermore, in response to wealth shocks, output, inflation, the interest rate, and debt rise. A non-accommodative policy curtails the debt expansion through a sharp raise of the policy rate. Interestingly, the various degrees of the systematic policy reaction to inflation have limited impact on the trajectory of income and wealth inequality in response to wealth and polarization shocks. The above evidence entail an additional message. Thanks to the pro-cyclical inflation response to these two shocks, monetary policy stabilizes the economy by monitoring aggregates rather than household-specific variables even in the presence of heterogeneous agents and economic fluctuations that emanate from changes in inequality.

4.3.3 Should Monetary Policy React To Inequality? Assuming that the volatilities of inflation and of the output gap are the only objectives of monetary policy, it is important to quantify how their trade-off depends on an interest rate policy that responds to distributional imbalances not only indirectly, through general equilibrium effects, but also directly. This section addresses this issue by considering policy rules in the form of (in log-linear terms):

$$
\hat{r}_t = \rho_r \hat{r}_{t-1} + \left(1 - \rho_r\right) \left[\psi_t \pi_t + \psi_y (\hat{y}_t - \hat{y}_f) + \psi_{\Delta y} \Delta (\hat{y}_t - \hat{y}_f) + \psi_j \hat{x}_j\right] + \epsilon_{mp}^{\text{mp}}
$$

(4.1)

where $\hat{x}_j^j$ is replaced, in turn, with the top income decile ($\hat{i}s_t$), the top wealth decile ($\hat{w}s_t$), and the middle-class–top consumption differential ($n^\mu c^\mu_t - n^\tau c^\tau_t$). The associated reaction coefficients are given by $\psi_j \in \{\psi_{iis}, \psi_{wss}, \psi_{(c^\mu - c^\tau)}\}$. I set all parameters at their posterior mean and, in the spirit of Levin et al. (1999) and Iacoviello (2005), search for the $\{\psi_x, \psi_j\}$ values that minimize a welfare loss function of inflation and output gap variabilities across different parameterizations of the relative weight between the two.

As displayed in Fig.(7), altogether, the alternative rules achieve negligible to no gains in terms of the inflation–output gap variability trade-off, with the gains emanating from an increased sensitivity of the interest rate to fluctuations in aggregate demand capturing changes in inequality. More specifically, in the case of a policy response to income inequality, the interest rate responds to the wage polarization shock capturing changes in income inequality, and the economy shifts in a region of slightly higher inflation and output gap volatilities compared to the trade-off emanating from the “optimal rule” featuring an opti-
Figure 7: Policy Frontier

Notes: Inflation – output gap trade-off across monetary policy rules.

- Optimal, $\psi_x = 0$
- Optimal, $\psi_{tis} \neq 0$
- Optimal, $\psi_{tws} \neq 0$
- Optimal, $\psi_{(c^\tau - c^\mu)} \neq 0$
- Estimated

Inflation–output gap trade-off across monetary policy rules. In the case of a policy response to either the consumption differential or the top wealth share, the inflation–output gap variability trade-off stemming from rules augmented with inequality shifts south-east, and monetary policy achieves moderate gains in terms of the output gap variability that are unattainable by the optimal rule but faces a much higher inflation volatility than that of the optimal rule. For a loss function placing weight almost exclusively on output gap variability, a policy response to wealth inequality yields negligible gains of about 2-3% in terms of the output gap volatility compared to the optimal policy for a level of inflation volatility around 0.5%.

As for the coefficients $\{\psi_{tis}, \psi_{tws}, \psi_{(c^\tau - c^\mu)}\}$, as the welfare weight on inflation volatility goes from zero to one, $\psi_{tis}$ rises from -0.12 to -0.03, $\psi_{tws}$ rises from -0.45 to -0.03, and $\psi_{(c^\tau - c^\mu)}$ rises from -0.36 to -0.03. Hence, all the coefficients are considerably different from zero when the welfare criterion places more weight on output gap than on inflation volatility since

15 The curve involves an optimal $\psi_\pi$ conditionally on the posterior distribution of all model parameters, and is situated below the point indicated by the estimated policy rule over the historical data.
the variables attached to those coefficients heavily depend on distributional shocks inducing persistent shifts in aggregate demand and, thereby, in the output gap (the connection of demand and the output gap fluctuations is reinforced by the fact that the flexible equilibrium does not feature distributional shocks). Conversely, a welfare function favoring inflation over output gap stabilization places negligible weight on changes in inequality.

4.4 DISTRIBUTIONAL IMPLICATIONS OF AGGREGATE SHOCKS.

Although demand and supply side shocks are labeled as “aggregate” shocks following convention, they may in fact have distributional consequences because their transmission is filtered through MPC heterogeneity and imperfect insurance. This section, therefore, investigates the effect of aggregate shocks on inequality. According to Table (5), income inequality is mainly explained by polarization shocks. In contrast, supply and demand side shocks entail profound implications for wealth inequality by galvanizing 28/5% and 11/5% of its short/medium-run fluctuations, respectively. The short-run effect of supply shocks is mainly attributed to technology shocks through their impact on the debt overhang, whereas the long-run effect is distributed across all supply shocks. All demand side shocks but government spending shocks have about a co-equal influence on the swings of wealth inequality.

Fig.(8) displays the diffusion of demand side disturbances. More specifically, a reduction in the risk premium raises the consumption of both types of households; in fact, middle-class consumption rises more than top consumption does. Due to the workings of the aggregate demand channel, output expands and inflation exhibits a pro-cyclical response. Income inequality \( t_{is} \) rises because the increasing profit margins \( t_{is^m} \) are unequally distributed across the population while the earnings \( t_{is^{ea}} \) and capital income \( t_{is^b} \) channels have a small effect. In contrast, wealth inequality decreases \( t_{ws} \). Low lending costs result in middle-class households borrowing from the top \( t_{ws^{b}} \) to raise their consumption and ownership of firms \( t_{ws^{w}} \) falls). The latter and the negligible asset price effect to the top \( t_{ws^{q}} \) edge out the increase in borrowing, and result in a plummeting top wealth share.

Investment and government spending shocks generate expansions that raise profits and the top income share. Nevertheless, both shocks depress aggregate consumption: (i) investment shocks lead to a sizable decrease in top consumption but to an increase in the assets of the top; (ii) government spending shocks raise the tax burden for middle-class families disproportionally since the model was built on the premise of an equal tax across
households, and result in a consumption contraction. In response to both shocks, thus, the top ownership of shares rises ($tws^\omega$) and along with the borrowing of the middle class ($tws^b$) and the small asset price effects generate an increase in wealth inequality ($tws$).

Fig.(9) reports the transmission of supply side innovations. Stochastic increases in price markups generate pro-cyclical responses in both income and wealth inequality. In response to exogenous increases in prices, the consumption of all agents falls by about the same amount, and drives down production, labor, and the real wage. Given the low borrowing costs due to high inflation, the middle class partially smooths its consumption by borrowing from the top ($tws^b$) and expands its ownership of shares ($tws^\omega$ falls). As a result, the top wealth share ($tws$) falls. Despite the price increases favoring the firms’ profits, the demand contraction is sizable and results in low profits flowing to the top ($tis^{pr}$) and, thereby, in a falling top income share ($tis$). Wage markup shocks lead to economy wide conditions that are similar to those generated by price markup shocks, and to a similar, albeit smaller, decrease of income inequality due to weakened profits flowing to the top. Nonetheless, wage markup shocks raise wealth inequality because middle-class households deplete their real assets triggering an asset price decline ($tws^q$ rises) that benefits the top who holds a larger fraction of shares. Technological advances raise the consumption of both families, trigger an economic expansion, and boost profits which, in turn, spur an increase in income inequality. Interestingly, those advances generate a reduction in wealth inequality since the low borrowing costs help middle-class families debt-finance an increase in their ownership shares while boosting asset prices that negatively feed back to the top wealth share.

4.5 Robustness Checks.

4.5.1 Collaterals and the Elasticity of Output to Wealth Shocks. The analysis so far has not made clear how the transmission of distributional shocks depends on the degree of financial market imperfections and, in particular, on the importance of collaterals captured by the loan-to-value ratio ($m$); the higher the $m$, the lower the imperfections\textsuperscript{16}. Fig.(10) displays the transmission of wage and wealth shocks under alternative values for $m$. It unveils that the elasticities of output to wage and wealth shocks are of the same sign but of different magnitude depending on $m$. The fact that even low values of $m$ generate positive elasticities to the wealth shock illustrates that those shocks differ from the ones considered in Iacoviello (2005) where the output elasticity changes sign for low $m$.

\textsuperscript{16}In terms of steady state effects, a higher $m$ raises debt, as well as the top income and wealth shares.
Figure 8: Distributional Implications of Demand Side Shocks

Figure 9: Distributional Implications of Supply Side Shocks

Notes: impulse response functions (posterior mean). All variables in % deviation from steady state. 1st and 2nd row: aggregate variables. 3rd row: top income share (tis): earnings (tis\textsuperscript{ea}), bond income (tis\textsuperscript{b}), and profits (tis\textsuperscript{pr}) channels, with tis = tis\textsuperscript{ea} + tis\textsuperscript{b} + tis\textsuperscript{pr}. 4th row: top wealth share (tws): shares (tws\textsuperscript{ω}), bonds (tws\textsuperscript{b}), and asset price gains/losses (tws\textsuperscript{q}) channels, with tws = tws\textsuperscript{ω} + tws\textsuperscript{b} + tws\textsuperscript{q}.
More precisely, a high degree of financial market imperfections (low $m$) leads to a small output spike on impact and a highly persistent response of a small volatility subsequently. In contrast, a high $m$ renders the collateral channel important and, thereby, (i) dampens down the debt reduction in the case of polarization shocks, and (ii) amplifies the debt buildup in the case of wealth shocks. In case (i), the easier access to credit does not require the middle class to massively deplete its assets; as a result, wealth inequality does not rise as much as it would for a low $m$. In case (ii), the massive increase of middle-class borrowing is channeled to increase the assets of the middle class; consequently, wealth inequality falls much more than that it would for a low $m$. The effect of the above shocks on the top income share does not depend on $m$ as much as their effect on the top wealth share does.

Figure 10: Collaterals and the Transmission of Distributional Imbalances

Notes: Transmission of polarization & wealth shocks (posterior mean) across different loan-to-debt values.

4.5.2 Identification. To further understand the influence of inequality data compared to that of aggregate data on the estimates for the parameters associated with the distributional dimension of the model, I repeat the estimation without including the top deciles in
the observation vector as well as wage and wealth shocks in the stochastic structure. The
results below suggest that income and wealth inequality series are in fact informative. The
estimation yields top income and wealth deciles (651% and 73%, respectively, at the steady
state) that are at odds with U.S. data. Compared to the benchmark run, $\phi^r$ rises from 0.15
to 0.35 and $\phi^\mu$ rises from 0.37 to 0.52. Credit supply shocks become less volatile and their
influence on debt rises from 30/17% in the benchmark model to 40/35% in the estimation
without inequality data, whereas their influence on output remains unchanged. The loading
factor for consumer credit debt ($\Psi_d$) rises from (0.77) to (0.87).

4.5.3 Credit and Wealth Shocks, and a Comment on Taxes. Table (5) shows that
wealth and credit shocks each account for a sizable part of the debt fluctuations. Are these
two shocks, however, somehow connected? Several results suggest some degree of connection.
First, the two innovations have a negative correlation of -0.29 despite their modeling as
iid processes\textsuperscript{17}. Second, a negative connection between the two shocks is observed in the
historical decompositions of Fig.(3). Third, as discussed in the above section, re-estimating
the model by excluding top shares from the observation set as well as polarization and wealth
shocks from the stochastic structure raises the influence of credit shocks on debt.

Altogether, these results suggest that disentangling wealth from credit shocks is im-
portant in understanding changes in the economy. Including shifts in wealth inequality in
the estimation helps in that direction by disciplining the path of variables appearing in the
observation equation for wealth (3.6). As a result, wealth and credit shocks spur some qual-
itatively and quantitatively similar dynamics in Fig.(2), but the former entail more volatile
asset price changes than the latter do, trigger a counter-cyclical instead of a pro-cyclical
wealth inequality, and do not contribute to the debt pileup prior to the Great Recession. Fi-
nally, worth mentioning is that consistently with the literature showing that the top income
share is connected to the top tax rate [Piketty et al., 2014; Piketty and Saez, 2013], I find a
0.28 correlation between polarization and government spending shocks.

4.5.4 Prior. The postulated prior specification is not dogmatic. At the prior, distribu-
tional shocks account for 0%, 2%, 67%, and 1% of the short-term cycles in output, debt,
income inequality, and wealth inequality, respectively (see Appx.). That effect is considerably
smaller than the estimated one (10%, 75%, 100%, and 61%, respectively; Table 5).

\textsuperscript{17} In contrast, the correlation between wealth and risk premium shocks is negligible (0.01), which does
not validate the connection between risk premium and taste shocks for assets shown in Fisher (2015).
4.5.5 Marginal Propensity To Consume. This section quantifies the model-implied MPC heterogeneity across top and middle-class households. Fig.(11) displays the posterior distribution of MPC out of several variables and all sources of stochastic variation. Several insights emerge. First, middle-class households are more prone to consume out of an increase in output than top households are. Additionally, middle-class households reduce their consumption in response to debt more strongly than top households increase theirs (panel 1,1). Furthermore, the evidence suggests negligible reaction of a group’s consumption to the other group’s consumption (panel 2,2). In addition, the consumption responses to a wage shock are of the opposite sign across the population and orders of magnitude larger than the MPC observed for other shocks and variables (panel 2,3). Moreover, according to panels (2,4) and (3,1), in response to wealth and credit shocks, the MPC has the opposite sign across the population and is more than ten times higher for the middle class than for the top. Interestingly, panels (1,3) and (1,4) suggest a weak feedback from employment and asset prices to consumption choices for both groups. Lastly, it is worth mentioning that for homogeneous wealth preferences \((\phi^\tau = \phi^\mu)\), the MPC heterogeneity is attenuated (Appx.).

Figure 11: Marginal Propensity To Consume Differentials

Notes: Posterior distribution of consumption responses across variables and sources of stochastic variation.
4.5.6 **Portfolio Costs.** The elasticity of portfolio costs \( (S_w) \) is kept to a low value (0.1) – small costs is the conventional view in the literature; see Iacoviello (2005) for example. Considering high values for \( S_w \) while conditioning on the posterior parameter distribution leads to a monotonic increase in the influence of wealth shocks: rising \( S_w \) from 0.1 to 1 increases the influence of wealth shocks on output from 2% to 89%. Such an unrealistic increase suggests that the posterior distribution of \( S_w \) depends on that of the other parameters. Unreported results suggest that when \( S_w \) is estimated, it obtains moderate values around 2, dampens down the influence of wealth shocks to some extent because part of the debt persistence is now captured by the sluggishness induced by high portfolio costs, and boosts the general equilibrium effects of aggregate shocks on debt. Nevertheless, no sizable changes are observed in the parameters and the overall influence of distributional shocks.

5 **Concluding Remarks**

The present paper adds to the literature on the macroeconomic ramifications of inequality by examining the historical fluctuations of inequality, debt, and aggregate series jointly over five decades through the lens of a proposed and estimated structural model. The takeaway message suggests that swings in inequality have limited effect on business cycles, but influence household debt gyrations to a large extent. The monetary policy transmission is not impaired in this framework because changes in inequality operate through aggregate demand. This paper sets the stage for further explorations across several dimensions. For example, delving into the swings of inequality in environments where debt plays a more crucial role for economic stability than that considered in this paper may reveal a larger macroeconomic influence of those swings.

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Distributional Imbalances, Monetary Policy, and the U.S. Business Cycle


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Appendices

(not for printed publication; for online reference only)

A. Model

A.1 Nonlinear.

This section collects the nonlinear non-stationary equilibrium equations.

A.1.1 Households. The first order equilibrium conditions for \( \mu \) family read as follows:

\[
\Xi_{\mu t}^\mu = 1/ \left[ C_{\mu t}^\mu - \eta C_{t-1}^\mu \right] \\
\Xi_{\tau t}^\mu = E_t \beta \Xi_{\tau t+1}^\mu \frac{e^{\nu t} R_t}{\Pi_{t+1}} + \Lambda_t^\mu \\
\Xi_t^\mu Q_t \left[ 1 + S'_\omega \left( \frac{\Omega_t^\mu}{\Omega_{t-1}^\mu} \right) \right] = \beta \Xi_{\tau t+1}^\mu Q_{t+1} \left[ 1 - S_\omega \left( \frac{\Omega_{t+1}^\mu}{\Omega_t^\mu} \right) + \frac{\Omega_t^{\mu+1}}{\Omega_t^\mu} S'_\omega \left( \frac{\Omega_{t+1}^\mu}{\Omega_t^\mu} \right) \right] \\
+ \frac{\phi^{\mu+1} \mu_t^\mu}{\Omega_t^\mu} + \Xi_t^\mu \xi_t + \Lambda_t^\mu m_t E_t \left( \frac{Q_{t+1} \Pi_{t+1}}{e^{\nu t} R_t} \right)
\]

\{\Xi_t^\mu, \Lambda_t^\mu\} are the multipliers associated with the budget constraint. (A.1) pins down the multiplier, (A.2) describes the inter-temporal consumption substitution, and (A.3) governs the inter-temporal wealth accumulation. The marginal rate of substitution between j-type labor and consumption is:

\[ W_{t}^{i,h,r}(j) = \frac{\theta(L_{t}^i(j))^x / \Xi_t^\mu}{\Xi_t^\mu} = \frac{\theta(L_{t}(j))^x / \Xi_t^\mu}{\Xi_t^\mu} \]

The first order equilibrium conditions for \( \tau \) family read as follows:

\[
\Xi_{\tau t}^\tau = 1/ \left[ C_{\tau t}^\tau - \eta C_{t-1}^\tau \right] \\
\Xi_{\tau t}^\tau = E_t \beta \Xi_{\tau t+1}^\tau e^{\nu t} R_t / \Pi_{t+1} \\
\Xi_t^\tau Q_t \left[ 1 + S'_\omega \left( \frac{\Omega_t^\tau}{\Omega_{t-1}^\tau} \right) \right] = \beta \Xi_{\tau t+1}^\tau Q_{t+1} \left[ 1 - S_\omega \left( \frac{\Omega_{t+1}^\tau}{\Omega_t^\tau} \right) + \frac{\Omega_t^{\tau+1}}{\Omega_t^\tau} S'_\omega \left( \frac{\Omega_{t+1}^\tau}{\Omega_t^\tau} \right) \right] \\
+ \frac{\phi^{\tau+1} \mu_t^\tau}{\Omega_t^\tau} + \Xi_t^\tau \xi_t + \Lambda_t^\mu m_t E_t \left( \frac{Q_{t+1} \Pi_{t+1}}{e^{\nu t} R_t} \right)
\]

\{\Xi_t^\tau\} is the multiplier associated with the budget constraint. The marginal rate of substitution between labor and consumption for labor type “j” of family \( i \) is given by:

\[ W_{t}^{i,h,r}(j) = \theta(L_{t}^i(j))^x / \Xi_t^\tau = \theta(L_{t}(j))^x / \Xi_t^\tau \]

A.1.2 Capital Production. The optimization problem of the capital producing firm (2.7) pins down the equilibrium rental rate of capital:

\[ 1 \]
\[ R_t^{k,r} \equiv R_t^k/P_t = a'(u_t) \]  

The price of capital, \( Q_t^k \), is determined by

\[ Q_t^k/P_t = E_t(\Xi_{t+1}^{avg}/\Xi_t^{avg}) \left[ (R_t^{k+1}/P_{t+1})u_{t+1} - a(u_{t+1}) + (1-\delta)Q_{t+1}^k/P_{t+1} \right] \quad (A.10) \]

Investment dynamics are pinned down by

\[ 1 = \frac{Q_t^k}{P_t} v_t^i \left[ 1 - S \left( \frac{I_t}{I_{t-1}} \right) - \frac{I_t}{I_{t-1}} S' \left( \frac{I_t}{I_{t-1}} \right) \right] + E_t \frac{\Xi_{t+1}^{avg}}{\Xi_t^{avg}} \frac{Q_{t+1}^k}{P_{t+1}} v_{t+1}^i \left( \frac{I_{t+1}}{I_t} \right)^2 S' \left( \frac{I_{t+1}}{I_t} \right) \quad (A.11) \]

A.1.3 Intermediate Good Firms. Maximization of (2.11) yields the optimal price for an optimizing firm as the weighted average of current and future marginal costs:

\[ E_t \sum_{s=0}^{+\infty} (\zeta_p)^s \left[ \frac{\Xi_{t+s}^{avg}P_t}{\Xi_t^{avg}P_{t+s}} \right] Y_{t+s|i}(\lambda_{p,t+s}-1) \left[ P_t^p(i)X_{t,s}^p - \frac{\lambda_{p,t+s}}{\lambda_{p,t+s}-1} MC_{t+s} \right] = 0 \quad (A.12) \]

Taking into account the infrequent price adjustment and that all optimizing firms choose the same price \( P_t^o \), the evolution of the aggregate price index (2.8) is described by

\[ P_t = \left[ (1-\zeta_p)(P_t^o)^{1-\lambda_{p,t}} + \zeta_p (\Pi_{p-1}^{p} \Pi^{1-t_p} P_{t-1})^{1-\lambda_{p,t}} \right]^{1/(1-\lambda_{p,t})} \quad (A.13) \]

A.1.4 Labor Unions. Maximization of (2.14) yields the optimal wage, \( W_t^o \), chosen by all re-optimizing unions:

\[ E_t \sum_{s=0}^{+\infty} (\zeta_w)^s \left[ \frac{\Xi_{t+s}^{avg}P_t}{\Xi_t^{avg}P_{t+s}} \right] L_{t+s}(j)(\lambda_{w,t+s}-1) \left[ W_t^o X_{t,s}^w - \frac{\lambda_{w,t+s}}{\lambda_{w,t+s}-1} W_{t+s}^h(j) P_{t+s} \right] = 0 \quad (A.14) \]

The aggregate wage is given by:

\[ W_t = \left[ (1-\zeta_w)(W_t^o)^{1-\lambda_{w,t}} + \zeta_w (e^\gamma \Pi_{t-1}^{p} \Pi^{1-t_w} W_{t-1})^{1-\lambda_{w,t}} \right]^{1/(1-\lambda_{w,t})} \quad (A.15) \]

A.2 Stationary Model.

Trend growth is given by \( Z_t = Z_{t-1} e^\gamma \). I render the model stationary before estimating it. Small letters denote stationary real variables, e.g. \( c_t^r = C_t^r/Z_t \), \( b_t^r = B_t^r/(P_t Z_t) \) for \( j \in \{ \mu, \tau \} \), \( y_t = Y_t/Z_t \), \( k_t = K_t/Z_t \), \( v_t = V_t/Z_t \), \( div_t = Div_t/Z_t \), \( \pi_{t}^{int} = \Pi_{t}^{int}/Z_t \). The multipliers read as: \( \xi_t^j = \Xi_t^j/Z_t \) for \( j \in \{ \mu, \tau \} \), and \( \lambda_{t}^c = \Lambda_t^c/Z_t \). The real price of equity is \( q_t = Q_t/Z_t \); the real rental rate of capital is \( r_t^{k,r} = R_t^k/P_t \). The real capital price is: \( q_t^k = Q_t^k/P_t \). The equity shares are stationary by construction and re-expressed with small letters: \( \omega_t^j = \Xi_t^j/1 \).

A.2.1 Households. The first order conditions (A.1-A.3) for the middle class become:
Investment dynamics are governed by

\[ \xi_t^\mu = 1 \left[ c_t^\mu - \eta c_{t-1}^\mu / (e^\gamma) \right] \]  
\[ \xi_t^\mu = E_t \beta^\mu \xi_{t+1}^\mu \frac{1}{e^\gamma} \frac{\Pi_{t+1}}{R_t} + \lambda_t^\mu \] (A.16) 
\[ \xi_t^\mu q_t \left[ 1 + S'_\omega \left( \omega_{t-1}^\mu / \omega_{t-1}^\mu \right) \right] = \beta^\mu E_t \xi_{t+1}^\mu q_{t+1} \left[ 1 - S_\omega \left( \omega_{t+1}^\mu / \omega_t^\mu \right) + \frac{\omega_{t+1}^\mu}{\omega_t^\mu} S'_\omega \left( \omega_{t+1}^\mu / \omega_t^\mu \right) \right] + \frac{\phi^\mu v_t^\omega}{\omega_t^\mu} + \xi_t^\mu v_t + \lambda_t^\mu e^\gamma m_t \left( \frac{q_{t+1} \Pi_{t+1}}{e^{\gamma^t \gamma}} \right) \] (A.17)

while those for the top (A.5–A.7) read as:

\[ \xi_t^\tau = 1 / \left[ c_t^\tau - \eta c_{t-1}^\tau / (e^\gamma) \right] \]  
\[ \xi_t^\tau = E_t \beta^\tau \xi_{t+1}^\tau \frac{1}{e^\gamma} \frac{\Pi_{t+1}}{R_t} \] (A.19) 
\[ \xi_t^\tau q_t \left[ 1 + S'_\omega \left( \omega_{t-1}^\tau / \omega_{t-1}^\tau \right) \right] = \beta^\tau E_t \xi_{t+1}^\tau q_{t+1} \left[ 1 - S_\omega \left( \omega_{t+1}^\tau / \omega_t^\tau \right) + \frac{\omega_{t+1}^\tau}{\omega_t^\tau} S'_\omega \left( \omega_{t+1}^\tau / \omega_t^\tau \right) \right] + \frac{\phi^\tau v_t^\tau}{\omega_t^\tau} + \xi_t^\tau v_t \] (A.20)

The budget constraints (2.3) and (2.6) for the bottom become:

\[ c_t^\mu - \frac{b_t^\mu}{e^{\nu^t \gamma}} R_t + q_t \left[ \omega_t^\mu - \left( 1 - S_\omega \left( \omega_t^\mu / \omega_{t-1}^\mu \right) \right) \omega_{t-1}^\mu \right] + t_t^\mu = \frac{S_t w_t^\gamma L_t}{n^\mu} - \frac{b_{t-1}^\mu}{e^\gamma \Pi_t} + \omega_{t-1}^\mu \] (A.22)

and

\[ b_t^\mu / [e^{\nu^t \gamma} R_t] \leq m_t E_t \left( q_{t+1} \omega_t^\mu \Pi_{t+1} e^\gamma / [e^{\nu^t \gamma} R_t] \right) \] (A.23)

A.2.2 Capital Producers. The effective capital and the rental rate read as

\[ k_t = u_t k_{t-1}^\mu \frac{1}{e^\gamma} \quad \text{and} \quad R_t^k = a'(u_t) \] (A.24)

Period-t (real) dividends (2.7) are given by

\[ div_t \equiv R_t^k k_t - a(u_t) k_{t-1}^\mu \frac{1}{e^\gamma} - i_t - \Phi_k \] (A.25)

The law of capital accumulation (??) becomes:

\[ \bar{k}_t = (1 - \delta) k_{t-1}^\mu \frac{1}{e^\gamma} + v_t^i \left( 1 - S \left( \frac{i_t}{i_{t-1}} e^\gamma \right) \right) i_t \] (A.26)

The dynamics of the price of capital (A.10) are pinned down by the following condition:

\[ q_t^k = E_t \left( \xi_{t+1}^{q_{avg}} \frac{1}{e^\gamma} \right) \left[ R_{t+1}^k u_{t+1} - a(u_{t+1}) + \left( 1 - \delta \right) q_{t+1}^k \right] \] (A.27)

Investment dynamics are governed by
A.2.3 Average Stochastic Discount Factor. The stationary factor reads as
\[ \xi^\text{avg}_{t+s}/\xi^\text{avg}_t \equiv (\beta^r)^s [n^\tau \xi^\tau_{t+s} + n^\mu \xi^\mu_{t+s}] / [n^\tau \xi^\tau_t + n^\mu \xi^\mu_t] \]  
(A.29)

A.2.4 Intermediate Good. The production function (2.9) reads as:
\[ y_t(i) = e^{\tilde{z}_t} k_t^\alpha(i) L_t(i)^{1-\alpha} - \Phi_y \]  
(A.30)

The capital-labor ratio reads as
\[ k_t(i)/L_t(i) = [\alpha/(1-\alpha)](W_t/P_tZ_t)/(R_t^k/P_t) = [\alpha/(1-\alpha)](w_t^r/R_t^{k,r}) \]  
(A.31)

and the (real) marginal cost (2.10) as:
\[ mc_t^r \equiv MC_t/P_t = (\alpha)^{-\alpha}(1-\alpha)^{-\alpha}(w_t^r)^{(1-\alpha)}(R_t^{k,r})^\alpha e^{-\tilde{z}_t} \]  
(A.32)

Aggregate (real) profits in the intermediate good sector are:
\[ \pi_t^{\text{int}} \equiv \Pi_t^{\text{int}}/Z_t = y_t - w_t^r L_t - R_t^{k,r} k_t \]  
(A.33)

The optimal price for optimizing firms (A.12) is determined by
\[ E_t \sum_{s=0}^{+\infty} (\zeta_p)^s [\xi^\text{avg}_{t+s}/\xi^\text{avg}_t] (X^p_{t,s}/P_{t+s})^{-\lambda_p} y_{t+s} + \frac{1}{v_{t+s}^p} \left[ \frac{P_t^{\alpha,r} X_{t,s}^p}{\prod_{t=1}^{s} \Pi_{t+s}} - (1 + v_{t+s}^p) mc_{t+s}^r \right] = 0 \]  
(A.34)

where \( P_t^{\alpha,r} \equiv P_t^{c}/P_t \) and the time-varying price markup is redefined as \((1 + v_t^p) \equiv \lambda_t^p / (\lambda_t^p - 1)\), that is, \( \lambda_t^p = 1 + 1/v_t^p \). The evolution of the aggregate price index (A.13) is described by
\[ 1 = (1 - \zeta_p)(P_t^{\alpha,r})^{1-\lambda_t^p} + \zeta_p (\Pi_{t-1}^{\alpha,r} \Pi^{1-\alpha}/\Pi_t)^{1-\lambda_t^p} \]  
(A.35)

A.2.5 Labor Demand. Labor demand for type “j” workers and the aggregate wage (2.12) are given by:
\[ L_t(j) = \left( \frac{w_t(j)}{w_t} \right)^{-\lambda_t^w} L_t \quad \text{and} \quad w_t = \left( \int w_t(j)^{1-\lambda_t^w} dj \right)^{1/(1-\lambda_t^w)} \]  
(A.36)

The labor disutility (2.13) expressed in terms of the final good is given by
\[ w_t^h(j) = W_t^h(j)/Z_t = \theta(L_t(j))^{\lambda} [n^\mu \xi^\mu_t + n^\tau \xi^\tau_t] \]  
(A.37)

The first order condition determining the (real) optimal wage (A.14) \( w_t^c = w_t^c(j) \) is given by
\[ E_t \sum_{s=0}^{\infty} (\zeta_w)^s \left[ \frac{\epsilon_{avg} \gamma_{avg}}{\epsilon_{avg} \gamma_{avg}} \right] \frac{1}{u_{t+s}} \left[ \frac{w_t^{0,x} X_{t,s}}{\epsilon \sum_{i=1}^{\infty} \Pi_{t+s}^i \Pi_{t+l}^i} - (1 + v_t^{w}) u_{t+s}(j) \right] L_{t+s}(j) = 0 \quad (A.38) \]

The gross time-varying wage markup is redefined as \((1 + v_t^w) \equiv \lambda_{w,t}^w / (\lambda_{w}^w - 1)\). The (real) aggregate wage reads as:

\[ w_t^r = \left( 1 - \zeta_w \right) \left( u_t^{0,x} \right)^{1-\lambda_{w,t}} + \zeta_w \left( e^\gamma \Pi_{t-1}^x \Pi_{1-tw} u_t^{r} / [e^\gamma \Pi_t] \right)^{1-\lambda_{w,t}} \]  

(A.39)

**A.2.6 Policy.** The following equation describes the policy rule (2.15) in the stationary model

\[ \frac{R_t}{R} = \left( \frac{R_{t-1}}{R} \right)^{\rho_r} \left[ \left( \frac{\Pi_t}{\Pi} \right)^{\psi_w} \left( \frac{y_t}{y_t} \right)^{\psi_y} \left( \frac{y_t/y_{t-1}}{y_t/y_{t-1}} \right)^{\psi_{\Delta}} \right]^{1-\rho_r} e^{\gamma \Pi_{mp,t}} \]  

(A.40)

**A.2.7 Aggregation.** Aggregate consumption is the weighted sum of type-specific consumption profiles: \( c_t = n^r c_t^r + n^\mu c_t^\mu \). The labor and capital aggregates are given by \( L_t = \int_0^1 L_t(i) di \) and \( k_t = \int_0^1 k_t(i) di \), respectively. Market clearing in the debt market dictates \( n^r b_t^r = n^\mu b_t^\mu \), and in the equity market: \( n^r \omega_t^r + n^\mu \omega_t^\mu = \omega_t \equiv 1 \), where the sum of all equity shares is normalized to unity. Aggregate output is given by \( Y_t = e^{\gamma} k_t^0 L_t^{1-\alpha} - \Phi_y \). Aggregate profits in the intermediate good sector are \( \{ \pi_t^{int} = y_t - w_t^r L_t - R_t^{k,r} k_t \} \). The period-t dividends of the fund managing capital production are given by \( \{ div_t \equiv R_t^{k,r} k_t - a(u_t) k_t / e^\gamma - i_t - \Phi_k \} \). Thus, economy wide profits are: \( v_t = \pi_t^{int} + div_t \). The resource constraint (2.16) becomes:

\[ y_t = c_t + i_t + g_t + a c_t + \Phi_k \]  

(A.41)

\[ a c_t = a(u_t) k_t / e^\gamma + q_t \left[ n^\mu \omega_{t-1}^\mu S_{\omega} \left( \omega_t^\mu / \omega_{t-1}^\mu \right) + n^r \omega_{t-1}^r S_{\omega} \left( \omega_t^r / \omega_{t-1}^r \right) \right] \]  

(A.42)

**A.3 Steady State**

**A.3.1 Economy wide variables.** Examining the solution of the steady state reveals that the steady state of economy wide aggregates coincides with that derived from the representative agent model. The following normalizations are considered: \( u = 1 \), \( a(1) = 0 \), \( S(e^\gamma) = S'(e^\gamma) = 0 \), \( S''(e^\gamma) \equiv S'' \), \( \delta = 0.025 \), \( g/y = 0.18 \). The (net) markups \( v_p \) and \( v_w \) are estimated in this paper. The real marginal cost is given by eq.(A.34): \( mc^r = 1/(1 + v_p) \), with eq.(A.35) implying \( P^{0,r} = P^0 / P = 1 \). The price of capital in (A.28) becomes \( q^k = 1 \), and the real rental rate of capital in (A.27) and (A.24) reads as: \( R^{k,r} = (e^\gamma / \beta) - (1 - \delta) = a'(1) \). The effective and raw capital are connected through eq.(A.24): \( k = k/e^\gamma \). The latter combined with the capital accumulation equation (A.26) yields the investment-to-output
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ratio: \( i/y = (k/y)(e^\gamma - (1 - \delta)) \). Fixed costs in capital production (A.25) are set in order to yield zero steady state dividends: \( \Phi_k/y = R^{k,r}k/y - i/y \). Eq.(A.32) pins down the steady state real wage: \( w^r = [mc^r(\alpha)^\alpha(1-\alpha)(R^{k,r})^{-\alpha}]^{1/(1-\alpha)} \). The capital-to-labor ratio is given by (A.31): \( k/L = [\alpha/(1-\alpha)](w^r/R^{k,r}) \). After using the steady state analogues of equations (A.30, A.31, A.32), the aggregate profits in the intermediate good sector (A.33) become: \( \Pi^f_t = y - w^rL - R^{k,r}k = [(w^rL)/(1-\alpha)][(1/mc^r) - 1] - \Phi_y \). The fixed cost term is, then, set in order to yield zero profits. The labor-to-output ratio is then given using (A.30): \( L/y = (1 + \Phi_y/y)/(k/L)^{\alpha} \). The resource constraint (A.41) pins down the aggregate consumption-to-output ratio: \( c/y = 1 - (g/y) - (i/y) - (\Phi_k/y) \). The government budget constraint is described by \( g = t = t^\mu = t^\tau \).

The discounting between two consecutive periods is: \( \xi_{avg}^{a+1}/\xi_{avg}^{avg} = \beta^\tau \) according to (A.29). The latter coincides with the discounting of the representative agent specification given the particular definition of the average discount factor. The risk-free rate is given by the Euler equation for the top (A.20):

\[
R = \Pi e^\gamma / \beta^\tau
\]  

(A.43)

It coincides with the risk-free rate in the representative agent model given that the discount factor of the top (\( \beta^\tau \)) is equal to the single discount factor of the representative agent model (both are fixed at 0.9995). The inverted multipliers (A.16, A.19) read as: \( 1/\xi^\mu = [1 - \eta/e^\gamma]c^\mu \) and \( 1/\xi^\tau = [1 - \eta/e^\gamma]c^\tau \). Equations (A.38) and (A.39) link the real wage with the marginal disutility of work expressed in terms of the final good and with the optimal wage: \( w^r = w^{o,r} = (1 + \nu_w)w^h \). Plugging the expressions for the multipliers in the labor disutility (A.37) implies \( w^h = \theta LX[n^\mu/\xi^\mu + n^\tau/\xi^\tau] = \theta LX[1 - \eta/e^\gamma][n^\mu c^\mu + n^\tau c^\tau] = \theta LX[1 - \eta/e^\gamma]c \). The latter condition coincides with the analogous condition of the representative agent model and allows to pin down the level of \( L \) and that of all the real variables from thereon.

A.3.2 Family-specific variables. The Euler equation for the middle class (A.17) combined with the risk free rate (A.43) yields:

\[
\lambda^\mu = (\beta^\tau - \beta^\mu)\xi^\mu / \beta^\tau
\]  

(A.44)

which is positive for \( \beta^\tau > \beta^\mu \), implying that the middle class borrows from the top at the steady state. After using (A.17), the Euler equations (A.21) and (A.18) yield the share holdings across agents:
\[ \omega^\tau q = \left[ \frac{\phi^\tau (1 - \eta/e^\gamma)}{1 - \beta^\tau} \right] c^\tau \quad \text{and} \quad \omega^\mu q = \left[ \frac{\phi^\mu (1 - \eta/e^\gamma)}{1 - \beta^\mu - (\beta^\tau - \beta^\mu)m} \right] c^\mu \quad (A.45) \]

The last two equations suggest that the top-to-middle-class wealth ratio \( \omega^\tau q / \omega^\mu q \) depends on three factors: i) the ratio of the strength of wealth consideration in the utility function of the top and the middle class \( \phi^\tau / \phi^\mu \); ii) the consumption ratio \( c^\tau / c^\mu \); and iii) the difference in the magnitudes between \( \beta^\tau \) and \( \beta^\mu \). The debt limit \( m \) also influences the top-to-middle-class ratio of ownership shares. The constraint (A.23) pins down the intra-household debt at the steady state:

\[ b^\mu = m \Pi e^{\gamma} \omega^\mu q \quad (A.46) \]

Then, the market clearing condition pins down \( b^\tau \): \( n^\tau b^\tau = n^\mu b^\mu \). The budget constraint (A.22) for an agent in the middle class reads as:

\[ c^\mu + b^\mu \left[ \frac{1}{\Pi e^{\gamma}} - \frac{1}{R} \right] = s w^\tau L / n^\mu - g \quad (A.47) \]

Plugging (A.45) in (A.46), and the result in (A.47) yields a solution for the consumption of the middle class \( c^\mu \) as a function of aggregate variables already pinned down and of parameters. Then, the consumption of the top \( c^\tau \) can be pinned down either from the definition of aggregate consumption \( c = n^\tau c^\tau + n^\mu c^\mu \) or the steady state expression of the budget constraint of the top. Equipped with \{\( c^\mu, c^\tau \}\}, I work backwards and find \{\( \xi^\mu, \xi^\tau \}\) from (A.16, A.19), \{\( \omega^\mu q, \omega^\tau q \}\) from (A.45), and \( \lambda^\mu \) from (A.44). Given the equity levels, the intra-household debt \( (b^\mu) \) is determined by (A.46), and the equity price \( (q) \) is found from the equity market clearing condition: \( n^\tau \omega^\tau q + n^\mu \omega^\mu q = 1 \times q \). Working backwards again, one pins down \{\( \omega^\mu, \omega^\tau \}\).

### A.4 Log-linearized Equilibrium.

This section provides the equilibrium conditions that are log-linearized around the above steady state of deterministic growth. The log-deviation of a generic stationary variable \( x_t \) from its steady state \( x \) is denoted as \( \hat{x}_t \equiv ln(x_t/x) \). Additionally, \( \hat{\pi}_t^{int} \equiv ln(R_t^{int}/R^{int}) \), \( \hat{\pi}_t \equiv ln(\Pi_t/\Pi) \), and \( \hat{\pi}_t \equiv ln(R_t/R) \). Since the intermediate good \( (\pi_t^{int}) \) and aggregate \( (v_t) \) profits, as well as the dividends \( (\text{div}_t) \), have a zero steady state value, I define their log-linearized analogues as a ratio to final output, i.e. \( \hat{\pi}_t = v_t/y = \hat{\pi}_t^{int} + \hat{\text{div}}_t = \pi_t^{int}/y + \text{div}_t/y \).

### A.4.1 Households.

The first order conditions for the middle class (A.16-A.18) yield
Period-t (real) dividends \((A.25)\) are given by

\[
(\text{A.55}) \text{ uses the government budget constraint:}
\]

\[
\hat{\omega}_t^b \equiv \ln(\hat{v}_t^b) \text{ and } \hat{\omega}_t^o \equiv \ln(\hat{\omega}_t).
\]

The conditions for the top (A.19-A.21) imply

\[
(1 - \eta/\gamma) \hat{\xi}_t^u = \hat{c}_t^u - (\eta/\gamma) \hat{c}_{t-1}^u \tag{A.48}
\]

\[
\hat{\xi}_t^u = \left( \frac{\beta^u R}{\Pi e^\gamma} \right) E_t \left( \hat{\xi}_{t+1}^u + \hat{\omega}_t^b + \hat{\tau}_t - \hat{\pi}_{t+1} \right) + \left( 1 - \frac{\beta^u R}{\Pi e^\gamma} \right) \hat{\lambda}_t^u \tag{A.49}
\]

\[
\hat{\omega}_t^u \left[ 1 + \beta^u + \frac{\phi^u}{\omega^u \eta} \frac{\xi_{t+1}^u}{S_{t+1}^m} \right] + \left( \frac{1}{S_{t+1}^m} \right) \left( \hat{\xi}_t^u + \hat{\omega}_t \right) = \hat{\omega}_{t-1}^u + \beta^u E_t \hat{\omega}_{t+1}^u + \left( \frac{\beta^u}{S_{t+1}^m} \right) E_t \hat{\omega}_{t+1}^u + \left( \frac{\phi^u}{\omega^u \eta} \right) \hat{\omega}_t + \left( \frac{y}{S_{t+1}^n} \right) \hat{\omega}_t
\]

The two budget constraints for the bottom (A.23, A.22) read as:

\[
\hat{b}_t^u = \hat{m}_t + E_t \hat{\omega}_{t+1} + \hat{\omega}_t^u + E_t \hat{\pi}_{t+1} \tag{A.54}
\]

\[
\phi^u \hat{\xi}_t^u - (b^u / R)(\hat{b}_t^u - \hat{\tau}_t - \hat{\omega}_t^b) + (\Omega^u / \eta)(\hat{\omega}_t^u - \hat{\omega}_{t-1}^u) = (sw^u L / n^u) (\hat{\omega}_t^u + \hat{\lambda}_t) + (sw^u L / n^u) \hat{s}_t
\]

\[
- (b^u / [\Pi e^\gamma]) (\hat{\omega}_{t-1} - \hat{\pi}_t) + (\Omega^u / \eta) \hat{\omega}_t - g\hat{\omega}_t \tag{A.55}
\]

where (A.55) uses the government budget constraint: \(t = t^u = t^r = g\) and \(\hat{t}_t = \hat{b}_t^u = \hat{b}_t^u = \hat{\omega}_t^u\).

The deviation of the income share from its steady state value is defined as: \(\hat{s}_t \equiv \ln(s_t / s)\).

### A.4.2 Capital Production.

The effective capital and the rental rate (A.24) read as

\[
\hat{k}_t = \hat{u}_t + \hat{k}_{t-1} \quad \text{and} \quad \hat{r}_t^k = \left[ \psi / (1 - \psi) \right] \hat{u}_t \tag{A.56}
\]

Period-t (real) dividends (A.25) are given by

\[
\hat{d}v_t = (R^{k,r} k / y) \left[ \hat{r}_t^k + \hat{k}_t - \hat{u}_t - \left( \frac{e^\gamma - 1 + \delta}{e^\gamma / \beta^r - 1 + \delta} \right) \hat{\tau}_t \right] \tag{A.57}
\]

The law of capital accumulation (A.26) becomes:

\[
\hat{k}_t = [(1 - \delta) / e^\gamma] (\hat{k}_{t-1}) + [1 - (1 - \delta) / e^\gamma] (\hat{d}v_t + \hat{\tau}_t) \tag{A.58}
\]
where \( \hat{v}_i^t \equiv \ln(v_i^t) \). The dynamics of the price of capital (A.27) are pinned down by:

\[
\hat{q}_t^k = E_t \left( \hat{\pi}^{avg}_{t+1} - \hat{\pi}^{avg}_{t} \right) + \left( \frac{R^{k,r}}{R^{k,r} + 1 - \delta} \right) E_t \pi_{t+1}^r + \left( \frac{1 - \delta}{R^{k,r} + 1 - \delta} \right) E_t \hat{q}_{t+1}^k \tag{A.59}
\]

Investment dynamics (A.28) are governed by:

\[
\hat{i}_t \left( \frac{1 - \beta}{1 + \beta^r} \right) \left( \hat{\pi}^{avg}_{t+1} - \hat{\pi}^{avg}_{t} \right) + \left( \frac{\beta^r}{1 + \beta^r} \right) \left( E_t \hat{\pi}_{t+1}^r \right) + \left( \frac{1}{1 + \beta^r} \right) \left( \frac{1}{\epsilon^{2n} S^n} \right) \right] \left( \hat{q}_t^k + \hat{i}_t \right) \tag{A.60}
\]

### A.4.3 Discounting

The average discounting (A.29) between two consecutive periods reads as

\[
\hat{\pi}_t^{avg} - \hat{\pi}_t^{avg} = \left( \frac{n^r \xi^r}{n^r \xi^r + n^\mu \xi^\mu} \right) (\hat{\pi}_t^{avg} - \hat{\pi}_t^{avg}) + \left( \frac{n^\mu \xi^\mu}{n^r \xi^r + n^\mu \xi^\mu} \right) (\hat{\pi}_t^{avg} - \hat{\pi}_t^{avg}) \tag{A.61}
\]

### A.4.4 Intermediate Good

Log-linearizing the aggregate production function yields

\[
\hat{y}_t = (1 + \Phi_y/y) [\alpha \hat{K}_t + (1 - \alpha) \hat{L}_t + \hat{z}_t] \tag{A.62}
\]

The linearized equation for the capital-labor ratio (A.31) reads as

\[
\hat{k}_t = \hat{\omega}_t^r - \hat{r}_t^k + \hat{L}_t \tag{A.63}
\]

and the (real) marginal cost (A.32) as

\[
\hat{m}_r = (1 - \alpha) \hat{w}_t^r + \alpha \hat{r}_t^k - \hat{z}_t \tag{A.64}
\]

The linearized aggregate (real) profits (A.33) in the intermediate good sector are:

\[
\hat{\pi}_t^{int} \equiv \pi_t^{int}/y = \hat{y}_t - \left( \frac{w^r L}{y} \right) (\hat{\omega}_t^r + \hat{L}_t) - \left( \frac{R^{k,r} k}{y} \right) (\hat{r}_t^k + \hat{K}_t) \tag{A.65}
\]

Linearizing and combining equations (A.34) and (A.35) yields the Phillips curve:

\[
\hat{\pi}_t = \left( \frac{\beta^r}{1 + \epsilon_p \beta^r} \right) E_t \hat{\pi}_{t+1} + \left( \frac{1}{1 + \epsilon_p \beta^r} \right) \hat{\pi}_{t-1} + \left[ \left( 1 - \zeta_p (1 - \zeta_p \beta^r) \right) \right] \left( \hat{m}_r + \left( \frac{\nu_p}{1 + \nu_p} \right) \hat{\pi}_t^{w} \right) \tag{A.66}
\]

### A.4.5 Labor Demand

Linearizing the labor demand and the wage aggregator in (A.36), the labor disutility (2.13), and the aggregate wage dynamics (A.39) and, then, plugging all those equations in the linearized condition for the optimal wage (A.38) yields:

\[
\hat{w}_t - \hat{w}_{t-1} + \hat{\pi}_t - \epsilon_w \hat{\pi}_{t-1} = \beta^r \left[ E_t \hat{\pi}_{t+1} - \hat{\pi}_t + E_t \hat{\pi}_{t+1} + \epsilon_w \hat{\pi}_t \right] + \left[ \left( 1 - \zeta_w (1 - \zeta_\pi \beta^r) \right) \right] \left( \chi \hat{L}_t - \left( \frac{(n^\mu \xi^\mu) \hat{\xi}_t^r + (n^r \xi^r) \hat{\xi}_t^\mu}{n^\mu \xi^\mu + n^r \xi^r} \right) - \hat{\omega}_t + \left( \frac{\nu_w}{1 + \nu_w} \right) \hat{\pi}_t^{w} \right) \tag{A.67}
\]

The latter is similar to the analogous condition of the representative agent model (B.11) with the difference been detected in the average discount factor of the right-hand-side expression.
A.4.6 Policy. The linearized policy rule is derived from (A.40):
\[ \hat{r}_t = \rho \hat{r}_{t-1} + (1 - \rho) \left[ \psi \pi \hat{r}_t + \psi_y \hat{y}_t + \psi \Delta y \Delta (\hat{y}_t - \hat{y}_t^{lf}) \right] + \epsilon_t^{mp} \]  
(A.68)
where \( \Delta \) stands for the first-difference operator.

A.4.7 Aggregation & Market Clearing. Equity and bonds market clearing imply:

\[ (n^\tau \omega^\tau) \hat{\omega}^\tau_t + (n^\mu \omega^\mu) \hat{\omega}^\mu_t = 0 \]  
(A.69)

\[ \hat{b}_t^\tau = \hat{b}_t^\mu \]  
(A.70)

Aggregate consumption is the weighted sum of family-specific consumptions:

\[ \hat{c}_t = [n^\mu c^\mu / c] \hat{c}_t^\mu + [n^\tau c^\tau / c] \hat{c}_t^\tau \]  
(A.71)

The log-linearized resource constraint (A.41) reads as:

\[ (c/y) \hat{c}_t + (i/y) \hat{i}_t + (g/y) \hat{y}_t + (R^{k,r} k/y) \hat{u}_t = \hat{y}_t \]  
(A.72)

Finally, the aggregate period-t profits distributed back to households are given by

\[ \hat{v}_t = \hat{\pi}_t^{int} + \hat{div}_t \]  
(A.73)

A.4.8 Equilibrium Definition. The eight equations (A.48)–(A.53), (A.54), and (A.55) of the household side determine a solution for eight variables: \( \{ \hat{\xi}_t^\mu, \hat{\xi}_t^\tau, \hat{\lambda}_t^\mu, \hat{\lambda}_t^\tau, \hat{\xi}_t^{avg}, \hat{\xi}_t^\mu, \hat{\xi}_t^\tau \} \). The bond holdings of the top \( \{ \hat{b}_t^\mu \} \) are, then, pinned down by the bonds market clearing condition (A.70). The price of equity \( \{ \hat{q}_t \} \) is pinned down by the equity market clearing condition (A.69). Aggregate consumption \( \{ \hat{c}_t \} \) is given by (A.71). The six equations (A.56)–(A.60) in the capital production side determine a solution for the following six variables: \( \{ \hat{k}_t, \hat{\delta}_t^r, \hat{q}_t^k, \hat{\gamma}_t, \hat{\zeta}_t, \hat{\nu}_t \} \). Equation (A.61) yields the average discount factor \( \{ \hat{\xi}_t^{avg} \} \). The five equations (A.62)–(A.66) pin down the following five variables: \( \{ \hat{y}_t, \hat{L}_t, \hat{\pi}_t^{int}, \hat{\pi}_t, \hat{mc}_t^r \} \). Equation (A.67) determines the real wage \( \{ \hat{w}_t^r \} \). The nominal interest rate \( \{ \hat{r}_t \} \) is found by (A.68). A solution for the utilization rate \( \{ \hat{u}_t \} \) stems from the resource constraint (A.72). Aggregate profits \( \{ \hat{v}_t \} \) are given by (A.73).

A.4.9 Dimensionality Reduction. To reduce the state dimensionality, \( \{ \hat{\xi}_t^\mu, \hat{\xi}_t^\tau, \hat{\xi}_t^{avg} \} \) are substituted out of the system using equations (A.48, A.51, A.61). Similarly, the bonds and equity market clearing conditions (A.70, A.69) are used to eliminate \( \{ \hat{b}_t^\mu \} \) and \( \{ \hat{\omega}_t^\mu \} \). \( \{ \hat{k}_t \} \) is eliminated using (A.24). \( \{ \hat{mc}_t^r \} \) is substituted out using (A.64). \( \{ \hat{\pi}_t^{int}, \hat{div}_t, \hat{\nu}_t \} \) are eliminated using (A.65, A.57, A.73).
A.4.10 Shocks. All the shock processes are collected in Table (A.1). Aggregate shocks (risk premium, investment, price and wage markup) are scaled exactly in the same way as in the canonical model described in Appendix B in order to preserve comparability across the two specifications. It is worth pointing out that scaling the risk premium requires making an additional adjustment at the observation equation for the top wealth share (??). Some distributional shocks are also scaled. In particular, income shocks ($\hat{s}_t$) entering in the budget constraint (A.55) are scaled to enter with a coefficient of one; they are then properly adjusted in the observation equation for the top income share. Wealth shocks ($\hat{\upsilon}_\omega t$) are scaled to enter with a unitary coefficient in (A.53) and with a properly adjusted coefficient in (A.49). The shock to the debt limit ($\hat{m}_t$) is not scaled.

Table A.1: Shock Processes

<table>
<thead>
<tr>
<th>Demand Side</th>
<th>Supply Side</th>
<th>Distributional</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Risk Premium $\hat{v}^b_t = \rho_b \hat{v}^b_{t-1} + \epsilon^b_t$</td>
<td>5. Technology $\hat{z}<em>t = \rho_z \hat{z}</em>{t-1} + \epsilon^z_t$</td>
<td>8. Income Shock $\hat{s}<em>t = \rho_s \hat{s}</em>{t-1} + \epsilon^s_t$</td>
</tr>
<tr>
<td>2. Investment Adjustment Cost $\hat{v}^i_t = \rho_i \hat{v}^i_{t-1} + \epsilon^i_t$</td>
<td>6. Price Markup $\hat{v}^p_t = \rho_p \hat{v}^p_{t-1} + \epsilon^p_t$</td>
<td>9. Wealth Shock $\hat{v}^w_t = \rho_w \hat{v}^w_{t-1} + \epsilon^w_t$</td>
</tr>
<tr>
<td>3. Government Spending $\hat{g}<em>t = \rho_g \hat{g}</em>{t-1} + \epsilon^q_g + \rho_{gz} \epsilon^z_t$</td>
<td>7. Wage Markup $\hat{v}^w_t = \rho_w \hat{v}^w_{t-1} + \epsilon^w_t$</td>
<td>10. Credit Shock $\hat{m}<em>t = \rho_m \hat{m}</em>{t-1} + \epsilon^m_t$</td>
</tr>
<tr>
<td>4. Monetary Policy Innovation $\epsilon_{mp} \sim N(0, \sigma^2_{mp})$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

B Representative Agent Model

The representative agent specification of the present paper is essentially the Smets and Wouters (2007) model with the addition of measurement errors in the estimation, and the estimation of steady state price and wage markups. Contrary to Smets and Wouters (2007), I consider AR(1) instead of ARMA(1,1) processes for the price and wage markup shocks. The representative agent model is derived from the distributional model for $n^\tau = 1$ and $\phi^\tau = 0$. The steady state economy wide aggregates coincide across the two models. The
Nikolaos Charalampidis

The complete set of log-linearized equations is reported below.

\[ \hat{c}_t = \left( \frac{1}{1 + \frac{\eta}{e^{\gamma}}} \right) \left[ E_t \hat{c}_{t+1} + (\eta/e^{\gamma})(\hat{c}_{t-1}) - (1 - \frac{\eta}{e^{\gamma}})(\hat{r}_t - E_t \hat{\pi}_{t+1} - \nu_t^h) \right] \] (B.1)  

**Inter-Temporal Consumption**

\[ \hat{k}_t = \left( \frac{1 - \delta}{e^{\gamma}} \right) (\hat{k}_{t-1}) + \left( 1 - \frac{1 - \frac{\delta}{e^{\gamma}}}{e^{\gamma}} \right) (\hat{i}_t + \nu_i^l) \] (B.2)  

**Capital Accumulation**

\[ \hat{q}_t^k = - (\hat{r}_t - E_t \hat{\pi}_{t+1} + \nu_t^h) + \left( \frac{R_{k,r}}{R_{k,r}^r + 1 - \delta} \right) E_t \hat{r}_{t+1}^k + \left( \frac{1 - \delta}{R_{k,r}^r + 1 - \delta} \right) E_t \hat{q}_{t+1}^k \] (B.3)  

**Capital Price**

\[ \hat{i}_t = \left( \frac{\beta}{1 + \beta} \right) (E_t \hat{i}_{t+1}) + \left( \frac{1}{1 + \beta} \right) (\hat{i}_{t-1}) + \left[ \left( \frac{1}{1 + \beta} \right) \left( \frac{1}{e^{\gamma} S''} \right) \right] (\hat{q}_t^k + \nu_i^l) \] (B.4)  

**Investment Dynamics**

\[ \hat{r}_t^{k,r} = (\psi/(1 - \psi)) \hat{u}_t \] (B.5)  

**Capital Rental Rate**

\[ \hat{k}_t = \hat{u}_t + \hat{k}_{t-1} \] (B.6)  

**Effective Capital**

\[ \hat{k}_t = \hat{w}_t^r - \hat{r}_t^{k,r} + \hat{L}_t \] (B.7)  

**Capital Demand**

\[ \hat{y}_t = (1 + \Phi_y/y) \left( \alpha \hat{k}_t + (1 - \alpha) \hat{L}_t + \hat{z}_t \right) \] (B.8)  

**Production Function**

\[ \hat{m}_t^c = (1 - \alpha) \hat{w}_t^r + \alpha \hat{r}_t^{k,r} - \hat{z}_t \] (B.9)  

**Marginal Cost**

\[ \hat{\pi}_t = \left( \frac{\beta}{1 + \epsilon_p \beta} \right) E_t \hat{\pi}_{t+1} + \left( \frac{1}{1 + \epsilon_p \beta} \right) \hat{\pi}_{t-1} + \left[ \left( \frac{1 - \epsilon_p (1 - \epsilon_p \beta)}{\epsilon_p (1 + \epsilon_p \beta)} \right) \right] \left( \hat{m}_t^c + \left( \frac{\nu_p}{1 + \nu_p} \right) \hat{\nu}_t^p \right) \] (B.10)  

**Inflation**

\[ \hat{w}_t^r - \hat{\pi}_{t-1} + \hat{\pi}_t - \epsilon_w \hat{\pi}_{t-1} = \beta [E_t \hat{w}_{t+1} - \hat{w}_t^r + E_t \hat{\pi}_{t+1} - \epsilon_w \hat{\pi}_t] + \left[ \left( \frac{1 - \epsilon_w (1 - \epsilon_w \beta)}{\epsilon_w (1 + \epsilon_w \beta)} \right) \right] \left( \chi \hat{L}_t + \left( \frac{1}{1 - \frac{\eta}{e^{\gamma}}} \right) (\hat{c}_t - (\eta/e^{\gamma}) (\hat{c}_{t-1})) - \hat{w}_t^r + \left( \frac{\nu_w}{1 + \nu_w} \right) \hat{\nu}_t^w \right) \] (B.11)  

**Wage Dynamics**
Market Clearing

\[
(c/y)\hat{c}_t + (i/y)\hat{i}_t + (g/y)\hat{g}_t + (R^{k,r} k/y) \hat{u}_t = \hat{y}_t
\] (B.12)

Monetary Policy

\[
\hat{\pi}_t = \rho_{\pi} \hat{\pi}_{t-1} + (1 - \rho_{\pi}) \left[ \psi_{\pi} \hat{\pi}_t + \psi_y (\hat{y}_t - \hat{y}_{t}^f) + \psi_{\Delta y} \Delta (\hat{y}_t - \hat{y}_{t}^f) \right] + \epsilon_{t}^{mp}
\] (B.13)

B.1 Shocks.

A few shocks are scaled to enter with a coefficient of one; the risk premium shock is scaled in eq.(B.1) and adjusted accordingly in eq.(B.3); the investment adjustment cost is scaled in eq.(B.4) and adjusted accordingly in eq.(B.2); the price and wage markup shocks are scaled in equations (B.10) and (B.11), respectively; the government spending shock is scaled in eq.(B.12). These adjustments improve the converge of the sampler, introduce correlated priors, and illustrate the impact of the disturbances’ prior standard deviation.

C Flexible Price And Wage Equilibrium

The flexible price and wage equilibrium is the same in both the benchmark and the representative agent models. It is derived from the above set of equations for flexible prices and wages. The variables associated with that equilibrium are denoted with the superscript “f”.
\[ \sum_{j=0}^{3} n^\tau \left[ \frac{(1-s_{t-j})W_{t-j}^{\tau}L_{t-j}}{n^\tau} + \Omega_{t-j}^{\tau}V_{t-j} + \frac{B_{t-j-1}^{\tau}}{e^{\varphi_{t-j}R_{t-j}L_{t-j}}} P_{t-j-1} - \frac{B_{t-j}^{\tau}}{e^{\varphi_{t-j}R_{t-j}L_{t-j}}} \right] = \left( D.1 \right) \]

\[ \sum_{j=0}^{3} n^\tau \left[ \frac{Z_{t-j}(1-s_{t-j})W_{t-j}^{\tau}L_{t-j}}{n^\tau Z_{t-j}} + Z_{t-j} \Omega_{t-j}^{\tau} \frac{V_{t-j}}{Z_{t-j}} + Z_{t-j} \frac{B_{t-j-1}^{\tau}}{Z_{t-j} P_{t-j-1}} - Z_{t-j} \frac{B_{t-j}^{\tau}}{e^{\varphi_{t-j}R_{t-j}P_{t-j}}} \right] = \left( D.2 \right) \]

\[ \sum_{j=0}^{3} n^\tau Z_{t-j} \left[ \frac{(1-s_{t-j})w_{t-j}^{\tau}L_{t-j}}{n^\tau} + \omega_{t-j}^{\tau}v_{t-j} + \frac{b_{t-j-1}^{\tau}}{e^{\gamma + z_{t-j}^{\tau}}} - \frac{b_{t-j}^{\tau}}{e^{\gamma + z_{t-j}^{\tau}}} \right] = \left( D.3 \right) \]

\[ \sum_{j=0}^{3} n^\tau Z_{t-j} \left[ \frac{(1-s_{t-j})w_{t-j}^{\tau}L_{t-j}}{n^\tau} + \omega_{t-j}^{\tau}v_{t-j} + \frac{b_{t-j-1}^{\tau}}{e^{\gamma + z_{t-j}^{\tau}}} - \frac{b_{t-j}^{\tau}}{e^{\gamma + z_{t-j}^{\tau}}} \right] = \left( D.4 \right) \]

\[ = \ldots \text{(first order expansion around the steady state)} \]

\[ \approx (1 - s) + \left( \frac{n^\tau b^\tau}{e^{\gamma \Pi wL}} - \frac{n^\tau b^\tau}{Re^{\gamma L}} \right) + \left( D.5 \right) \]

\[ + \sum_{j=0}^{3} \nu_j \left[ -s \hat{\theta}_{t-j} + \left( \frac{n^\tau b^\tau}{e^{\gamma \Pi wL}} \right) \left( \hat{b}_{t-j-1} - \hat{\pi}_{t-j} - \hat{w}_{t-j} - \hat{L}_{t-j} \right) + \right] \]

\[ + \sum_{j=0}^{3} \nu_j \left[ -\left( \frac{n^\tau b^\tau}{Re^{\gamma L}} \right) \left( \hat{b}_{t-j} - \hat{\pi}_{t-j} - \hat{w}_{t-j} - \hat{L}_{t-j} \right) \right] + \left( D.7 \right) \]

\[ \]
The annual wealth share (3.6) of the top includes the equity shares and the outstanding household debt measured at the end of each period, where in the denominator the assets of the top cancel out with liabilities of the middle class ($n^\tau B^\tau_t = n^\mu B^\mu_t$) and the total ownership shares in the economy are equal to one ($n^\tau \Omega^\tau_t + n^\mu \Omega^\mu_t = 1$):

$$\sum_{j=0}^{3} n^\tau \left[ Q_{t-j} \Omega^\tau_{t-j} + \frac{B^\tau_{t-j}}{e^{V_t-j R_{t-j} P_{t-j}}} \right] = \sum_{j=0}^{3} [Q_{t-j}]$$  \hspace{1cm} (D.9)

$$\sum_{j=0}^{3} n^\tau Z_{t-j} \left[ \frac{Q_{t-j} \Omega^\tau_{t-j} + B^\tau_{t-j}/Z_{t-j}}{e^{V_t-j R_{t-j} P_{t-j}}} \right] = \sum_{j=0}^{3} Z_{t-j} \left[ \frac{Q_{t-j}}{Z_{t-j}} \right]$$  \hspace{1cm} (D.10)

$$\sum_{j=0}^{3} n^\tau Z_{t-j} \left[ q_{t-j} \omega^\tau_{t-j} + \frac{b^\tau_{t-j}}{e^{V_t-j R_{t-j}}} \right] = \sum_{j=0}^{3} Z_{t-j} [q_{t-j}]$$  \hspace{1cm} (D.11)

$$\sum_{j=0}^{3} n^\tau Z_{t-j} \left[ q \omega e^{\hat{\omega}_{t-j}} + \frac{b^\tau_{t-j}/R q}{e^{V_t-j R_{t-j}}} \right] = \sum_{j=0}^{3} Z_{t-j} [qe^{\hat{\omega}_{t-j}}]$$  \hspace{1cm} (D.12)

$$\approx (n^\tau \omega^\tau + \frac{n^\tau b^\tau}{R q} + \sum_{j=0}^{3} \nu_j \left[ (n^\tau \omega^\tau) \hat{\omega}_{t-j}^\tau + \left( \frac{n^\tau b^\tau}{R q} \right) \left( \hat{b}_{t-j} - \hat{r}_{t-j} - \hat{\nu}_{t-j}^b - \hat{q}_{t-j} \right) \right]$$  \hspace{1cm} (D.13)

$$= \bar{w} s + 3 \sum_{j=0}^{3} \nu_j \left[ (n^\tau \omega^\tau) \hat{\omega}_{t-j}^\tau + \bar{w} s b \left( \hat{b}_{t-j} - \hat{r}_{t-j} - \hat{\nu}_{t-j}^b - \hat{q}_{t-j} \right) \right]$$  \hspace{1cm} (D.14)

where $\bar{w} s \equiv (n^\tau \omega^\tau + \frac{n^\tau b^\tau}{R q}) = n^\tau \omega^\tau + \bar{w} s b$, and $\bar{w} s b \equiv \left( \frac{n^\tau b^\tau}{R q} \right)$.

### E Data Overview

In Tables (E.1) and (E.2), I report the first and second moments in the inequality, debt and the main aggregate series (in an annual frequency to ease the exposition). Table (E.1) suggests that both the top income and wealth deciles exhibit a positive growth rate over the sample. The growth rate for the top wealth decile (0.16) is smaller than that of the top income decile (0.40). For the top income decile, in particular, positive growth takes place during the sup-period after 1983. During the post-1983 period, both income and
wealth inequality exhibit strong growth, whereas the growth rates for the economy, personal consumption, and prices slowdown. Along with rising inequality, household debt in the form of home mortgages rises as well during that period.

According to the unconditional correlations of Table (E.2), the top income decile is strongly pro-cyclical whereas the top wealth decile is mildly counter-cyclical. Both income and wealth top deciles are negatively correlated with inflation. During the 1984-2009, however, the top income decile becomes positively correlated with inflation. Both debt measures, home mortgages and consumer credit, are positively correlated with the top income decile. The top wealth decile is positively correlated with debt during 1954-1983, but that correlation weakens and, in fact, becomes negative during 1984-2009.

### Table E.1: Descriptive Statistics, First Moments

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Income Decile</td>
<td>0.40</td>
<td>-0.01</td>
<td>0.86</td>
</tr>
<tr>
<td>Top Wealth Decile</td>
<td>0.16</td>
<td>-0.24</td>
<td>0.62</td>
</tr>
<tr>
<td>Output</td>
<td>1.8</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Consumption</td>
<td>2.0</td>
<td>2.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Inflation</td>
<td>3.4</td>
<td>4.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Home Mortgages</td>
<td>4.7</td>
<td>3.9</td>
<td>5.5</td>
</tr>
<tr>
<td>Consumer Credit</td>
<td>3.2</td>
<td>3.0</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*Notes: Annual Frequency. Average (real per capita) growth rates of output and consumption. Top 10% income and wealth shares. Data sources: FRED. World Inequality Database.*

### Table E.2: Descriptive Statistics, Correlations

<table>
<thead>
<tr>
<th>Y</th>
<th>C</th>
<th>π</th>
<th>HM</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954-2009</td>
<td>-0.07</td>
<td>-0.01</td>
<td>-0.33</td>
<td>0.02</td>
</tr>
<tr>
<td>TIS</td>
<td>0.49</td>
<td>0.46</td>
<td>-0.16</td>
<td>0.34</td>
</tr>
<tr>
<td>1954-1983</td>
<td>-0.01</td>
<td>0.09</td>
<td>-0.27</td>
<td>0.21</td>
</tr>
<tr>
<td>TIS</td>
<td>0.43</td>
<td>0.46</td>
<td>-0.19</td>
<td>0.37</td>
</tr>
<tr>
<td>1984-2009</td>
<td>-0.22</td>
<td>-0.24</td>
<td>-0.21</td>
<td>-0.56</td>
</tr>
<tr>
<td>TIS</td>
<td>0.68</td>
<td>0.56</td>
<td>0.37</td>
<td>0.23</td>
</tr>
</tbody>
</table>


Figure (E.1) plots the evolution of the series for household debt: outstanding consumer
credit debt and home mortgage debt, both downloaded from FRED. The series are converted in real per capita terms using the GDP implicit price deflator. Their log-difference is displayed. After the early 1980s, the two series exhibit distinct differences in their evolution.

Fig.(E.2) plots the evolution of the top income and wealth deciles and of the (log-) real per capita household debt in terms of home mortgages and consumer credit. After the early 1980s, all the series exhibit an upward trend.

Fig.(E.3) reports the actual evolution of the top income and wealth deciles along with their cyclical components and the associated measurement errors of the observation equations. The cyclical top income decile is more volatile than the cyclical top wealth share. Furthermore, the cyclical component of the top income decile clearly exceeds its trend starting from the 1990s.

Figure E.1: Outstanding Household Debt

Notes: Real per capita household debt growth in the form of home mortgages and consumer credit. Source: FRED.
Figure E.2: Inequality And Household Debt

Notes: Logarithm of real per capita home mortgage debt and consumer credit (left axis). Top 10% income and wealth shares (right axis). Data sources: FRED, World Inequality Database.

Figure E.3: Income and Wealth Inequality: Trends, Cycles, Measurement Errors, and Data

Notes: Logarithm of real per capita home mortgage debt and consumer credit (left axis). Top 10% income and wealth shares (right axis). Data sources: FRED, World Inequality Database.
F Additional Results

F.1 Measurement Errors.

Tables (F.1) and (F.2) display the posterior standard deviation (std) of the measurement errors (m.e.) for the variables that are matched to a single observable. Their priors are tight and imply negligible measurement errors in order to preserve comparability with traditional estimated DSGE models that do not include measurement errors for those observables.

Table F.1: Posterior Distribution – Common Measurement Errors

<table>
<thead>
<tr>
<th>Prior</th>
<th>Posterior Mean [5-95%]</th>
<th>Rep. Agent Mean [5-95%]</th>
<th>D. Imbalances Mean [5-95%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu_w$ IG(0.01, 0.001)</td>
<td>0.0101[0.0085, 0.0118]</td>
<td>0.0101[0.0085, 0.0119]</td>
<td></td>
</tr>
<tr>
<td>$\mu_y$ IG(0.01, 0.001)</td>
<td>0.0100[0.0085, 0.0116]</td>
<td>0.0101[0.0086, 0.0120]</td>
<td></td>
</tr>
<tr>
<td>$\mu_c$ IG(0.01, 0.001)</td>
<td>0.0100[0.0085, 0.0117]</td>
<td>0.0100[0.0085, 0.0119]</td>
<td></td>
</tr>
<tr>
<td>$\mu_i$ IG(0.01, 0.001)</td>
<td>0.0100[0.0085, 0.0117]</td>
<td>0.0100[0.0085, 0.0119]</td>
<td></td>
</tr>
<tr>
<td>$\mu_\pi$ IG(0.01, 0.001)</td>
<td>0.0100[0.0085, 0.0117]</td>
<td>0.0101[0.0086, 0.0118]</td>
<td></td>
</tr>
<tr>
<td>$\mu_r$ IG(0.01, 0.001)</td>
<td>0.0100[0.0085, 0.0116]</td>
<td>0.0100[0.0086, 0.0118]</td>
<td></td>
</tr>
<tr>
<td>$\mu_l$ IG(0.01, 0.001)</td>
<td>0.0100[0.0085, 0.0118]</td>
<td>0.0099[0.0085, 0.0116]</td>
<td></td>
</tr>
</tbody>
</table>


Table F.2: Posterior Distribution – Distributional Measurement Errors

<table>
<thead>
<tr>
<th>Prior</th>
<th>Posterior Mean [5-95%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>std m.e. income inequality</td>
<td>$\mu_{tis}$ IG(0.01, 0.001)</td>
</tr>
<tr>
<td>std m.e. wealth inequality</td>
<td>$\mu_{tws}$ IG(0.01, 0.001)</td>
</tr>
</tbody>
</table>

Notes: Author’s computations. Estimates from the benchmark model.

F.2 Prior.

Table (F.3) displays the forecast error variance decomposition of the benchmark model at the prior mean 8/40 quarters ahead. The findings are considerably different from those at the posterior mean, suggesting that the postulated prior is not dogmatic. In other words, the results found in the paper do not depend on the prior specification.

F.3 Representative Agent Model.

Table (F.4) shows the FEVD in the representative agent model. Figures (F.1, F.2, F.3) display a comparison of the IRFs of aggregate variables in response to aggregate shocks between the present model and the representative agent model. Fig.(F.4) compares the output gaps in the present model and the representative agent model.
Table F.3: Business Cycles – The Role of the Prior

<table>
<thead>
<tr>
<th>shock</th>
<th>( \hat{y}_t )</th>
<th>( \hat{r}_t )</th>
<th>( \hat{w}_t^r )</th>
<th>( \hat{\pi}_t )</th>
<th>( \hat{\tau}_t )</th>
<th>( \hat{b}_{\tau t} )</th>
<th>( \hat{t}_s^t )</th>
<th>( \hat{t}_{w\tau}^t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>income</td>
<td>0/0</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>1/1</td>
<td>66/66</td>
<td>1/2</td>
</tr>
<tr>
<td>wealth</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>credit</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>1/0</td>
<td>0/0</td>
</tr>
<tr>
<td>distributional</td>
<td>0/0</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>2/2</td>
<td>67/67</td>
<td>1/2</td>
</tr>
<tr>
<td>technology</td>
<td>15/15</td>
<td>2/3</td>
<td>2/2</td>
<td>1/1</td>
<td>1/1</td>
<td>2/3</td>
<td>1/1</td>
<td>3/3</td>
</tr>
<tr>
<td>price markup</td>
<td>9/9</td>
<td>8/7</td>
<td>75/63</td>
<td>31/31</td>
<td>10/10</td>
<td>4/4</td>
<td>6/6</td>
<td>4/4</td>
</tr>
<tr>
<td>wage markup</td>
<td>9/10</td>
<td>14/15</td>
<td>14/13</td>
<td>9/9</td>
<td>4/4</td>
<td>5/9</td>
<td>1/1</td>
<td>1/2</td>
</tr>
<tr>
<td>supply side</td>
<td>34/34</td>
<td>24/25</td>
<td>91/78</td>
<td>42/42</td>
<td>15/15</td>
<td>11/16</td>
<td>7/7</td>
<td>8/9</td>
</tr>
<tr>
<td>risk premium</td>
<td>56/54</td>
<td>41/40</td>
<td>7/11</td>
<td>49/49</td>
<td>74/73</td>
<td>73/53</td>
<td>24/24</td>
<td>84/82</td>
</tr>
<tr>
<td>investment</td>
<td>5/6</td>
<td>30/30</td>
<td>1/9</td>
<td>3/3</td>
<td>4/5</td>
<td>9/25</td>
<td>1/1</td>
<td>1/2</td>
</tr>
<tr>
<td>govt spending</td>
<td>1/1</td>
<td>1/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
<td>0/0</td>
<td>0/0</td>
</tr>
<tr>
<td>policy</td>
<td>4/4</td>
<td>4/4</td>
<td>1/1</td>
<td>6/6</td>
<td>6/6</td>
<td>5/4</td>
<td>2/2</td>
<td>5/5</td>
</tr>
<tr>
<td>demand side</td>
<td>66/66</td>
<td>76/74</td>
<td>9/21</td>
<td>58/58</td>
<td>85/84</td>
<td>87/83</td>
<td>26/26</td>
<td>90/89</td>
</tr>
</tbody>
</table>

Notes: Forecast Error Variance Decomposition 8/40 quarters ahead, computed at the prior mean.

Comparing the FEVD for the economy wide variables of the benchmark model with that of the representative agent model reveals that the two have some differences implying that introducing inequality and debt in the model has indirect implications for the influence of demand supply side shocks on economy wide variables. The influence of demand side shocks on output in the benchmark model is smaller in the short run (46% vs 67%) and larger in the long run (57% vs 36%) than it is in the representative agent model. The influence of demand shocks on inflation in the present model (22/27%) is higher than that in the RA model (1/2%). This result is also reflected in a higher inflation responsiveness to demand shocks in the benchmark model than in the representative agent model as it is seen in Fig.(F.2). As for the entire set of impulse response functions, those for the economy wide variables in the benchmark model are in line with those in the RA model. Their cumulative differences are described in the paper.

Finally, Fig.(F.4) displays the small implications of including heterogeneous agents and distributional imbalances for the evolution of the output gap (the largest deviation in the output gap between the representative agent model and the model of the present paper is at about 1%). It is worth pointing out that since the structure of the flexible equilibrium is the same in both the representative agent and the benchmark model, and features the same set of shocks, the small difference between the two model-implied output gaps emanates from
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the interaction of distributional imbalances with nominal price and wage rigidities.

Table F.4: Business Cycles – Representative Agent Model

<table>
<thead>
<tr>
<th>variable</th>
<th>$\hat{y}_t$</th>
<th>$\hat{i}_t$</th>
<th>$\hat{w}_t^r$</th>
<th>$\hat{\pi}_t$</th>
<th>$\hat{r}_t$</th>
</tr>
</thead>
<tbody>
<tr>
<td>technology</td>
<td>25/56</td>
<td>3/13</td>
<td>7/45</td>
<td>7/9</td>
<td>4/7</td>
</tr>
<tr>
<td>price markup</td>
<td>8/6</td>
<td>6/6</td>
<td>26/20</td>
<td>81/74</td>
<td>22/19</td>
</tr>
<tr>
<td>wage markup</td>
<td>0/2</td>
<td>0/2</td>
<td>64/30</td>
<td>11/15</td>
<td>4/9</td>
</tr>
<tr>
<td>supply side</td>
<td>33/64</td>
<td>9/21</td>
<td>98/95</td>
<td>99/98</td>
<td>31/35</td>
</tr>
<tr>
<td>risk premium</td>
<td>38/18</td>
<td>12/7</td>
<td>1/1</td>
<td>0/0</td>
<td>20/26</td>
</tr>
<tr>
<td>investment</td>
<td>14/10</td>
<td>74/67</td>
<td>1/4</td>
<td>0/1</td>
<td>1/3</td>
</tr>
<tr>
<td>govt spending</td>
<td>3/1</td>
<td>0/1</td>
<td>0/0</td>
<td>0/0</td>
<td>0/1</td>
</tr>
<tr>
<td>policy</td>
<td>11/6</td>
<td>5/4</td>
<td>0/1</td>
<td>0/0</td>
<td>48/36</td>
</tr>
<tr>
<td>demand side</td>
<td>67/36</td>
<td>91/79</td>
<td>2/5</td>
<td>1/2</td>
<td>69/65</td>
</tr>
</tbody>
</table>

Notes: Forecast Error Variance Decomposition 8/40 quarters ahead, computed at the posterior mean.

Figure F.1: Demand Side Innovations: A Comparison Across Models

F.4 Quantifying the Effect of Imbalances on Inflation.

Figures (F.5) and (F.6) display a graphical depiction of the influence of endogenous and exogenous distributional imbalances on aggregate demand and inflation described in detail in the paper. The figures corroborate that the distributional shocks as well as the channels of MPC differentials and imperfect insurance have a more profound influence on aggregate demand than on inflation.

Nevertheless, including inequality and debt series in the estimation attenuates to some degree the general equilibrium effects on inflation. The latter are reflected in an elevated indexation, a weakened price stickiness, an elevated volatility of price markup shocks, and an attenuated persistence of price markup shocks. They are observed in the bottom right panel of Fig.(F.6) where the shocks of the benchmark model are fed in the representative agent model and result in inflation series that deviate from the observed ones.

F.5 Marginal Propensity to Consume and Wealth Preferences.

Fig.(F.7) plots the difference in the MPC between the benchmark model with $\phi^r \neq \phi^\mu$ and an alternative model featuring $\phi^r = \phi^\mu$. According to the evidence displayed in the figure, the MPC difference in all panels has a moderate non-zero value suggesting that imposing homogeneous preferences over wealth attenuates the heterogeneity in the consumption responses in the population.

F.6 Five Decades of Business Cycles and Inequality Swings.

What is the historical influence of demand, supply, and distributional shocks on the swings of the top income and wealth shares across U.S. business cycles? Fig.(F.8) and (F.9) cope with that question. Fig.(F.8) suggests that the relative stability of the top 10% income share from the 1950s to the mid-80s is attributed to all shocks balancing out on aggregate. The rise of the top income share since the mid-80s is mainly explained by wage polarization, supply side shocks, wealth shocks, credit relaxation, and demand shocks to some extent.

The post-1990 rise of wealth inequality is driven by wage polarization, credit relaxation, wealth shocks. In contrast, in the pre-1990 period, worth mentioning are the inequality-increasing effect of technology shocks during the 1970s-80s, and the sizable influence of wealth shocks during the fluctuations of the top wealth share on the 1960s-70s.
Figure F.2: Policy Innovations: A Comparison Across Models

Figure F.3: Supply Side Innovations: A Comparison Across Models

Figure F.4: U.S. Output Gap Fluctuations

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Figure F.5: Quantifying the Effect of Imbalances on Aggregate Demand

Figure F.6: Quantifying the Effect of Imbalances on Inflation

Notes: Author’s computations. All figures in %.
Figure F.7: MPC Differentials and Preferences over Wealth

Notes: Posterior distribution of the difference between the consumption responses across variables and sources of stochastic variation (shown in each panel’s title) for top and middle-class households in the benchmark estimation and in the simulation featuring $\phi^T = \phi^\mu$. 
Notes: Historical decomposition of cumulative cyclical annual change (shown on top of each column) over a U.S. business cycle (trough to trough). Cumulative effect of each shock. Demand side shocks: risk premium, investment, interest rate, and government spending. Supply side shocks: technology, price markup, wage markup shocks. All figures are in %.