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IRVINE

Business Cycles, Disturbances, and Imbalances

DISSERTATION

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for the degree of

DOCTOR OF PHILOSOPHY

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by

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DEDICATION

To my brother, my mom, my dad, my two grandmas and my two grandpas for their love and thoughts that are always with me, for the values and beliefs they taught me and supported with their actions, and for standing on my side in the most difficult times. My accomplishments are their lifelong accomplishments. This dissertation belongs to them.

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ABSTRACT OF THE DISSERTATION

Business Cycles, Disturbances, and Imbalances

By

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Chapter 1 studies the effects of cyclical changes in U.S. income and wealth inequality on macroeconomic gyrations, shifts in aggregate demand, debt swings, and on the effectiveness of monetary policy. It does so though the lens of a structural model with heterogeneous agents that is brought to the data to jointly explain a set of macroeconomic series and a time-varying dimension of inequality, namely the evolution of the U.S. income and wealth inequality since the 1950s to 2009. The paper shows that changes in income and wealth inequality explain a small fraction of output cycles, operate through persistent changes in Aggregate Demand, and cause large swings in household indebtedness. Despite that influence, changes in income and wealth inequality since the mid-80s to 2009 cannot explain the cyclical debt pileup of that period which is accounted for by credit relaxation. Despite the imbalances of the model in terms of the time-varying and unequal distribution of income and wealth, monetary policy has a small effect on income and wealth inequality, and effectively stabilizes the economy by responding aggressively to inflation even if the observed economy wide fluctuations emanate from changes in income and wealth inequality.

Although the recent dramatic decline of the labor share has attracted a lot of attention, the origins and implications of the historical swings of that share during 1964–2016 still remain unexplored. Chapter 2 fills that void. More specifically, Chapter 2 investigates the

driving forces and the implications of the fluctuations in the U.S. labor share. To that end, it considers a structural model featuring various potential drivers of the labor share, such as the relative price of investment, labor unionization, measurement errors etc. To that set of potential drivers, the present work adds production automation aiming to encapsulate routine-biased technological shifts, and shows how to bring the model to the data in order to explain the labor share – something that is not straightforward. The analysis shows that changes in production automation explain about 10% of output fluctuations, a third of the labor share across time, about the entire decline in the labor share since the 1990s, and trigger a countercyclical response in labor hours that cannot be matched by any other conventional aggregate shock in a structural framework.

Chapter 3 sheds lights on the unexplored determinants of the notoriously persistent Euro-Area unemployment from a macroeconomic perspective. More precisely, it quantifies the relative importance of a plethora of drivers of unemployment swings by jointly examining unemployment and wage fluctuations through the lens of a structural model estimated on several wage series to strengthen the identification of shifts in labor market competitiveness. I find that these shifts determine long-run unemployment cycles, but their short-run effect depends on the unemployment–wage co-movement: the stronger the co-movement – as it is in Portugal and Spain compared to Greece and Italy – the lower their effect. Furthermore, the low degree of labor market competitiveness is catalytic for the unemployment spike of the Great Recession. Nevertheless, reforms boosting competition during the recovery period generate subdued wage growth. It is worth mentioning that this paper contributes in the Bayesian estimation of DSGE models as well by applying an efficient treatment of the state space dimensionality. In particular, it borrows an approach from the econometrics literature considering reduced-form models, and operationalizes it within the context of a DSGE model.

Finally, Chapter 4 tackles two unresolved issues in the literature on subdued wage growth. First, not all contributions use the same wage measure, sample period, or economies. Second, all contributions employ reduced-form models impeding a general equilibrium approach that would quantify the relative importance of various driving factors of wage growth. I address those issues by studying the big four Euro-Area economies in a structural framework involving a plethora of disturbances extracted from the data through Bayesian estimation on five wage indicators since the 1990s. More importantly, I pin down the influence of those factors during a particular period of time, namely during output recoveries from troughs. I find a cyclical real wage recovery in Germany after the sovereign debt crisis that is statistically different from the past and is driven by a weakening in firms' pricing power despite a productivity slowdown. In contrast, a cyclical (real) wage-less output recovery is observed in France and Italy. In France, the productivity slowdown dominates the weakening in firms' market power. In Italy, the latter effect along with a demand pick up boosting wages do not suffice to exceed the weakening in workers' market power. In Spain, cyclical wage growth is positive – the sizable weakening in firms' pricing power and rising demand exceed the weakening in workers' market power – only in real terms and not in nominal terms, highlighting the importance of jointly examining price and wage inflation.

Chapter 1

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

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; Banrejee 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 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 (2016) who introduces a similar, albeit deterministic, scheme[2]. In a similar spirit, Lansing and Markiewicz (2016) consider shocks in a labor aggregator reflecting changes in the skill pre-

[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.

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

mium. 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 renege 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.

1.0.1 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

[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.

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 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.

1.0.2 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, 2016; 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. (2016). 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)[4]. 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 perspec-

[4]This is true for Iacoviello (2008), Kumhof et al. (2015), and Cairó and Sim (2018) as well.

tive 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; Mumtaz 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 Galí 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[5]; 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.

1.1 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. τ indexes the top family and μ indexes the middle-class family, populated by measures of n^τ and $n^\mu = 1 - n^\tau$ identical households, respectively. The families differ in terms of their wealth preferences and discounting. Perfect consumption insurance holds within families. Households participate in intra-family

[5] Luo and Zou (2009), Zou (2015), and Bakshi and Chen. (1996) tread along that line.

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.

Households.

Household i, with $i \in \{\mu, \tau\}$, chooses a sequence of consumption, loans, and shares, $\{C_t^i, B_t^i, \Omega_t^i\}$, to maximize the present discounted value of future utility:

$$E_t \sum_{s=0}^{+\infty} (\beta^i)^s \left[ln\left(C_{t+s}^i - \eta C_{t+s-1}^i\right) - \theta \int_0^1 \frac{[L_{t+s}^i(j)]^{1+\chi}}{1+\chi} dj + \phi^i \upsilon_{t+s}^{\omega} ln\left(\Omega_{t+s}^i\right) \right] \tag{1.1}$$

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. η mirrors external habit formation, χ is the inverse Frisch elasticity, and ϕ^i captures the strength of preferences over wealth (shares) which differs across families: $\phi^\mu \neq \phi^\tau$[6]. $\beta^\mu < \beta^\tau$ renders middle-class families more impatient than the top in a way analogous to that in Iacoviello (2005). υ_t^ω stands for the wealth shock affecting wealth preferences. The combination of that shock and heterogeneous ϕ^i creates wealth dispersion, and potentially captures unequal access to investment opportunities. $ln(\upsilon_t^\omega)$ follows an AR(1) process with parameters $\{\rho_\omega, \sigma_\omega\}$. The budget constraint for a middle-class household is given by

[6] η, θ, χ 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 η, θ, χ would require heterogenous consumption and labor data.

$$C_t^i + Q_t \left[\Omega_t^i - \left(1 - S_\omega(\Omega_t^i/\Omega_{t-1}^i)\right)\Omega_{t-1}^i\right] + T_t^i/P_t = Y_t^i \tag{1.2}$$

$$Y_t^i \equiv \textstyle\int W_t^{i,h,r}(j)L_t^i(j)dj + F_t^\mu + [B_t^i/(e^{\upsilon_t^b}R_tP_t) - B_{t-1}^i/(P_{t-1}\Pi_t)] + \Omega_t^i V_t \tag{1.3}$$

The budget constraint of a top household is symmetric to the above, bonds enter with the opposite sign though. Y_t^i is the pre-tax income. υ_t^b is a risk premium shock following an AR(1) process with parameters $\{\rho_b, \sigma_b\}$. $S_\omega(\cdot)$, 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. Π_t stands for price inflation. V_t denotes economy wide profits. T_t^i stands for nominal taxes. $W_t^{i,h,r}(j)$ 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:

$$W_t^{i,h,r}(j) = \theta[L_t^i(j)]^\chi/\Xi_t^i \tag{1.4}$$

$$= \theta L_t(j)^\chi/\Xi_t^i \tag{1.5}$$

where Ξ_t^i is the multiplier associated with the budget constraint. The second equality in (1.5) 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 ($W_t^r L_t$), but along the lines of Walsh (2016) 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_t^i from the unions read as

$$F_t^{\mu} = s_t W_t^r L_t / n^{\mu} - \int W_t^{i,h,r}(j) L_t^i(j) dj \tag{1.6}$$

for the middle class and, symmetrically, as $F_t^{\tau} = (1 - s_t) W_t^r L_t / n^{\tau} - \int W_t^{i,h,r}(j) L_t^i(j) dj$ 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. $\widehat{s}_t \equiv ln(s_t/\bar{s})$ 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 $B_t^i/(e^{v_t^b} R_t P_t)$ is up to a period-t limit determined by:

$$B_t^i / [e^{v_t^b} R_t P_t] \leq m_t E_t \left(Q_{t+1} \Omega_t^i \Pi_{t+1} / [e^{v_t^b} R_t] \right) \tag{1.7}$$

Two remarks are in order. First, modeling the polarization shock through (1.6) 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.

Capital.

As in Chen et al. (2012), a representative capital producer invests I_t in raw capital, $\bar{K}_t$, subject to adjustment costs $S(I_t/I_{t-1})$. It chooses the utilization rate u_t that determines the effective capital, $K_t = u_t\bar{K}_{t-1}$, subject to utilization costs that are proportional to the last period's raw capital ($a(u_t)\bar{K}_{t-1}$). The rental rate of capital is denoted by R^k_t. The firm maximizes the present discounted value of future dividends,

$$E_t\sum_{s=0}^{\infty}[(\Xi^{avg}_{t+s}P_t)/(\Xi^{avg}_t P_{t+s})]\left[R^k_{t+s}K_{t+s} - P_{t+s}a(u_{t+s})\bar{K}_{t+s-1} - P_{t+s}I_{t+s} - Z_{t+s}P_{t+s}\Phi_k\right] \tag{1.8}$$

subject to the law of capital accumulation: $\bar{K}_t = (1-\delta)\bar{K}_{t-1} + \upsilon^i_t\left(1 - S(I_t/I_{t-1})\right)I_t$. 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 $S(e^\gamma)'' \equiv S > 0$. γ is the growth rate of aggregates along the balanced growth path, and $Z_t = e^\gamma Z_{t-1}$ reflects trend growth. δ is the depreciation rate. Fixed costs (Φ_k) ensure zero steady state dividends. υ^i_t is an investment disturbance; $ln(\upsilon^i_t)$ follows an AR(1) process with associated parameters $\{\rho_i, \sigma_i\}$. $\Xi^{avg}_{t+1}/\Xi^{avg}_t$ stands for the average discounting between $t+s$ and t, defined as: $(\beta^\tau)^s[n^\tau\Xi^\tau_{t+s} + n^\mu\Xi^\mu_{t+s}]/[n^\tau\Xi^\tau_t + n^\mu\Xi^\mu_t]$[7].

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 $Y_t = [\int_0^1 Y_t(i)^{(\lambda_{p,t}-1)/\lambda_{p,t}}di]^{\lambda_{p,t}/(\lambda_{p,t}-1)}$.

[7] 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.

$\lambda_{p,t}$ 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

$$Y_t(i) = [P_t(i)/P_t]^{-\lambda_{p,t}} Y_t \qquad \text{and} \qquad P_t = [\textstyle\int P_t(i)^{1-\lambda_{p,t}} di]^{1/(1-\lambda_{p,t})} \tag{1.9}$$

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^k), in order to produce output $Y_t(i)$ according to the production function:

$$Y_t(i) = e^{\widehat{z}_t} K_t(i)^{\alpha} \left(Z_t L_t(i)\right)^{1-\alpha} - Z_t \Phi_y \tag{1.10}$$

$\widehat{z}_t$ is the technology shock following an AR(1) process with associated parameters $\{\rho_z, \sigma_z\}$. Fixed production costs, Φ_y, guarantee zero steady state profits. Cost minimization yields the optimal capital-labor ratio, $K_t(i)/L_t(i) = [\alpha/(1-\alpha)](W_t/R_t^k)$, and marginal cost,

$$MC_t = (\alpha)^{-\alpha}(1-\alpha)^{-(1-\alpha)}(W_t)^{(1-\alpha)}(R_t^k)^{\alpha} Z_t^{-(1-\alpha)} e^{-\widehat{z}_t} \tag{1.11}$$

Each firm chooses price $P_t^{\circ}(i)$ with probability ζ_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 ι_p. Thus, the period-$(t+s)$ price of a firm that last chose its price in period t is given by $P_{t+s|t}(i) = P_t^{\circ}(i) X_{t,s}^p$, where $X_{t,s}^p \equiv \prod_{l=1}^{s} \Pi_{t+l-1}^{\iota_p} \Pi^{1-\iota_p}$ for $s > 0$ and $= 1$ for $s = 0$. The firm maximizes the present discounted value of current and expected future profits subject to output demand (2.2),

$$E_t \sum_{s=0}^{+\infty} (\zeta_p)^s \left[(\Xi_{t+s}^{avg} P_t) / (\Xi_t^{avg} P_{t+s}) \right] \left[P_{t+s|t}(i) - MC_{t+s} \right] Y_{t+s|t}(i) \tag{1.12}$$

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 $L_t = [\int L_t(j)^{(\lambda_{w,t}-1)/\lambda_{w,t}} dj]^{\lambda_{w,t}/(\lambda_{w,t}-1)}$. $\lambda_{w,t}$ 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 $\{\rho_w, \sigma_w\}$. The associated demand for type j and the aggregate wage are

$$L_t(j) = [W_t(j)/W_t]^{-\lambda_{w,t}} L_t \quad \text{and} \quad W_t = [\int W_t(j)^{1-\lambda_{w,t}} dj]^{1/(1-\lambda_{w,t})} \tag{1.13}$$

The type-j labor union, in turn, takes into account labor demand (2.11) and chooses wage $W_t^{\circ}(j)$ 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 (1.5) and the uniform distribution of labor types within each household, the latter is given by:

$$W_t^h(j) = n^{\mu} W_t^{\mu,h,r}(j) + n^{\tau} W_t^{\tau,h,r}(j) = \theta L_t(j)^{\chi} [n^{\mu}/\Xi_t^{\mu} + n^{\tau}/\Xi_t^{\tau}] \tag{1.14}$$

When wages are not reset, they are updated according to lagged and steady-state price inflation based on the indexation parameter ι_w: $W_{t+s|t}(j) = W_t^{\circ}(j)X_{t,s}^w$, where $X_{t,s}^w = \prod_{l=1}^{s}(e^{\gamma}\Pi_{t+l-1})^{\iota_w}(e^{\gamma}\Pi)^{1-\iota_w}$ for $s > 0$ and $= 1$ for $s = 0$. The objective function of a union is:

$$E_t \sum_{s=0}^{+\infty} (\zeta_w)^s \left[(\Xi_{t+s}^{avg} P_t)/(\Xi_t^{avg} P_{t+s})\right] \left[W_{t+s|t}(j) - W_{t+s}^h(j)P_{t+s}\right] L_{t+s}(j) \tag{1.15}$$

Policy.

Monetary policy follows a Taylor rule with interest rate smoothing:

$$R_t/R = (R_{t-1}/R)^{\rho_r}[(\Pi_t/\Pi)^{\psi_\pi}(Y_t/Y_t^f)^{\psi_y}[(Y_t/Y_{t-1})/(Y_t^f/Y_{t-1}^f)]^{\psi_{\Delta y}}]^{1-\rho_r}e^{\upsilon_t^{mp}} \tag{1.16}$$

$\upsilon_t^{mp} \sim N(0, \sigma_{mp}^2)$ 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 $ln(G_t/Z_t G) = \rho_g ln(G_{t-1}/Z_{t-1}G) + \rho_{gz}\epsilon_t^z + \epsilon_t^g$, with $\epsilon_t^g \sim N(0, \sigma_g^2)$. To avoid additional complications, the tax burden is equally distributed across households: $T_t^i = T_t^{\mu} = T_t^{\tau} = T_t$.[8]

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 (2.3) and the capital-labor ratio, the aggregate production function reads as: $Y_t = e^{\widehat{z}_t}K_t^{\alpha}(Z_t L_t)^{1-\alpha} - Z_t\Phi_y$. 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: $\Pi_t^{int} \equiv Y_t - W_t^r L_t - R_t^{k,r}K_t$. The

[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.

dividends from capital production are given by $Div_t \equiv R_t^{k,r} K_t - a(u_t)\bar{K}_{t-1} - I_t - Z_t \Phi_k$. Thus, the economy wide profits distributed to households according to their shares are: $V_t = \Pi_t^{int} + Div_t$. Combining the household (2.14) and government budget constraints, financial market clearing, and profits, yields the resource constraint

$$C_t + I_t + G_t + AC_t + \Phi_k Z_t = Y_t \tag{1.17}$$

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

Equilibrium.

The stationary model, the steady state, and the log-linearized equilibrium are reported in Appendix. The steady state of aggregate variables is the same as that of the representative agent economy. The interest rate is given by $R = \Pi e^\gamma / \beta^\tau$. Moreover, the steady state features heterogeneous consumption, debt, and shares, as well as a binding constraint (1.7) since $\beta^\tau > \beta^\mu$. 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.

1.2 Estimation

I conduct mixed-frequency estimation over quarterly and annual data series starting in 1954Q3 and stoping 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.

1.2.1 Data And Observation Equations.

$t = \{1, 2, \ldots, n_q\} \mapsto \{1964Q1, \ldots, 2007Q4\}$ 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 Ψ_b. The observation equations are reported below, where $dlnX_t \equiv 100(lnX_t - lnX_{t-1})$.

$$\begin{bmatrix} dlnHM_t \\ dlnCC_t \end{bmatrix} = \begin{bmatrix} 100\gamma_{hm} \\ 100\gamma_{cc} \end{bmatrix} + \begin{bmatrix} 1 \\ \Psi_b \end{bmatrix} \begin{bmatrix} \widehat{b}_t^{\mu} - \widehat{b}_{t-1}^{\mu} \end{bmatrix} + \begin{bmatrix} \epsilon_t^{hm} \\ \epsilon_t^{cc} \end{bmatrix}, \begin{bmatrix} \epsilon_t^{hm} \\ \epsilon_t^{cc} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \mu_{hm}^2 & \\ & \mu_{cc}^2 \end{bmatrix} \right) \tag{1.18}$$

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].

[9] The observation equations for that block of observables are similar to those in Smets and Wouters (2007), with the inclusion of measurement error, $\epsilon_t^j \sim N(0, \mu_j^2)$, for each generic j series being the difference.

[10] Imposing the balanced growth path trend on debt series would yield persistent and volatile measurement

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 (1.1) gives inklings of the correlation of income and wealth inequality with macroeconomic and debt series. Income inequality is strongly pro-cyclical, 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-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 1.1: Descriptive Statistics, Correlations

		TIS	TWS	Y	π	HM	CC
1954-2009	TIS	1.64	0.30	0.49	-0.16	0.34	0.32
	TWS	0.30	1.63	-0.07	-0.33	0.02	-0.07
1954-1983	TIS	1.50	0.32	0.43	-0.19	0.37	0.43
	TWS	0.32	1.90	-0.01	-0.27	0.21	0.08
1984-2009	TIS	1.69	0.15	0.68	0.37	0.23	0.19
	TWS	0.15	1.14	-0.22	-0.21	-0.56	-0.47

Notes: Growth rates, annual frequency. *Mnemonics:* TIS: Top 10% Income Share, TWS: Top 10% Wealth Share, Y: Real GDP per capita, π: inflation, HM: Real Home Mortgage Debt per capita, CC: Real Consumer Credit Debt per capita. *Data sources:* FRED Economic Data, World Inequality Database.

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:

$$\begin{aligned} TIS_T &= \sum_{j=0}^{3} \left(n^{\tau} Y_{t-j}^{\tau}\right) / \sum_{j=0}^{3} \left(n^{\tau} Y_{t-j}^{\tau} + n^{\mu} Y_{t-j}^{\mu}\right) \\ &\approx \overline{tis} + \sum_{j=0}^{3} (\nu_j \cdot \widehat{tis}_{t-j}) + (\mathbf{1} \cdot \kappa_{tis} \cdot t) + \epsilon_T^{tis} \end{aligned} \tag{1.19}$$

errors in (1.18); see earlier versions of this paper.

where $\widehat{tis}_t = \widehat{tis}_t^{ea} + \widehat{tis}_t^{b} + \widehat{tis}_t^{pr}$. The approximation (1.19) is obtained in equilibrium, after converting the ratio in terms of stationary variables, and taking a Taylor expansion (Appx. A.4). 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 $\overline{tis}_b \equiv n^\tau b^\tau (R - e^\gamma \Pi)/(e^\gamma \Pi w^r L R)$ stands for bond income flowing to the top. Steady state profits are zero. $\widehat{tis}_t$ stands for the cyclical component of the top income share; its weight is given by $\nu_j \equiv e^{(3-j)\gamma}/[e^{3\gamma} + e^{2\gamma} + e^{1\gamma} + 1]$. Measurement error, $\epsilon_T^{tis} \sim N(0, \mu_{tis}^2)$, 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, $\mathbf{1}$, is non-zero only during that period. $\{\widehat{tis}_t^{ea}, \widehat{tis}_t^{b}, \widehat{tis}_t^{pr}\}$ drive the swings of the top income share; they stand for earnings, bond income, and profits, respectively. They are given by:

Table 1.2: Cyclical Swings, Top Income Share

earnings channel	$\widehat{tis}_t^{ea} = -\bar{s} \cdot \widehat{s}_t - (\widehat{w}_t^r + \widehat{L}_t)\ \overline{tis}_b$	(1.20)
bond income channel	$\widehat{tis}_t^{b} = (\widehat{b}_{t-1}^\tau - \widehat{\pi}_t)\ [n^\tau b^\tau/(e^\gamma \Pi w^r L)] - (\widehat{b}_t^\tau - \widehat{r}_t - \widehat{v}_t^b)\ [n^\tau b^\tau/(w^r L R)]$	(1.21)
profits channel	$\widehat{tis}_t^{pr} = \widehat{\mathrm{v}}_t[(y/w^r L)\,(n^\tau \omega^\tau - \overline{tis})]$	(1.22)

According to (1.20–1.22), the top income share falls below its steady state if there is an increase in the wage share of the bottom ($\widehat{s}_t$), the average wage, employment, or inflation. In contrast, increases in the bottom borrowing and in profits ($\widehat{\mathrm{v}}_t$) 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 ($n^\tau \Omega_t^\tau Q_t + n^\mu \Omega_t^\mu Q_t = Q_t$) since family debt positions net out to zero:

$$TWS_T = \sum_{j=0}^{3} n^\tau \left[Q_{t-j}\Omega^\tau_{t-j} + \frac{B^\tau_{t-j}/P_{t-j}}{e^{\upsilon^b_{t-j}} R_{t-j}} \right] / \sum_{j=0}^{3} Q_{t-j}$$
$$\approx \overline{tws} + \sum_{j=0}^{3} (\nu_j \cdot \widehat{tws}^{tws}_{t-j}) + (\kappa_{tws} \cdot t) + \epsilon^{tws}_T \tag{1.23}$$

where $\widehat{tws}^{tws}_t = \widehat{tws}^\omega_t + \widehat{tws}^b_t + \widehat{tws}^q_t$. The approximation (1.23) is obtained after converting the ratio in terms of stationary variables, and taking a Taylor expansion. (Appx. A.4). The steady state top wealth share is given by $\overline{tws} = n^\tau\omega^\tau + \overline{tws}_b$: $n^\tau\omega^\tau$ is the top profit share, and $\overline{tws}_b \equiv n^\tau b^\tau/(Rq)$ is the top's outstanding assets to the value of shares in terms of the final good. $\widehat{tws}^{tws}_{t-j}$ stands for the cyclical component of the top wealth share. Measurement error, $\epsilon^{tws}_T \sim N(0, \mu^2_{tws})$, 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 $\{\widehat{tws}^\omega_t, \widehat{tws}^b_t, \widehat{tws}^q_t\}$ drive the fluctuations of the top wealth share; they stand for shares, bonds, and asset price gains/losses, respectively. They are given by:

Table 1.3: Cyclical Swings, Top Wealth Share

real assets (shares) channel	$\widehat{tws}^\omega_t = \widehat{\omega}^\tau_t \ (n^\tau\omega^\tau)$	(1.24)
bonds channel	$\widehat{tws}^b_t = (\widehat{b}^\tau_t - \widehat{r}_t - \widehat{\upsilon}^b_t) \ \overline{tws}_b$	(1.25)
asset price gains/losses channel	$\widehat{tws}^q_t = -\widehat{q}_t \ \overline{tws}_b$	(1.26)

According to (1.24–1.26), 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 ($\widehat{q}_t$) increase since all those changes decrease the contribution of outstanding bonds to the top wealth share.

Few assumptions underlie equations (1.18, 1.19, 1.23). (1.18) implies that the observed debt pertains to the bottom 90% of the income distribution[11]. 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 (1.19 and 1.23) 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.

1.2.2 State Space And Likelihood.

I stack the measurement equations for aggregates series and (1.18) vertically to obtain:

$$\Upsilon_t = \Gamma_q + H_0\zeta_t + H_1\zeta_{t-1} + M_t \quad , \quad M_t \sim N(0, \Sigma_q) \tag{1.27}$$

where Υ_t and Γ_q are $(o_q \times 1)$ vectors of quarterly observed series and intercepts, respectively. M_t collects the associated measurement errors. Σ_q is the diagonal covariance matrix. $\{H_0, H_1\}$ denote the $(o_q \times n_\zeta)$ selection matrices and include the slope coefficients. ζ_t is the period-t $(n_\zeta \times 1)$ state vector. Stacking (1.19) and (1.23) vertically yields:

$$\Upsilon_T = \Gamma_a + H_{30}\zeta_t + H_{31}\zeta_{t-1} + H_{32}\zeta_{t-2} + H_{33}\zeta_{t-3} + H_{34}\zeta_{t-4} + M_T \ , \ M_T \sim N(0, \Sigma_a) \tag{1.28}$$

where $\Upsilon_T \equiv [TIS_T, TWS_T]'$ and Γ_a are $(o_a \times 1)$ vectors $(o_a = 2)$ of annually observed

[11] Kumhof et al. (2015) and Cairó and Sim (2018) map debt to the bottom 95%.

series and intercepts, respectively. $M_T \equiv [\epsilon_T^{tis}, \epsilon_T^{tws}]'$ collects the measurement errors; Σ_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 (1.19) and (1.23).

Eq.(2.18) appears for four consecutive quarters until the end of a year when the inequality series are observed and linked to the model via (1.28). Stacking over time yields:

$$\begin{bmatrix} \Upsilon_{t=1} \\ \Upsilon_{t=2} \\ \Upsilon_{t=3} \\ \Upsilon_{t=4} \\ \Upsilon_{T=1} \\ \Upsilon_{t=5} \\ \Upsilon_{t=6} \\ \Upsilon_{t=7} \\ \Upsilon_{t=8} \\ \Upsilon_{T=2} \\ \vdots \end{bmatrix} = \begin{bmatrix} \Gamma_q \\ \Gamma_q \\ \Gamma_q \\ \Gamma_q \\ \Gamma_a \\ \Gamma_q \\ \Gamma_q \\ \Gamma_q \\ \Gamma_q \\ \Gamma_a \\ \vdots \end{bmatrix} + \begin{bmatrix} H_0 & \dots & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ H_1 & H_0 & \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & H_1 & H_0 & \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & H_1 & H_0 & \dots & \dots & \dots & \dots & \dots \\ H_{33} & H_{32} & H_{31} & H_{30} & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & H_1 & H_0 & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & H_1 & H_0 & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & H_1 & H_0 & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots & H_1 & H_0 & \dots \\ \dots & \dots & \dots & H_{34} & H_{33} & H_{32} & H_{31} & H_{30} & \dots \\ \dots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \end{bmatrix} \begin{bmatrix} \zeta_{t=1} \\ \zeta_{t=2} \\ \zeta_{t=3} \\ \zeta_{t=4} \\ \zeta_{t=5} \\ \zeta_{t=6} \\ \zeta_{t=7} \\ \zeta_{t=8} \\ \vdots \end{bmatrix} + \begin{bmatrix} M_{t=1} \\ M_{t=2} \\ M_{t=3} \\ M_{t=4} \\ M_{T=1} \\ M_{t=5} \\ M_{t=6} \\ M_{t=7} \\ M_{t=8} \\ M_{T=2} \\ \vdots \end{bmatrix} \tag{1.29}$$

The matrix representation of (2.19) is given by

$$\Upsilon = \Gamma + H\zeta + M \quad , \quad M \sim N\left(0_o, \Sigma_M \equiv I_{n_T} \otimes diag\left(diag[I_4 \otimes \Sigma_q]; diag[\Sigma_a]\right)\right) \tag{1.30}$$

where $o = [(4o_q + o_a)n_T] \times 1$. $\Upsilon \equiv [\Upsilon'_{t=1}, \Upsilon'_{t=2}, \Upsilon'_{t=3}, \Upsilon'_{t=4}, \Upsilon'_{T=1}, \ldots]'$ is the observation vector. $\Gamma \equiv [\Gamma'_q, \Gamma'_q, \Gamma'_q, \Gamma'_q, \Gamma'_a, \ldots]'$ 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. $M \equiv [M'_{t=1}, M'_{t=2}, M'_{t=3}, M'_{t=4}, M'_{T=1}, \ldots]'$ collects the measurement errors. H

is a sparse and block-banded matrix. According to (3.31), the likelihood of the data given the parameter vector Θ and the states ζ 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 Θ, and η_t collects the expectational errors. The structural shocks are grouped in the $(n_\epsilon \times 1)$ vector ϵ_t, and are fewer than the number of observables $(n_\epsilon < o_q + o_a)$. (3.26) gives the VAR(1) representation of the rational expectations solution of Sims (2002).

$$\zeta_t = \Phi_1(\Theta)\zeta_{t-1} + \Phi_2(\Theta)\epsilon_t \ , \quad \epsilon_t \sim N(0_{n_\epsilon}, I_{n_\epsilon}), \quad \forall t \geq 2 \tag{1.31}$$

$\{\Phi_1, \Phi_2\}$ are non-linear functions of Θ. ζ_1 is initialized with covariance D being the steady state covariance of the state vector evaluated at the prior mean of Θ. Defining the reduced-form errors, $\tilde{\epsilon}_t = \Phi_2\epsilon_t$ for $t > 1$ and $\tilde{\epsilon}_1 = \epsilon_1$, and stacking (3.26) across time yields:

$$\begin{bmatrix} I_{n_\zeta} & \cdots & \cdots & \cdots \\ -\Phi_1 & I_{n_\zeta} & \cdots & \cdots \\ \cdots & \ddots & \ddots & \cdots \\ \cdots & \cdots & -\Phi_1 & I_{n_\zeta} \end{bmatrix} \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \vdots \\ \zeta_T \end{bmatrix} = \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix}, \quad \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix} \sim N\left(0_{n_\zeta n_q}, \begin{bmatrix} D & \cdots \\ \vdots & \Omega \otimes I_{T-1} \end{bmatrix}\right) \tag{1.32}$$

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

$$Z\zeta = \tilde{\epsilon} \quad , \quad \tilde{\epsilon} \sim N(0_{n_\zeta n_q}, K_{\tilde{\epsilon}}^{-1}) \tag{1.33}$$

$\tilde{\epsilon} \equiv [\tilde{\epsilon}_1', \tilde{\epsilon}_2' \ldots, \tilde{\epsilon}_T']'$ is the $(n_\zeta n_q) \times 1$ 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 $\zeta|\Theta \sim N(\tilde{\zeta}, K^{-1})$ and $\tilde{\zeta} = 0_{n_\zeta n_q}$. 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 $(\widehat{\zeta})$ is computed from (3.32) below based on the efficient simulation of Chan and Jeliazkov (2009).

$$P\widehat{\zeta} = K\tilde{\zeta} + H'\Sigma_M^{-1}(\Upsilon - \Gamma) \tag{1.34}$$

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: $\log P(\Upsilon|\Theta) = +logP(\Upsilon|\Theta, \widehat{\zeta}) + logP(\widehat{\zeta}|\Theta) - logP(\widehat{\zeta}|\Upsilon, \Theta)$.

1.2.3 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[12] and reported in Table (D.1). Additionally, the fraction of top agents (n^τ) is 10% in accordance with the observed series. β^τ is set to 0.99, and β^μ 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 (ϕ^τ) is sampled from Beta centered at 0.1 (0.03 standard deviation, "std") often considered in the literature.

[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. δ and g are set to the values chosen in Smets and Wouters (2007).

ϕ^{μ} 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_{ω}) are small (0.1).

1.3 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.

1.3.1 Posterior Estimates.

The parameter estimates across the RA and the present model are displayed in Table (D.1). Zooming in on the parameters associated with the economy's aggregate dimension, habit (η) falls considerably from 0.77 in the RA model to 0.51. The inverse Frisch elasticity (χ) is a tad higher in the present model than in the RA model. Both price (ι_p) and wage (ι_w) indexation are a tad elevated compared to their RA estimates, whereas price (ζ_p) and wage (ζ_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 (ρ_i rises from 0.85 to 0.99, and σ_i increases from 0.30 to 0.53). The latter along with the increased elasticity of utilization costs (ψ) 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 (ψ_π) 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 (ϕ^μ, ϕ^τ) 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[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 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.

1.3.2 Economy Wide Implications of Inequality.

Economy Wide Effect.

I quantify the autonomous effect of distributional shocks on the U.S. business cycle in Table (1.5) which displays the forecast error variance decomposition 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

[13] Justiniano et al. (2015) consider such heterogeneous parameters in their robustness checks.

Table 1.4: Posterior Distribution

	Prior	**Posterior** Mean [5-95%]			**Prior**	**Posterior**
		Rep. Agent	D. Imbalances			D. Imbalances
α	N(0.30, 0.05)	0.21 [0.19, 0.24]	0.25 [0.23, 0.27]	ϕ_{μ}	B(0.15, 0.03)	0.37 [0.32, 0.42]
η	B(0.70, 0.10)	0.77 [0.71, 0.82]	0.51 [0.46, 0.55]	ϕ_{τ}	B(0.10, 0.03)	0.15 [0.13, 0.17]
χ	N(2.00, 1.00)	4.14 [2.94, 5.39]	5.14 [4.01, 6.35]	ρ_s	B(0.70, 0.20)	0.99 [0.99, 0.99]
ψ	B(0.50, 0.10)	0.37 [0.24, 0.56]	0.59 [0.47, 0.72]	σ_s	IG(0.15, 1.00)	2.77 [2.16, 3.49]
S	N(4.00, 1.00)	6.74 [5.45, 8.01]	2.48 [1.92, 3.13]	ρ_{ω}	B(0.70, 0.20)	1.00 [0.99, 1.00]
ζ_w	B(0.60, 0.10)	0.90 [0.84, 0.95]	0.77 [0.73, 0.80]	σ_{ω}	IG(0.15, 1.00)	0.27 [0.21, 0.38]
ζ_p	B(0.60, 0.10)	0.91 [0.87, 0.94]	0.90 [0.87, 0.92]	ρ_m	B(0.70, 0.20)	0.99 [0.99, 1.00]
ι_p	B(0.50, 0.15)	0.07 [0.03, 0.12]	0.09 [0.04, 0.16]	σ_m	IG(0.15, 1.00)	1.55 [1.38, 1.72]
ι_w	B(0.50, 0.15)	0.75 [0.61, 0.87]	0.80 [0.67, 0.91]	Ψ_d	N(1.00, 0.50)	0.77 [0.63, 0.90]
ρ_r	B(0.75, 0.10)	0.90 [0.88, 0.92]	0.85 [0.83, 0.87]	μ_{hm}	IG(0.15, 1.00)	0.70 [0.49, 0.88]
ψ_{π}	N(1.70, 0.25)	1.88 [1.55, 2.22]	2.17 [1.89, 2.46]	μ_{cc}	IG(0.15, 1.00)	1.12 [0.99, 1.24]
ψ_y	N(0.12, 0.05)	0.20 [0.13, 0.26]	0.17 [0.12, 0.23]	γ_{hm}	N(1.00, 0.04)	1.01 [0.95, 1.07]
$\psi_{\Delta y}$	N(0.12, 0.05)	0.23 [0.14, 0.31]	0.33 [0.25, 0.41]	γ_{cc}	N(0.70, 0.04)	0.70 [0.64, 0.76]
ρ_b	B(0.60, 0.20)	0.80 [0.71, 0.88]	0.91 [0.88, 0.93]	κ_{tis}	N(0.32, 0.03)	0.30 [0.24, 0.35]
σ_b	IG(0.15, 1.00)	0.12 [0.09, 0.15]	0.10 [0.08, 0.12]	κ_{tws}	N(0.00, 0.03)	0.03 [-0.02, 0.07]
ρ_z	B(0.60, 0.20)	0.99 [0.98, 0.99]	0.96 [0.94, 0.97]		(,)	[,]
σ_z	IG(0.15, 1.00)	0.55 [0.51, 0.60]	0.57 [0.52, 0.61]		(,)	[,]
ρ_i	B(0.60, 0.20)	0.85 [0.75, 0.98]	0.99 [0.99, 1.00]		(,)	[,]
σ_i	IG(0.15, 1.00)	0.30 [0.25, 0.36]	0.53 [0.44, 0.64]		(,)	[,]
ρ_p	B(0.60, 0.20)	0.81 [0.74, 0.87]	0.71 [0.65, 0.78]		(,)	[,]
σ_p	IG(0.15, 1.00)	0.07 [0.05, 0.08]	0.10 [0.08, 0.11]		(,)	[,]
ρ_w	B(0.60, 0.20)	0.13 [0.05, 0.22]	0.25 [0.14, 0.38]		(,)	[,]
σ_w	IG(0.15, 1.00)	0.60 [0.54, 0.67]	0.63 [0.54, 0.72]		(,)	[,]
σ_{mp}	IG(0.15, 1.00)	0.24 [0.22, 0.26]	0.26 [0.23, 0.28]		(,)	[,]
ρ_g	B(0.60, 0.20)	0.97 [0.95, 0.99]	0.94 [0.91, 0.96]		(,)	[,]
σ_g	IG(0.15, 1.00)	0.46 [0.42, 0.50]	0.45 [0.41, 0.49]		(,)	[,]
ρ_{gz}	B(0.50, 0.20)	0.32 [0.26, 0.38]	0.34 [0.29, 0.40]		(,)	[,]
γ	N(0.40, 0.03)	0.39 [0.35, 0.43]	0.41 [0.38, 0.44]		(,)	[,]
π	N(0.80, 0.03)	0.83 [0.78, 0.87]	0.88 [0.83, 0.93]		(,)	[,]
υ_w	N(0.50, 0.03)	0.50 [0.45, 0.54]	0.50 [0.45, 0.55]		(,)	[,]
υ_p	N(0.30, 0.03)	0.34 [0.29, 0.38]	0.27 [0.22, 0.31]		(,)	[,]
$\bar{l}$	N(0.00, 0.10)	0.03 [-0.12, 0.20]	0.17 [0.03, 0.31]		(,)	[,]
$logL$		-1433	-2764			

Notes: Author's computations. "Rep. Agent " refers to the Smets and Wouters (2007) model estimated over the 1954Q3-2009Q4 period.

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 1.5: Business Cycles and Distributional Shocks

	variable							
shock	$\widehat{y}_t$	$\widehat{\pi}_t$	$\widehat{r}_t$	$\widehat{b}_t^{\tau}$	$\widehat{tis}_t$	$\widehat{tws}_t$	$\widehat{c}_t^{\tau}$	$\widehat{c}_t^{\mu}$
wage polariz.	3/2	0/1	2/5	1/8	99/100	13/61	91/95	69/85
wealth pref.	4/2	1/1	5/5	44/27	0/0	40/9	2/1	3/1
credit supply	3/2	0/1	3/3	30/17	0/0	8/20	1/0	2/0
distributional	10/6	1/3	11/13	75/52	100/100	61/90	93/96	74/86
technology	32/28	1/2	0/0	15/7	0/0	16/3	0/1	6/3
price markup	10/5	68/60	16/8	2/1	0/0	6/1	0/0	1/0
wage markup	2/2	8/8	1/1	5/1	0/0	6/1	0/0	1/0
supply side	44/35	77/70	18/9	22/9	0/0	28/5	1/1	9/4
risk premium	28/14	12/13	49/46	1/2	0/0	5/2	0/0	9/3
investment	5/39	7/12	6/24	1/35	0/0	2/1	6/3	1/6
gov. spending	1/1	0/0	0/0	0/1	0/0	0/1	0/0	2/1
mon. policy	13/6	2/2	16/8	1/1	0/0	4/2	0/0	5/1
demand side	46/59	22/27	72/78	3/39	0/0	11/5	6/3	17/11

Notes: Forecast Error Variance Decomposition 8/40 quarters ahead, computed at the posterior mean. *Mnemonics:* $\{\widehat{y}_t, \widehat{\pi}_t, \widehat{r}_t, \widehat{b}_t^{\tau}, \widehat{tis}_t, \widehat{tws}_t, \widehat{c}_t^{\tau}, \widehat{c}_t^{\mu}\}$ 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.

Diffusion.

Figures (1.1) and (1.2) 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.

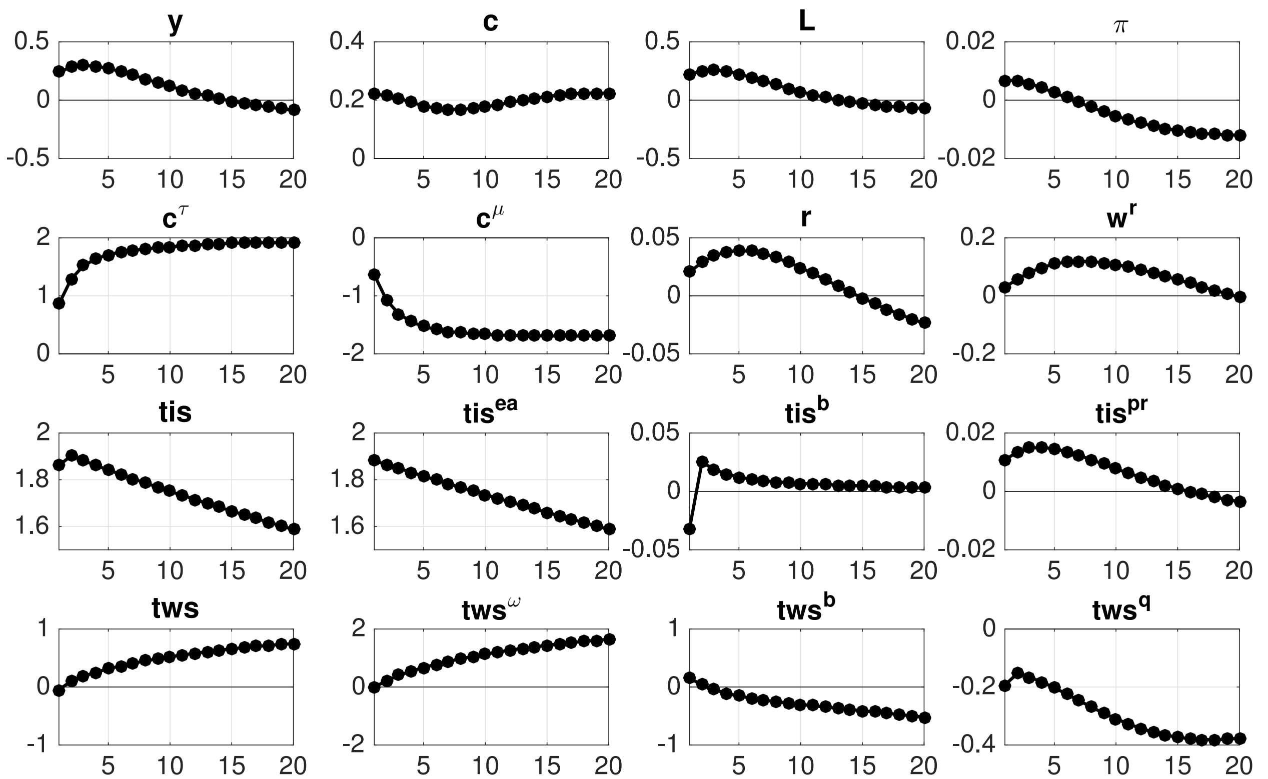
In response to wage polarization, top consumption rises whereas middle-class consumption falls. The two changes do net out to zero, and result in a gradual economy wide consumption increase – an aggregate demand stimulus – that eventually raises production, employment, and wages, and generates pro-cyclical, 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 1.1). 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^{ea}). The top families leverage their income to increase consumption (c^{τ}) 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^{ω} 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.

The effects of changes in the desire for wealth accumulation and in the borrowing capacity of the middle class are similar [Fig.1.2]. 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 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

Figure 1.1: Economy Wide Implications of Wage Polarization Shocks



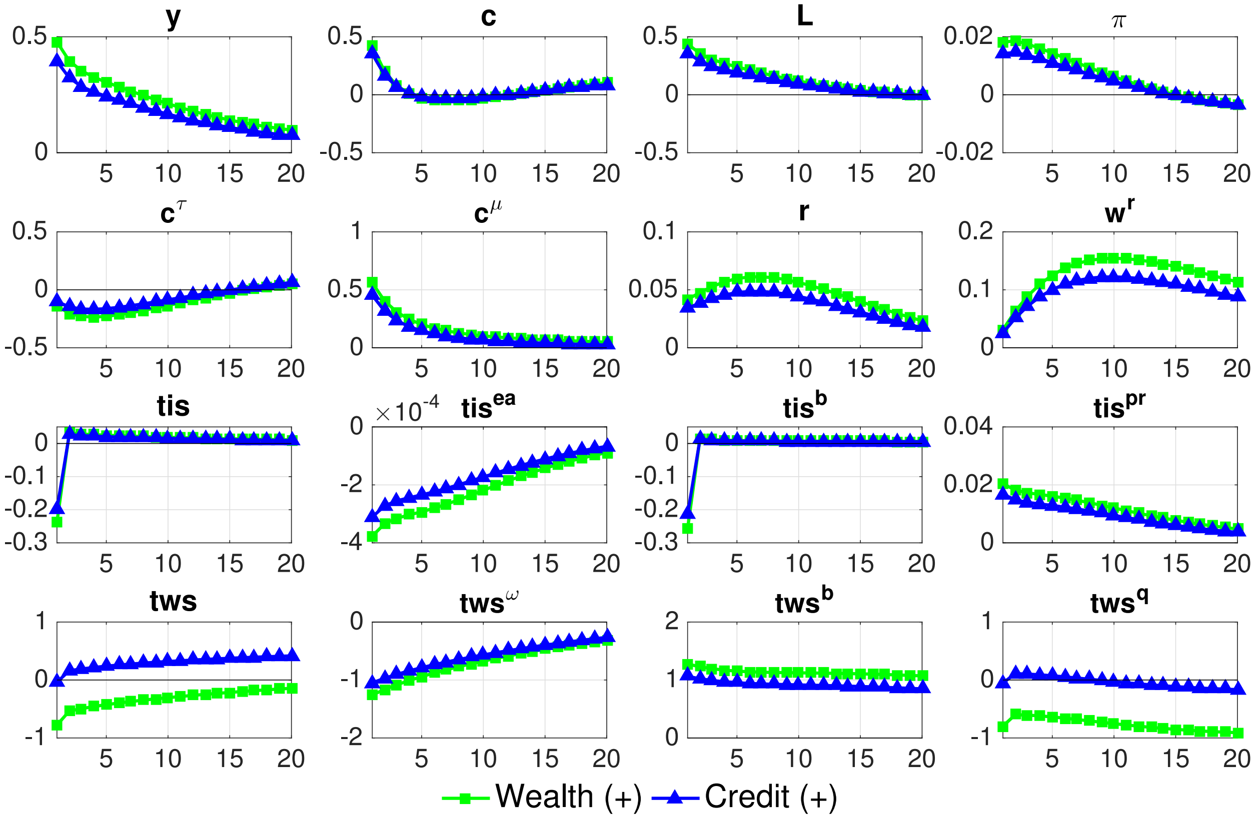
Notes: impulse response functions, % deviation from steady state. 3rd row:: top income share (tis): earnings (tis^{ea}), bond income (tis^b), and profits (tis^{pr}) channels, with $tis = tis^{ea} + tis^b + tis^{pr}$. 4th row:: top wealth share (tws): shares (tws^{ω}), bonds (tws^b), and asset price (tws^q)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

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.

Debt Pileup and Output Cycles.

Although the findings of Table (1.5) 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

Figure 1.2: 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 $tws = tws^{\omega} + tws^b + tws^q$.

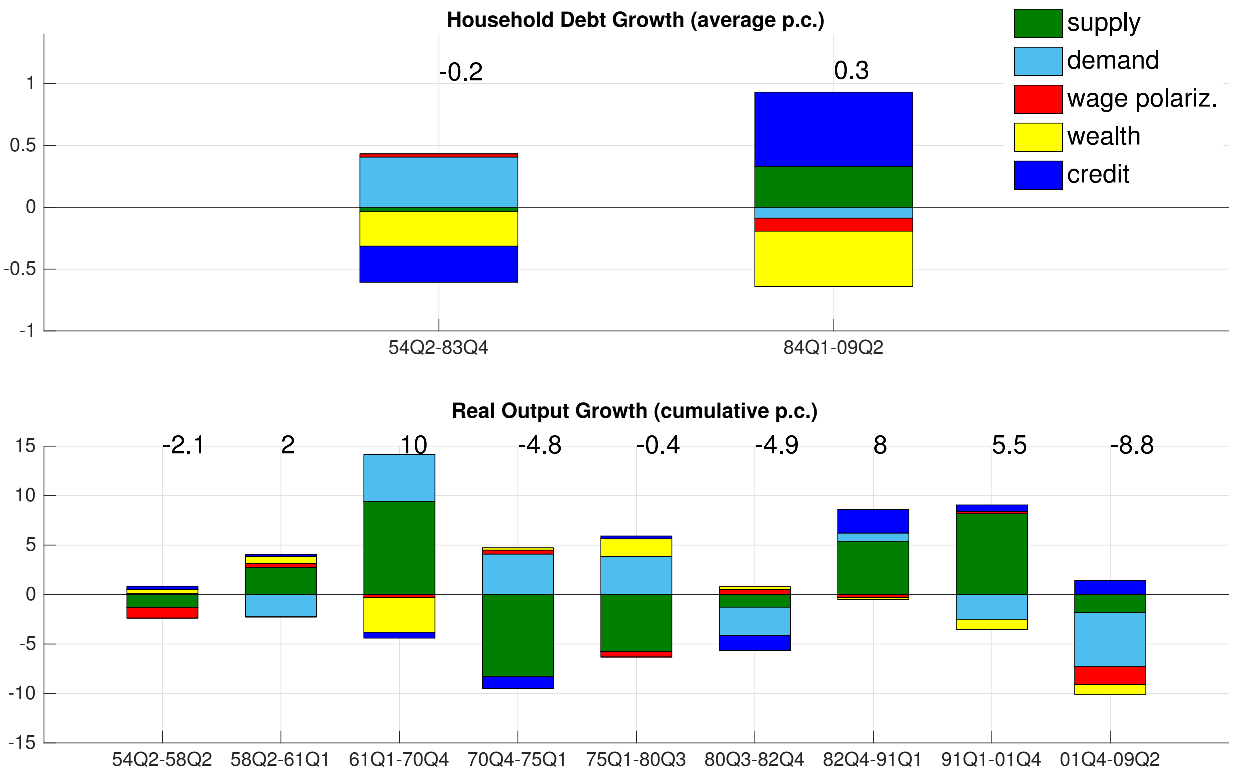
effect of distributional shocks on debt and output growth time-varying over the 1954-2009 period? Fig.(1.3) tackles this question.

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 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.(1.1). 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.(1.2). 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.(1.3) corroborates that distributional shocks have limited impact on output cycles. Wealth shocks are more influential during the cycles before the 1980s than 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 1.3: Debt Pileup and Output Cycles



Notes: Historical decomposition. Real per capita growth rates. *Top Panel:* Quarterly average debt. *Bottom Panel:* cumulative output. Figures shown on top of each column. Demand shocks: risk premium, investment, monetary, and government spending. Supply shocks: technology, price and wage markup.

Endogenous and Exogenous Imbalances.

This section disentangles the influence of exogenous distributional imbalances (distributional shocks) from the influence of mechanisms (heterogeneous ϕ's and imperfect insurance) that endogenously generate distributional imbalances. Table (1.6) 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 (η) 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 ϕ'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).

The bottom part of Table (1.6) entails another important result. Both exogenous distributional shocks and heterogeneous ϕ'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 (D.1) [low price indexation (0.07

Table 1.6: Measuring Endogenous and Exogenous Distributional Imbalances

	Mean	Volatility	Persistence	Deviation
Aggregate Demand				
Observed (minus measur. error)	0.48	0.74	0.26	0.00
No Exogenous Imbalances	0.49	0.85	-0.07	0.19
No Exog. Imbalances & $\phi^{\mu} = \phi^{\tau}$	0.49	0.81	-0.09	0.31
No Exog. & Endog. Imbalances	0.47	0.85	0.59	0.31
Inflation				
Observed (minus measur. error)	0.85	0.58	0.86	0.00
No Exogenous Imbalances	0.84	0.58	0.86	0.00
No Exog. Imbalances & $\phi^{\mu} = \phi^{\tau}$	0.83	0.58	0.86	0.00
No Exog. & Endog. Imbalances	0.80	0.71	0.91	0.05

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.

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.

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 (1.7) 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[14].

Table 1.7: Total Effect of Aggregate Shocks across Model Specifications

	y_t		π_t		r_t		c_t	
	RA	DI	RA	DI	RA	DI	RA	DI
technology	16.9	15.7	-0.7	-0.2	-0.7	0.1	12.9	9.6
price markup	-6.5	-6.0	1.2	0.7	1.0	0.7	-4.3	-3.4
wage markup	-3.0	-4.3	0.9	0.5	0.8	0.3	-3.9	-4.0
premium	8.1	10.5	0.0	0.7	1.4	2.9	8.8	6.1
investment	8.6	10.7	-0.2	0.7	0.4	1.6	0.8	-5.3
spending	2.7	0.5	0.1	-0.0	0.2	0.0	-5.9	-4.1
policy	6.1	6.4	0.1	0.2	-1.1	-0.2	5.8	3.8

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

1.3.3 Monetary Policy and Inequality.

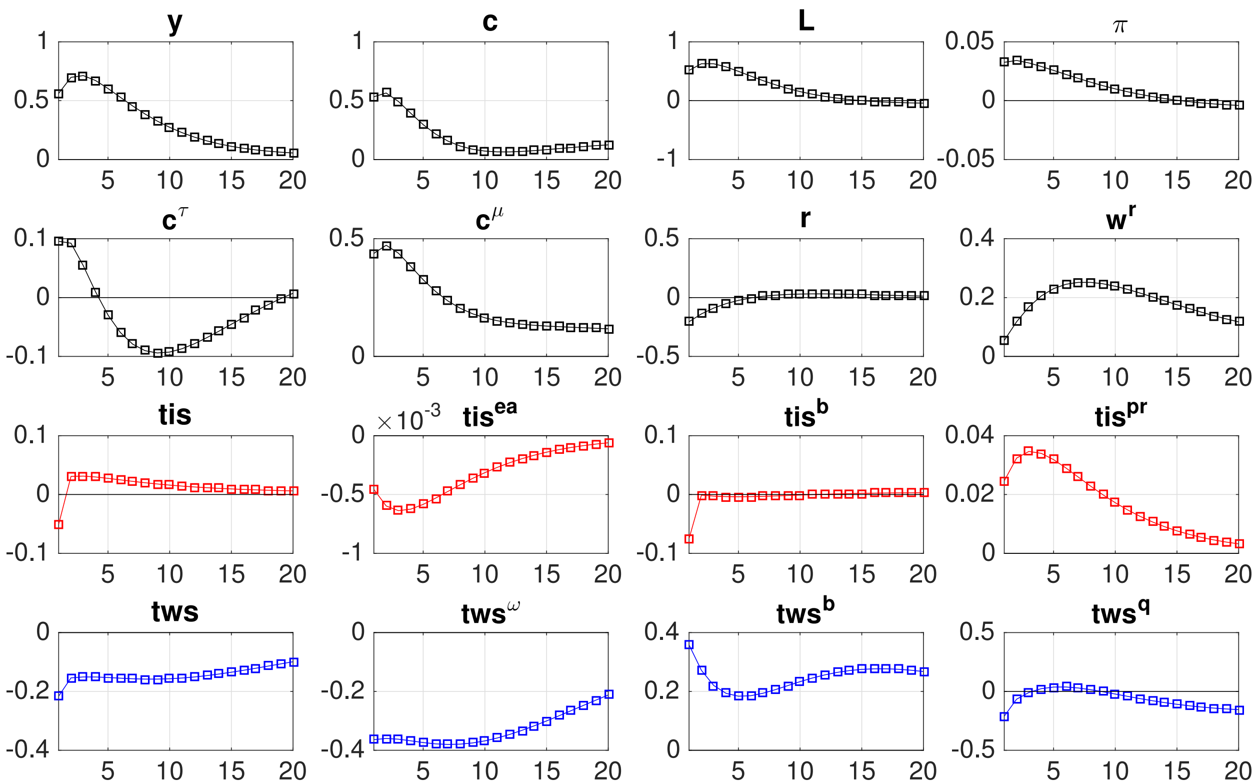
I examine three aspects of the monetary policy and inequality nexus: (i) the propagation of unpredictable changes in the policy instrument to inequality; (ii) the role of the policy stance against inflation in the transmission of distributional shocks; (iii) the inflation–output gap variability trade-off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

Unpredictable Policy over Half a Century.

Fig.(1.4) 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

[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.

Figure 1.4: Monetary Policy Disturbances

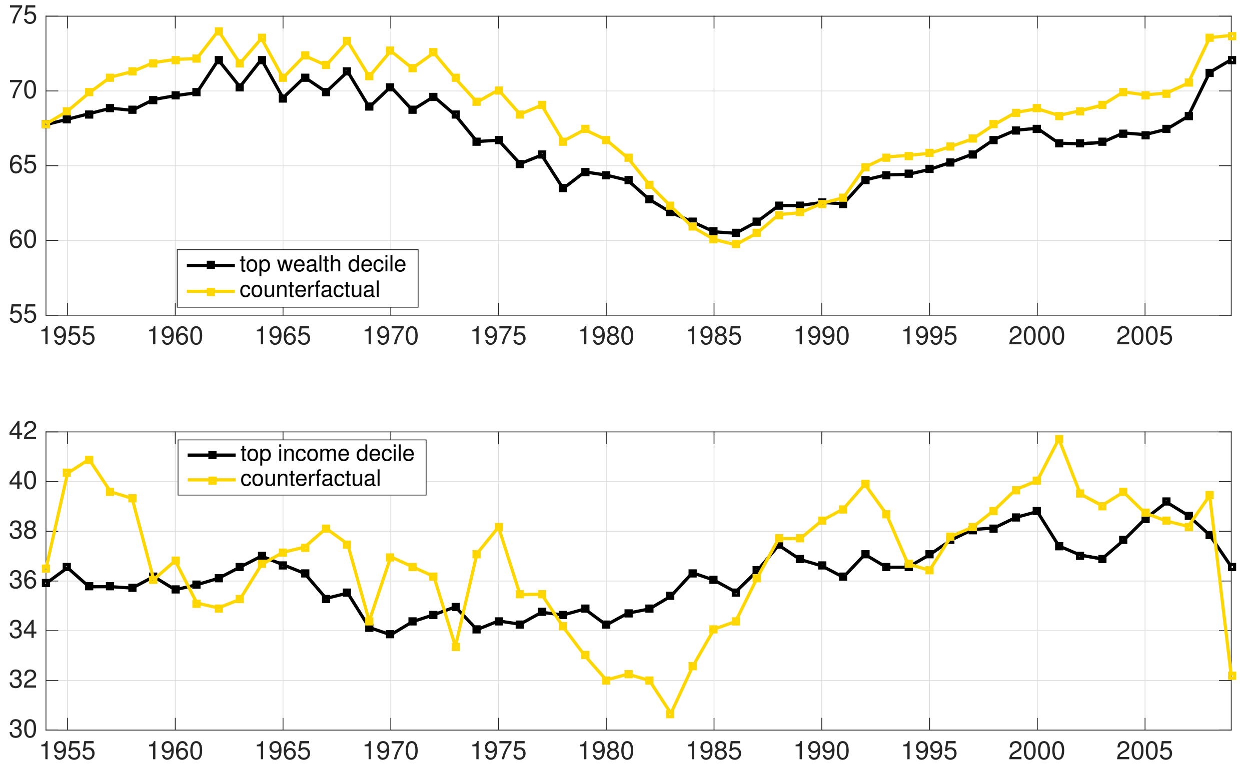


Notes: impulse response functions (posterior mean). All variables in % deviation from steady state. 1st and 2nd row: aggregate variables. 3rd row:: top income share (tis): earnings (tis^{ea}), bond income (tis^{b}), and profits (tis^{pr}) channels, with $tis = tis^{ea} + tis^{b} + tis^{pr}$. 4th row::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

inequality is negative (counter-cyclical) because the middle class uses the borrowed funds to raise its asset holdings (tws^{ω} falls). The latter along with the asset price rise (tws^{q} falls) that accompanies low interest rates, spur downward pressures to wealth inequality that dominate top's increased bond assets.

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.(1.5) 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)

Figure 1.5: Monetary Policy Surprises and Inequality Swings



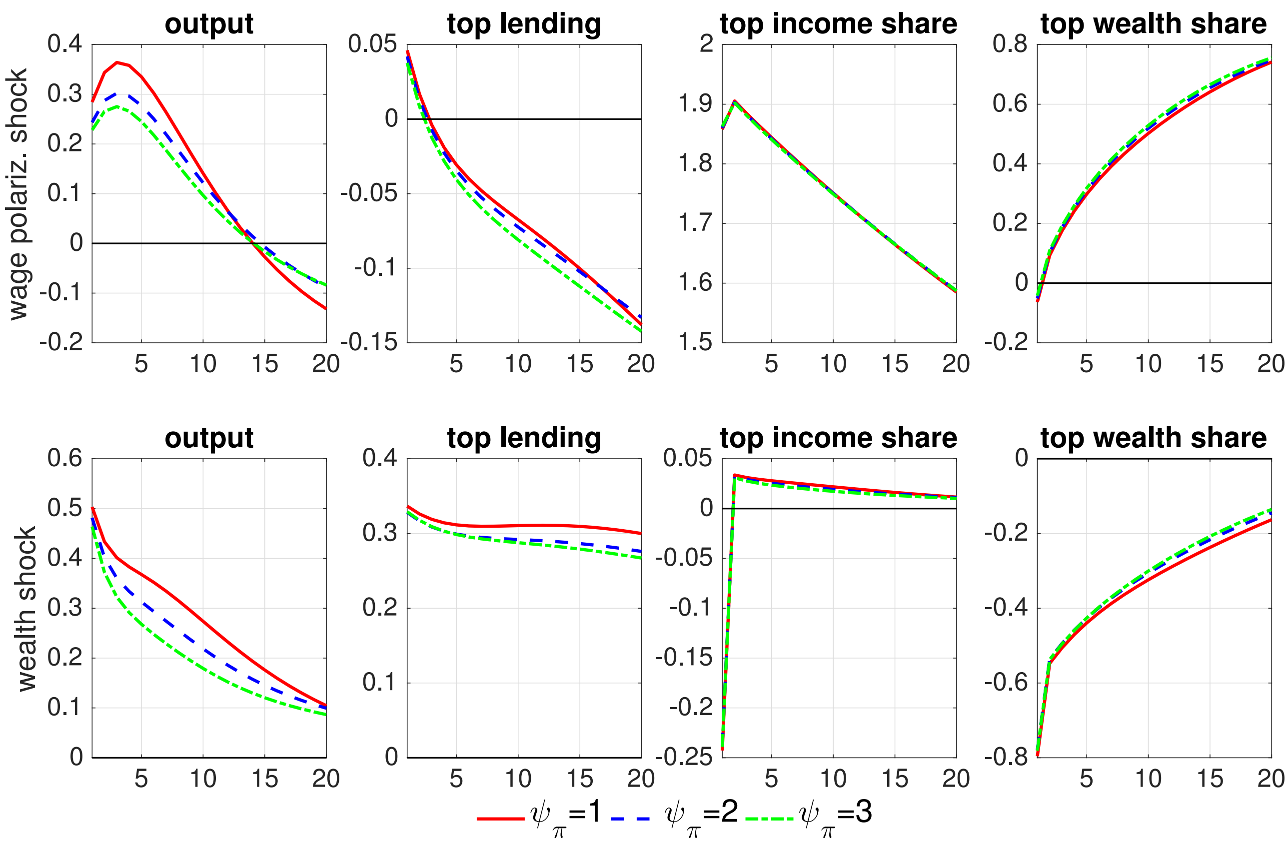
Notes: Counterfactual top 10% income and wealth shares for zero monetary policy surprises.

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.

Monetary Policy Stance.

I shed light on how the propagation of swings in inequality depends on the monetary policy stance. According to Fig.(1.6), the policy regime towards inflation (ψ_π) 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 1.6: 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.(1.1), 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.

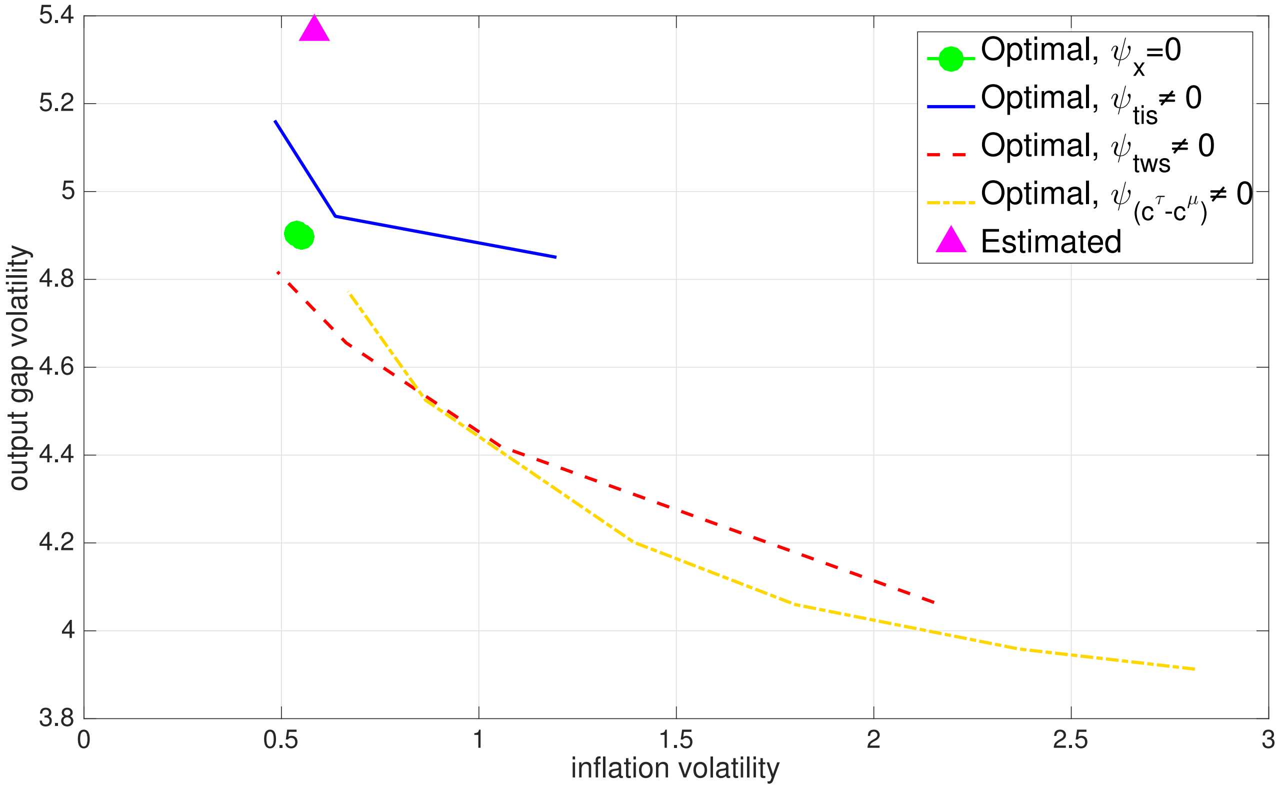
Should Monetary Policy React To Inequality?

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):

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r)\left[\psi_\pi \widehat{\pi}_t + \psi_y(\widehat{y}_t - \widehat{y}_t^f) + \psi_{\Delta y}\Delta(\widehat{y}_t - \widehat{y}_t^f) + \psi_j \widehat{x}_t^j\right] + \epsilon_t^{mp} \tag{1.35}$$

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

Figure 1.7: Policy Frontier



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

As displayed in Fig.(1.7), 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 optimal inflation response and no response to inequality[15]. In the case of a policy response to either the consumption differential or the top wealth share, the inflation–output gap variability trade-

[15]The curve involves an optimal ψ_π 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.

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 $\{\psi_{tis}, \psi_{tws}, \psi_{(c^{\mu}-c^{\tau})}\}$, as the welfare weight on inflation volatility goes from zero to one, ψ_{tis} rises from -0.12 to -0.03, ψ_{tws} rises from -0.45 to -0.03, and $\psi_{(c^{\mu}-c^{\tau})}$ 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 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.

1.3.4 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 (1.5), 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.(1.8) 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 (tis) rises because the increasing profit margins (tis^{pr}) are unequally distributed across the population while the earnings (tis^{ea}) and capital income (tis^{b}) channels have a small effect. In contrast, wealth inequality decreases (tws). Low lending costs result in middle-class households borrowing from the top (tws^{b}) to raise their consumption and ownership of firms (tws^{ω} falls). The latter and the negligible asset price effect to the top (tws^{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^{ω}) 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.(1.9) 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 smoothes its consumption by borrowing from the top (tws^{b}) and expands its ownership of shares (tws^{ω} falls). As a result, the top

Figure 1.8: Distributional Implications of Demand Side Shocks

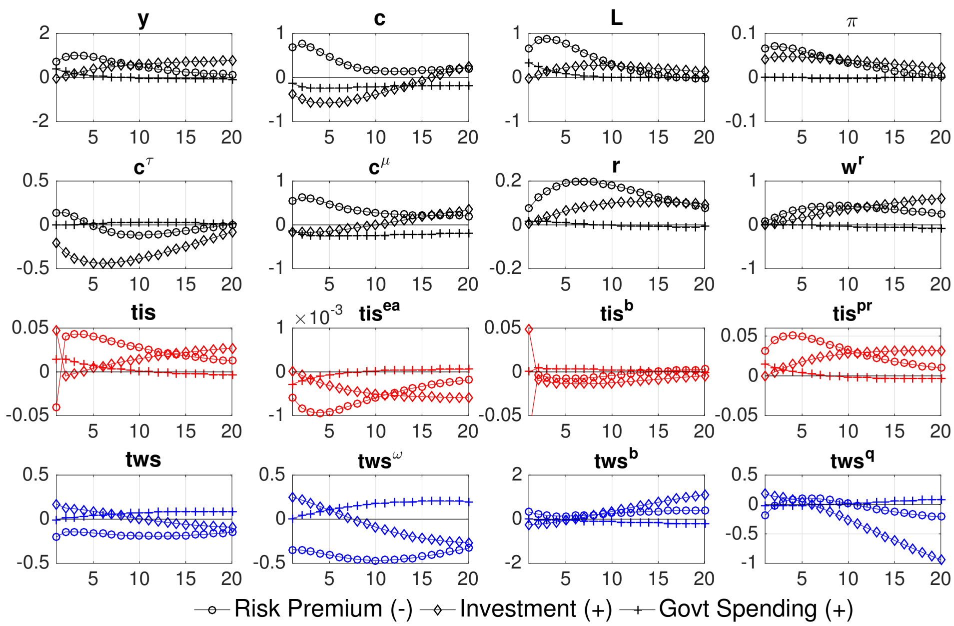
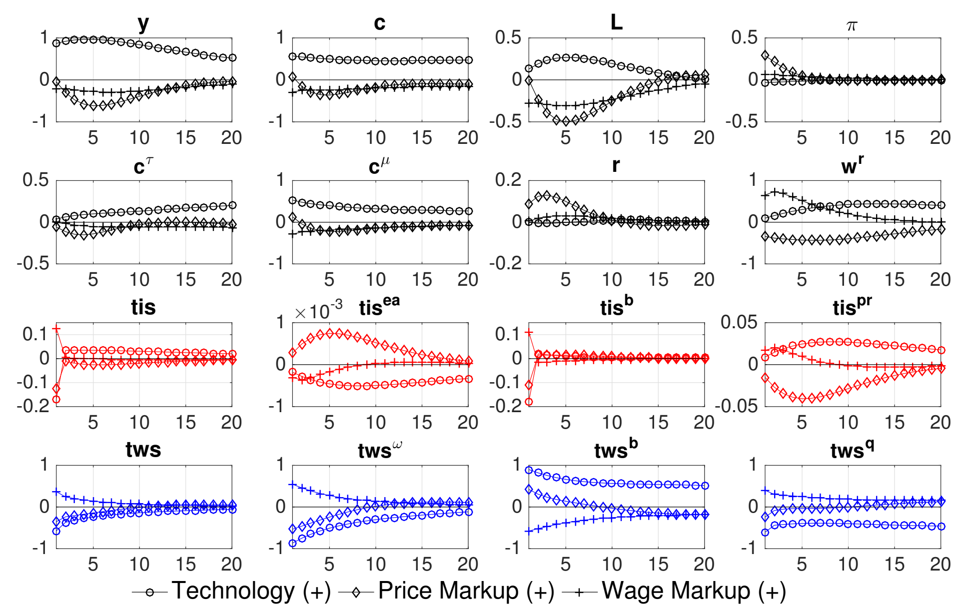


Figure 1.9: Distributional Implications of Supply Side Shocks



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^{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 $tws = tws^\omega + tws^b + tws^q$.

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.

1.3.5 Robustness Checks.

Collaterals and the Elasticity of Output to Wealth Shocks.

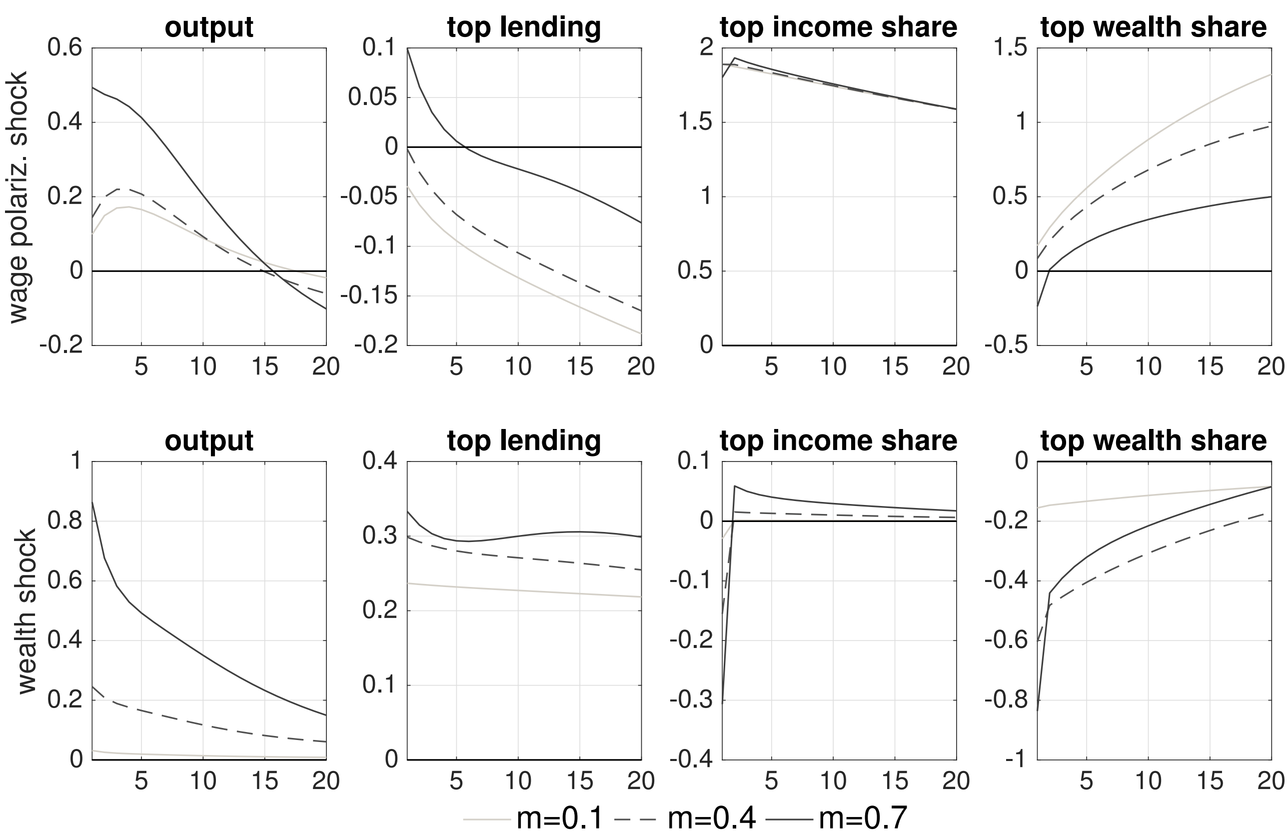
The analysis so far has not made clear how the transmission of distributional shocks depends on the degree of financial market imperfections and, in particular, on the importance of collaterals captured by the loan-to-value ratio (m); the higher the m, the lower the imperfections[16]. Fig.(1.10) displays 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.

More precisely, a high degree of financial market imperfections (low m) leads to a small

[16] In terms of steady state effects, a higher m raises debt, as well as the top income and wealth shares.

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 1.10: Collaterals and the Transmission of Distributional Imbalances



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

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, ϕ^{τ} rises from 0.15 to 0.35 and ϕ^{μ} 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 (Ψ_d) rises from (0.77) to (0.87).

Credit and Wealth Shocks, and a Comment on Taxes.

Table (1.5) 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[17]. Second, a negative connection between the two shocks is observed in the historical decompositions of Fig.(1.3). 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 important in

[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).

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 (1.23). As a result, wealth and credit shocks spur some qualitatively and quantitatively similar dynamics in Fig.(1.2), 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. Finally, 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.

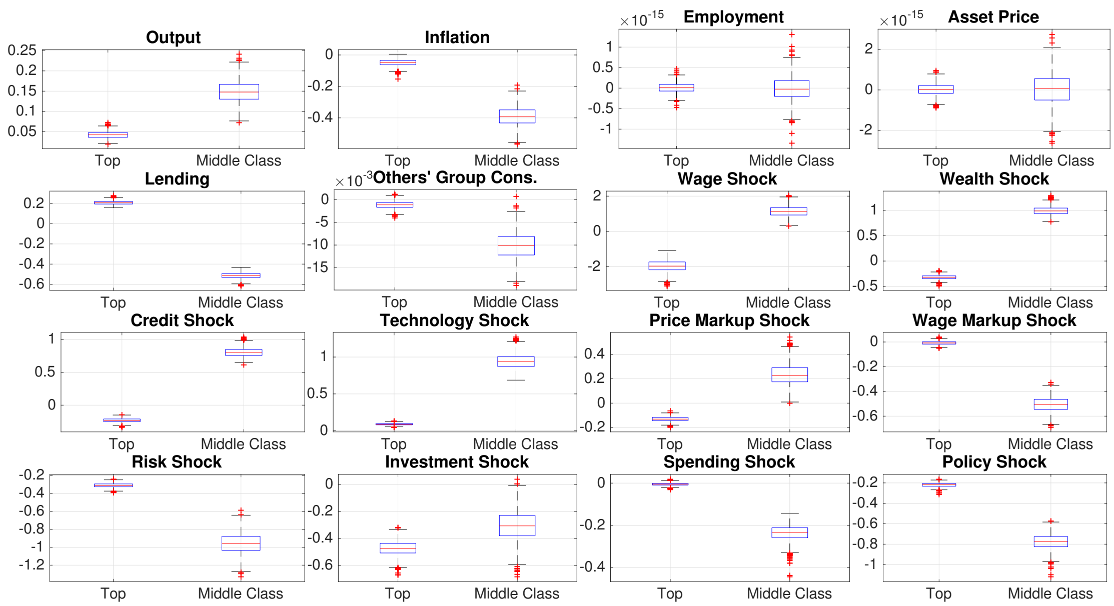
Prior.

The postulated prior specification is not dogmatic. At the prior, distributional 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 1.5).

Marginal Propensity To Consume.

This section quantifies the model-implied MPC heterogeneity across top and middle-class households. Fig.(1.11) 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 1.11: Marginal Propensity To Consume Differentials



Notes: Posterior distribution of consumption responses across variables and sources of stochastic variation.

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 wealths 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.

1.4 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 take-away 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.

Chapter 2

The U.S. Labor Income Share and Automation Shocks

It is well known by now that the U.S. labor income share exhibits a downward trend over the past decades. Empirical studies have identified several determinants of the labor share, namely production automation or, interchangeably, routine-biased technical change [Goos et al., 2014; Autor and Dorn, 2013; Dao et al., 2017; Abdih and Danninger, 2017; Graetz and Michaels, 2018], the relative price of investment [Karabarbounis and Neiman, 2014], labor market institutions and trade globalization [Abdih and Danninger, 2017], statistical errors and offshoring of labor activities [Elsby et al., 2014], as well as firms' market power [Autor et al., 2017b, 2017a; Dixon and Lim, 2018][1]. Automation, in particular, holds a position so prominent that it has led authors using simulated growth models to make predictions about the future role of machines that paint a bleak picture for labor [Acemoglou and Restrepo, 2017b; Kotlikoff and Sachs, 2012; Nordhaus, 2015; Berg et al., 2018].

Although the aforementioned studies focus on the relatively recent downward trajectory of

[1] Blanchard and Giavazzi (2003) argue for shifts in regulation of the European product and labor markets.

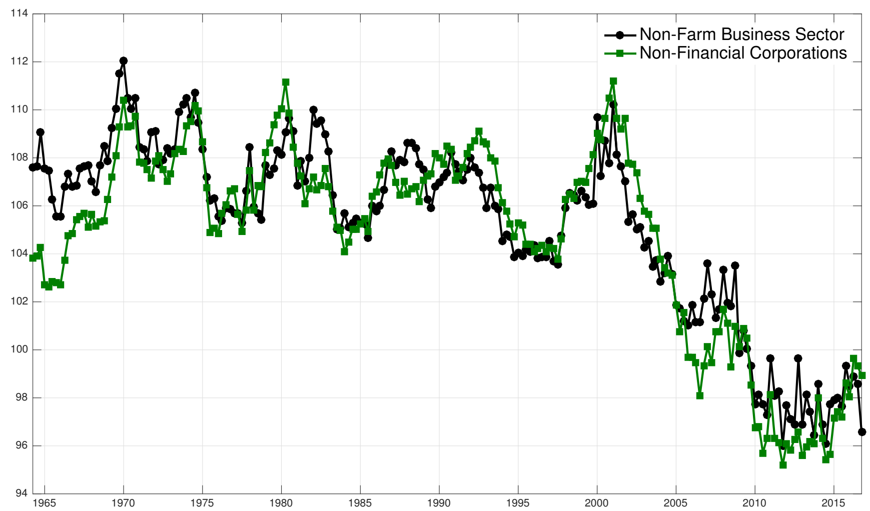
the labor share, the present paper contributes on this topic by considering the broad historical swings of that share since 1964 to 2016. Fig.(2.1), in fact, gives inklings on beyond garden-variety swings during the entire period under consideration. This paper places those swings in a macroeconomic context and examines them in conjunction with U.S. aggregate series through the lens of a stylized structural model. In doing so, it sheds light on the origins and the implications of the fluctuations in the labor share. In addition, it quantifies the influence of production automation shocks in a setup that includes the competing influence of the relative price of investment, of labor market institutions via the wage markup shocks, of the firms' market power via the price markup shocks, and of measurement errors.

This paper addresses the above through the lens of the medium-scaled New Keynesian dynamic general equilibrium model of Justiniano et al. (2011) who build the relative price of investment[2] in the framework of Christiano et al. (2005) and Smets and Wouters (2007). I consider two novel features. The first pertains to the inclusion of observables for the labor income share and their joint consideration with U.S. aggregates in a state-of-the-art Bayesian approach, and the second pertains to the introduction of automation shocks.

DSGE models featuring a single observable for wages, output, and labor do not allow matching series for the labor share because the model-implied analogue of the latter is uniquely pinned down. I include observables for the labor share by treating the wage as a latent state that is identified through multiple wage measures and a factor approach – this treatment of wages is examined in several cases [Galí et al., 2012a; Justiniano et al., 2013; Lindé et al., 2016; Charalampidis, 2018]. To strengthen identification, I consider multiple series, displayed in Fig.(2.1), and a factor approach for the labor share as well. A factor approach to both wages and the labor share allows to *jointly* sample the wage and the labor share, and

[2] Following the identification strategy of Justiniano et al. (2011), shocks to the marginal efficiency of investment (MEI) are disentangled from investment-specific shocks (IST) suggested by Greenwood et al. (1988), examined in Greenwood et al.(1997, 2000) and Fisher (2006), and introduced in an international real business cycle model in Mandelman et al. (2011). Moura (2018) confirms the sizable role of MEI shocks in a two-sector DSGE model but finds a weak link between the relative investment price and IST shocks.

Figure 2.1: Swings in the Labor Income Share



Notes: Indices. *Data Source:* U.S. Bureau of Labor Statistics

accounts for the possibility of measurement errors. Jointly sampling wages and the labor share disciplines the extracted wage from the data in a way that resembles, in a conceptual sense, to the Justiniano et al. (2011)'s use of the relative price of investment to disentangle investment-specific shocks from innovations in the marginal efficiency of investment.

In addition, the present approach helps identify production automation disturbances encapsulating routine-biased technological shifts. These disturbances are modeled as stochastic variations in the output elasticities with respect to the production factors, that is, in the exponents of the individual firm's production function along the lines of Lansing (2015) and Lansing and Markiewicz (2016) who study the asset-pricing and welfare implications of exogenous capital share shifts in a Real Business Cycle (RBC) model, respectively; of Rios-Rull and Santaeulàlia-Llopis (2010) who consider redistribution shocks; and of Young who incorporates capital share shifts in a RBC model without neutral technology. In a similar spirit, Goldin and Katz (2007) model shifts in the shares of a CES production function to study the premium between skilled and unskilled workers.

According to this paper's findings, two thirds and one third of fluctuations in the U.S. labor share are explained by persistent automation shocks in the short and long run, respectively. Wage markup shocks, reflecting changes in workers' market power, maintain a prominent role in the swings of the labor share: they account for 19% and 62% of the short- and long-run swings, respectively. This result is consistent with Abdih and Danninger (2017) who find an influence of changes in unionization on the decline of the labor share. Demand side shocks and, in particular, disturbances associated with investment and the relative price of investment exert limited influence on the labor share throughout the sample period – this finding differs from Karabarbounis and Neiman (2014) who find that the decline in the corporate labor share is attributed to the relative investment price.[3]

Furthermore, automation shocks account for the lion's share of the post-2000 tumble in the labor share. Thus, gauging the effect of automation shocks based on a structural macroeconomic perspective complements empirical studies [Goos et al., 2014; Autor and Dorn, 2013; Dao et al., 2017; Abdih and Danninger, 2017; Graetz and Michaels, 2018] that attribute a crucial role to routine-biased technical change. Moving the analysis beyond the recent decline of the labor share that has been the topic of most of the aforementioned studies, during 1970-1985, supply side shocks balance out the influence of automation shocks and result in a relative stable labor share. During 1985-2000, supply side shocks edge out automation shocks leading to a gradually declining labor share.

Turning to the macroeconomic implications of automation shocks, I find that these shocks entail a distinctive characteristic that is not matched by any other aggregate innovation: they spur a counter-cyclical response in labor hours. The latter is intuitive since automation shifts, at their core, entail a substitution of labor with capital, as well as a temporary output expansion. This characteristic implies that the present modeling of those disturbances is not susceptible to the critique of Acemoglou and Restrepo (2018) about various modeling ways of

[3] In addition, I find moderate measurement errors in the labor share which can be thought to reflect the evidence of Elsby et al. (2014).

automation shocks not being able to generate a fall in labor demand. Moreover, automation disturbances account for 29/9% of output cycles in the short/long run, and are correlated with the part of capital intensity indices in the private, non-farm, and manufacturing sectors that is not explained by the state of the economy.

Introducing observables for the labor share in a rigorous Bayesian estimation contributes in three additional branches of the literature. First, this work's *data-driven* approach differs from papers studying the implications of structural models, featuring labor search [Shao and Silos, 2014] or other deviations from Walrasian markets [Boldrin and Horvath, 1995; Gomme and Greenwood, 1995], in terms of the labor share through summary statistics from model simulations. Second, the present work's *extraction* of exogenous shifts in the output elasticities with respect to the factor shares from the data expands on papers examining the implications of labor or capital share shifts and employing either simulation [Lansing, 2015; Lansing and Markiewicz, 2016; Rios-Rull and Santaeulàlia-Llopis, 2010; Young, 2004; Castanẽda et al. (1998)] or regression analysis [Blanchard, 1997; Bentolila and Saint-Paul, 2003]. Third, this paper's *identification* of automation shocks works through the introduction of multiple wage and labor share observables. In contrast, capital-augmenting shocks studied in Cantore et al. (2015) and Di Pace and Villa (2016) who introduce CES production in a DSGE framework are not identified from information embedded in the factor shares because Cantore et al. (2015) match the observables in Smets and Wouters (2007), while Di Pace and Villa (2016) add unemployment and vacancies to that set. In addition, capital-augmenting shocks are susceptible to the critique of Acemoglou and Restrepo (2018).

Including observables for the labor share, in fact, entails profound implications for the model behavior. More specifically, the NK–DSGE model estimated on multiple wage measures without labor share observables yields a *pro-cyclical* model-implied labor share that is at odds with the *counter-cyclicality* of that share in the data. The model-implied pro-cyclicality is triggered by an overstated comovement between the labor share and the real wage compared to that in the data. In contrast, including series for the labor share in the observation set disciplines the evolution of its model-implied analogue to match the salient features of the data. This improvement is accomplished via the following channels.

First, the prominent role of price markup shocks in the model without the labor share observables is attenuated in the model with those series, because those shocks entail a pro-cyclical labor share that is at odds with the data. Second, and along the lines of Justiniano et al. (2011), shocks in the marginal efficiency of investment (MEI) are the main determinant of the business cycle in the model without the labor share series. Nevertheless, with the labor share in the observation set, MEI shocks become less persistent, obtain a moderate explanatory power on output, and retain a large influence only on investment fluctuations. Although MEI shocks, along with all demand-side shocks, trigger a counter-cyclical response in the labor share, the response is small in magnitude and rests on a high degree of wage indexation that renders the real wage less responsive to general equilibrium forces stemming from disturbances outside of the labor market. A high degree of wage indexation that attenuates the real wage response is needed for those shocks to yield a counter-cyclical labor share because they trigger a pro-cyclical response in both labor and the real wage. It is worth mentioning that the reduced influence of MEI shocks is analogous to that obtained in Kaihatsu and Kurozumi (2014) who introduce a financial accelerator and shocks to net worth and the external finance premium in Justiniano et al. (2011).

Third, wage markup and automation shocks yield a sizable counter-cyclical response in the labor share and, thus, are favored by the data. Wage markup shocks, therefore, obtain a more prominent role in economic fluctuations than that they have in Justiniano et al. (2011); they account for 8% and 38% of output fluctuations two years ahead in the model without and with the labor share series, respectively. Their pronounced influence is in line with the evidence of Smets and Wouters (2007) and Galí et al. (2012a).

Section 2 outlines the structural model. Section 3 develops the estimation and identification strategy. Section 4 presents the results. Section 5 concludes.

2.1 Full-fledged Model

This section outlines the model. I build automation shifts in the medium-scale DSGE model of Justiniano et al. (2011) who include the relative price of investment and non-stationary technology in the environment of Christiano et al. (2005) and Smets and Wouters (2007). The model features a zero lower bound on the policy rate as well.

A representative firm converts units of the final good to investment purchased by a capital producer. The latter produces capital that is channeled to a continuum of monopolistically competitive firms. Those firms combine capital and labor to produce intermediate goods, and choose prices in a staggered fashion. Households invest in one-period nominal bonds priced at a rate determined by monetary policy, consume the final good, and supply labor. Perfect risk sharing holds. Each household consists of a continuum of agents with different labor types. The differentiated labor is uniformly distributed, supplied along the intensive margin, and priced in a staggered fashion by monopolistically competitive unions.

2.1.1 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 that is sold to consumers at price P_t. The producer maximizes period-t profits: $\{P_tY_t - \int_0^1 P_t(i)Y_t(i)di\}$, subject to technology

$$Y_t = \left(\int_0^1 Y_t(i)^{(\lambda_{p,t}-1)/\lambda_{p,t}} di\right)^{\lambda_{p,t}/(\lambda_{p,t}-1)} \tag{2.1}$$

where $\lambda_{p,t}$ is the time varying elasticity of substitution across product varieties, with the gross price markup $\lambda_{p,t}/(\lambda_{p,t}-1)$ following an AR(1) process with parameters $\{\rho_p, \sigma_p\}$. The resulting demand for good "i" and the aggregate price index are given by

$$Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\lambda_{p,t}} Y_t \quad \text{and} \quad P_t = \left(\int_0^1 P_t(i)^{1-\lambda_{p,t}} di\right)^{1/(1-\lambda_{p,t})} \tag{2.2}$$

2.1.2 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^k), in order to produce output $Y_t(i)$ according to the production function:

$$Y_t(i) = K_t(i)^{\alpha_t} \left(Z_t L_t(i)\right)^{1-\alpha_t} - A_t \Phi_y \tag{2.3}$$

The neutral technology exhibits a unit root, $ln(Z_t/Z_{t-1}) = \gamma_z + \widehat{z}_t$, and multiplicatively augments labor. $\widehat{z}_t$ follows an AR(1) process with associated parameters $\{\rho_z, \sigma_z\}$. A_t is the composite technology pinned down by $Z_t \Omega_t^{\frac{\alpha_t}{1-\alpha_t}}$. Ω_t is the investment-specific technological factor – to be explained below. Fixed costs, Φ_y, guarantee zero steady state profits.

α_t and $1-\alpha_t$ stand for the time-varying output elasticities with respect to capital and labor, respectively. Stochastic variations in α_t aim to reflect shifts in automation – such as those related to routine-biased technological change – because they alter the responsiveness of output to the capital-labor mix in the production line. $ln(\alpha_t/\alpha)$ follows an AR(1) process with associated parameters $\{\rho_\alpha, \sigma_\alpha\}$. Such variations are recently considered in Lansing (2015), Lansing and Markiewicz (2016), and Rios-Rull and Santaeulàlia-Llopis (2010).

The above definition of automation shocks differs from papers modeling automation as a capital-augmenting process [Kotlikoff and Sachs, 2012; Nordhaus, 2015; Graetz and Michaels, 2018]. Such a modeling would be sensitive to the critique of Acemoglou and Restrepo (2018) about capital-augmenting automation not being able to generate a decrease in labor demand. In this paper, automation shocks do generate a decline in labor hours.

Cost minimization yields the following capital-to-labor ratio and marginal cost – both are influenced by the automation shock,

$$K_t(i)/L_t(i) = [\alpha_t/(1-\alpha_t)](W_t/R_t^k) \tag{2.4}$$

$$MC_t = (\alpha_t)^{-\alpha_t}(1-\alpha_t)^{-(1-\alpha_t)}(W_t)^{(1-\alpha_t)}(R_t^k)^{\alpha_t} Z_t^{-(1-\alpha_t)} \tag{2.5}$$

It is worth pointing out that the fact that the capital-to-labor ratio is affected by the automation shock imposes a cross-equation restriction on the evolution of that shock that differs from the cross-equation restrictions that would be imposed on a stationary neutral technology shock, if such a shock were included, because the latter would not affect the above ratio – see, for example, the equilibrium conditions in Smets and Wouters (2007).

Each firm chooses price $P_t^\circ(i)$ with probability ζ_p in order to maximize the present discounted value of expected future profits subject to output demand (2.2). In periods in which the price cannot be optimally chosen, it is updated according to a convex combination of the one-period-lagged (gross) inflation and the steady-state (gross) inflation according to the indexation parameter ι_p; thus, the period-$(t+s)$ price of a firm that last chose its price in period t is given by $P_{t+s|t}(i) = P_t^\circ(i) X_{t,s}^p$, where $X_{t,s}^p \equiv \prod_{l=1}^{s} \Pi_{t+l-1}^{\iota_p} \Pi^{1-\iota_p}$ for $s > 0$ and $= 1$ for $s = 0$. The present discounted value of current and future profits is given by

$$E_t \sum_{s=0}^{+\infty} (\zeta_p)^s \left[(\Xi_{t+s} P_t)/(\Xi_t P_{t+s})\right] \left[P_{t+s|t}(i) - MC_{t+s}\right] Y_{t+s|t}(i) \tag{2.6}$$

2.1.3 Investment.

A representative firm purchases Y_t^I units of the final good, and converts them to I_t units of the investment good according to: $I_t = \Omega_t Y_t^I$. Ω_t is the investment-specific technological factor (IST) and aims at capturing shifts in the price of investment goods over the price of consumption goods. Its non-stationary evolution is described by: $ln(\Omega_t/\Omega_{t-1}) = \gamma_\omega + \widehat{\upsilon}_t^\omega$, where $\widehat{\upsilon}_t^\omega$ follows an AR(1) process with associated parameters $\{\rho_\omega, \sigma_\omega\}$. The growth rate of the economy along the balanced growth path, therefore, is given by $\gamma = \gamma_z + \frac{\alpha}{1-\alpha}\gamma_\omega$. The investment good is sold to a capital producing firm at price P_t^I. Profit maximization leads to an equalization of marginal benefit to marginal cost:

$$P_t^I / P_t = 1/\Omega_t \tag{2.7}$$

2.1.4 Capital Production.

Capital production is delinked from the household problem[4]. A representative capital producing firm invests (I_t) in raw capital $(\bar{K}_t)$ subject to adjustment costs $S(I_t/I_{t-1})$. It chooses the utilization rate u_t that determines the effective capital, $K_t \equiv u_t \bar{K}_{t-1}$, subject to utilization costs that are proportional to the last period's raw capital $(a(u_t)\bar{K}_{t-1}/\Omega_t{}^5)$. Capital is sold to intermediate good producers at the nominal rental rate R_t^k. The firm maximizes the present discounted value of future dividends,

[4] With identical agents, centralized and decentralized capital production yield the same dynamics.
[5] Scaling these costs with Ω_t ensures the existence of a balanced growth path.

$$E_t \sum_{s=0}^{\infty} [(\Xi_{t+s} P_t)/(\Xi_t P_{t+s})] \left[R^k_{t+s} K_{t+s} - \frac{P_{t+s} a(u_{t+s}) \bar{K}_{t+s-1}}{\Omega_{t+s}} - P^I_{t+s} I_{t+s} - A_{t+s} P_{t+s} \Phi_k \right] \tag{2.8}$$

subject to the law of capital accumulation,

$$\bar{K}_t = (1-\delta)\bar{K}_{t-1} + \upsilon^i_t \left(1 - S(I_t/I_{t-1})\right) I_t \tag{2.9}$$

υ^i_t is the marginal efficiency of investment (MEI) shock affecting the transformation of investment goods to capital. $ln(\upsilon^i_t)$ follows an AR(1) process with associated parameters $\{\rho_i, \sigma_i\}$.

Investment in units of the consumption good is pinned down by $\widetilde{I}_t = (P^I_t/P_t)I_t$. 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 for utilization and investment are defined so that $a(1)''/a(1)' = \psi/(1-\psi)$, $S(\cdot) = S(\cdot)' = 0$, and $S(\cdot)'' \equiv S > 0$. δ is the depreciation rate. Fixed costs (Φ_k) ensure zero steady state dividends. Ξ_{t+s}/Ξ_t is the discount factor.

2.1.5 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

$$L_t = \left(\int L_t(j)^{(\lambda_{w,t}-1)/\lambda_{w,t}} dj \right)^{\lambda_{w,t}/(\lambda_{w,t}-1)} , \quad \forall j \in [0,1] \tag{2.10}$$

where $\lambda_{w,t}$ is the time varying elasticity of substitution across labor varieties, with the gross wage markup, $\lambda_{w,t}/(\lambda_{w,t}-1)$, following an AR(1) process with parameters $\{\rho_w, \sigma_w\}$. Profit maximization yields the following labor demand for each j type and the aggregate wage

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\lambda_{w,t}} L_t \ , \ \forall j \in [0,1] \quad \text{and} \quad W_t = \left(\int W_t(j)^{1-\lambda_{w,t}} dj\right)^{1/(1-\lambda_{w,t})} \tag{2.11}$$

Each labor union takes into account labor demand (2.11), and chooses wage $W_t^{\circ}(j)$, in a staggered way à la Calvo-Yun and Erceg et al. (2000), in order to maximize the expected present discounted value of future wages net of the economy wide type-j labor disutility expressed in terms of the final good, $W_t^h(j)$. In periods in which the wage is not reset, it is updated according to the weighted product of one-period-lagged and steady-state price inflation rates, with the weight being given by the indexation parameter ι_w: $W_{t+s|t}(j) = W_t^{\circ}(j) X_{t,s}^w$, where $X_{t,s}^w = \prod_{l=1}^{s}(e^{\gamma+\widehat{z}_{t+l-1}+(\alpha_{t+l-1}/[1-\alpha_{t+l-1}])\widehat{v}^{\omega}_{t+l-1}}\Pi_{t+l-1})^{\iota_w}(e^{\gamma}\Pi)^{1-\iota_w}$ for $s>0$ and $=1$ for $s=0$. The union's objective function is:

$$E_t \sum_{s=0}^{+\infty} (\zeta_w)^s \left[(\Xi_{t+s}P_t)/(\Xi_t P_{t+s})\right] \left[W_{t+s|t}(j) - W_{t+s}^h(j)P_{t+s}\right] L_{t+s}(j) \tag{2.12}$$

2.1.6 Demand Side.

The household chooses an infinite sequence of consumption and bonds $\{C_t, B_t\}$, to maximize the present discounted value of future expected utility:

$$E_t \sum_{s=0}^{+\infty} \beta^s \left[ln\left(C_{t+s} - \eta C_{t+s-1}\right) - \theta \int_0^1 \frac{L_{t+s}(j)^{1+\chi}}{1+\chi} dj\right] \tag{2.13}$$

Preferences are log-separable, and depend on the deviation of consumption from last period's average consumption and on labor disutility across all j types. η mirrors external habit formation, and χ is the inverse Frisch elasticity. The budget constraint is given by

$$C_t - B_t/(\upsilon_t^b R_t P_t) + T_t/P_t = \int_0^1 W_t^h(j)L_t(j)dj + F_t - B_{t-1}/(P_{t-1}\Pi_t) + V_t \tag{2.14}$$

$ln(\upsilon_t^b)$ is a risk premium shock following an AR(1) process with parameters $\{\rho_b, \sigma_b\}$. Π_t and T_t stand for (gross) price inflation and taxes, respectively. V_t denotes economy wide profits. $W_t^h(j)$ is the type-j real wage that would prevail in the absence of rigidities, and which would be equal to the marginal labor disutility in consumption terms: $\theta L_t(j)^\chi/\Xi_t$. F_t stands for transfers made by the unions ensuring an equitable wage distribution.

2.1.7 Policy.

Monetary policy may be restricted by the zero lower bound in turbulent times. The observed interest rate (r_t^o) is set according to

$$r_t^o = \max\{0, r + ln(R_t/R)\} \tag{2.15}$$

where the interest rate during normal times is determined by a conventional policy rule,

$$R_t/R = (R_{t-1}/R)^{\rho_r}\left[(\Pi_t/\Pi)^{\psi_\pi}\left(Y_t/Y_t^f\right)^{\psi_y}\left((Y_t/Y_{t-1})/(Y_t^f/Y_{t-1}^f)\right)^{\psi_{\Delta y}}\right]^{1-\rho_r} e^{\epsilon_t^{mp}} \tag{2.16}$$

where $R = 1 + r$; $\rho_r \in (0, 1)$ captures interest rate smoothing; $\psi_\pi > 1$, $\psi_y, \psi_{\Delta y} \geq 0$; and

$\epsilon_t^{mp} \sim N(0, \sigma_{mp}^2)$ is a white noise disturbance. Fiscal policy follows a balanced budget, with spending given by $ln(G_t/A_t/G) = \rho_g ln(G_{t-1}/A_{t-1}/G) + \rho_{gz}\epsilon_t^z + \epsilon_t^g$, with $\epsilon_t^g \sim N(0, \sigma_g^2)$. Y_t^f denotes output under flexible prices and wages. Automation shocks shift that equilibrium.

2.1.8 Aggregation.

Aggregating (2.3) and (2.4) across firms yields the aggregate production function: $Y_t = K_t^{\alpha_t}(Z_t L_t)^{1-\alpha_t} - A_t\Phi_y$. Intermediate good profits and dividends read as: $\Pi_t^{int} \equiv P_t Y_t - W_t L_t - R_t^k K_t$, $Div_t \equiv R_t^k K_t - P_t a(u_t)\bar{K}_{t-1}/\Omega_t - P_t\widetilde{I}_t - P_t A_t \Phi_k$. Thus, the economy wide profits distributed to households are: $V_t = \Pi_t^{int} + Div_t$. Combining the constraint (2.14), the government's balanced budget, and profits, yields the resource constraint:

$$C_t + \widetilde{I}_t + G_t + a(u_t)\bar{K}_{t-1}/\Omega_t + \Phi_k A_t = Y_t \tag{2.17}$$

2.1.9 Equilibrium.

The variables are rendered stationary after normalizing them by the composite technology. The log-linearized equilibrium is reported in Appendix.

The model features 9 structural shocks. Eight of them appear in Justiniano et al. (2011): risk premium, technology, wage and price markup, spending, IST, MEI, and monetary policy shocks. An automation shock is the additional disturbance.

observables to their model analogue $(\widehat{ls}_t)$ Matching data for the labor income share is viable because the wage is a latent state – had we used a single measure for wages the right-hand-side of (**??**) and, in turn, the labor income share would uniquely be pinned down rendering impossible to match data series for the latter. In this approach, the evolution of the observed labor income share influences the wage component that is extracted from the two wage series. In other words, the observed labor share series provide discipline to the whole model – a discipline that incarnates the idea of *jointly* examining the U.S. aggregate and labor income share series. It is in a similar spirit to the motivation of Justiniano et al. (2011) about using the relative price of investment goods to provide discipline in the estimation.

2.1.10 State Space and Likelihood.

I stack all the measurement equations vertically, and obtain the following matrix equation:

$$\Upsilon_t = \Gamma_q + H_0\zeta_t + H_1\zeta_{t-1} + M_t \quad , \quad M_t \sim N(0, \Sigma_q) \tag{2.18}$$

where Υ_t and Γ_q are $(o_q \times 1)$ vectors of observables and intercepts, respectively. $\{H_0, H_1\}$ denote the $(o_q \times n_\zeta)$ selection matrices and include the slope coefficients of the measurement equations. ζ_t is the period-t $(n_\zeta \times 1)$ state vector. M_t collects the measurement errors. Σ_q is the diagonal covariance matrix of measurement errors. Stacking (2.18) over time yields:

$$\begin{bmatrix} \Upsilon_{t=1} \\ \Upsilon_{t=2} \\ \Upsilon_{t=3} \\ \vdots \end{bmatrix} = \begin{bmatrix} \Gamma_q \\ \Gamma_q \\ \Gamma_q \\ \vdots \end{bmatrix} + \begin{bmatrix} H_0 & \dots & \dots & \dots \\ H_1 & H_0 & \dots & \dots \\ \dots & H_1 & H_0 & \dots \\ \dots & \ddots & \ddots & \ddots \end{bmatrix} \begin{bmatrix} \zeta_{t=1} \\ \zeta_{t=2} \\ \zeta_{t=3} \\ \vdots \end{bmatrix} + \begin{bmatrix} M_{t=1} \\ M_{t=2} \\ M_{t=3} \\ \vdots \end{bmatrix} \tag{2.19}$$

The matrix representation of (2.19) is given by

$$\Upsilon = \Gamma + H\zeta + M \quad , \quad M \sim N\left(0_o, \Sigma_M \equiv I_{n_q} \otimes \Sigma_q\right) \tag{2.20}$$

where 0_o is $(o_q n_q) \times 1$. $\Upsilon \equiv [\Upsilon'_{t=1}, \Upsilon'_{t=2}, \ldots]'$ is the observation vector. $\Gamma \equiv [\Gamma'_q, \Gamma'_q, \ldots]'$ is a vector of intercepts. $\zeta \equiv [\zeta'_1, \zeta'_2, \ldots]'$ is the $(n_\zeta n_q) \times 1$ state vector. $M \equiv [M'_{t=1}, M'_{t=2}, \ldots]'$ collects the measurement errors. H is a sparse and block-banded matrix. According to (3.31), the likelihood of the data given the parameter vector Θ and the states ζ is $P(\Upsilon - \Gamma|\Theta, \zeta)$, where $(\Upsilon - \Gamma)|\Theta, \zeta \ \sim \ N(H\zeta, \Sigma_M)$.

The log-linearized equilibrium conditions of the model are casted in the form

$$\Gamma_{2,\tau}(\Theta)E_t\zeta_{t+1} + \Gamma_{0,\tau}(\Theta)\zeta_t = \Gamma_{1,\tau}(\Theta)\zeta_{t-1} + \Psi_\tau(\Theta)\epsilon_t \tag{2.21}$$

The system matrices $\{\Gamma_{0,\tau}, \Gamma_{1,\tau}, \Gamma_{2,\tau}, \Psi_\tau\}$ are functions of the parameter vector Θ, and depend on the underlying economic regime $\tau \in \{n, zlb\}$. The two regimes differ in the specification of the policy rule: $\tau = n$ denotes normal times where monetary policy is not constrained, and $\tau = zlb$ denotes times with a binding zero lower bound on the policy rate. The structural shocks are grouped in the $(n_\epsilon \times 1)$ vector $\epsilon_t \sim N(0_{n_\epsilon}, I_{n_\epsilon})$, and are fewer than the number of observables $(n_\epsilon < o_q)$. The solution of the system can be represented as

$$\zeta_t = \Phi_{1,t}(\Theta)\zeta_{t-1} + \Phi_{2,t}(\Theta)\epsilon_t \tag{2.22}$$

where the system matrices $\{\Phi_{1,t}, \Phi_{2,t}\}$ are potentially time-varying and their dependence on Θ is suppressed in terms of the notation in the following sections.

Estimation in Normal Times.

During normal times, $\{\Phi_{1,t}, \Phi_{2,t}\}$ are time-invariant and obtained from the rational expectations solution of Sims (2002). The estimation proceeds in the following way. ζ_1 is initialized at the observed data for observed variables and at zero otherwise, with a covariance D being the steady state covariance of the state vector evaluated at the prior mean of Θ. Defining the reduced-form errors, $\tilde{\epsilon}_t = \Phi_2 \epsilon_t$ for $t > 1$ and $\tilde{\epsilon}_1 = \epsilon_1$, and stacking (3.26) across time yields:

$$\begin{bmatrix} I_{n_\zeta} & \dots & \dots & \dots \\ -\Phi_1 & I_{n_\zeta} & \dots & \dots \\ \dots & \ddots & \ddots & \dots \\ \dots & \dots & -\Phi_1 & I_{n_\zeta} \end{bmatrix} \begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \vdots \\ \zeta_T \end{bmatrix} = \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix}, \quad \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix} \sim N\left(0_{n_\zeta n_q}, \begin{bmatrix} D & \dots \\ \vdots & \Phi \otimes I_{T-1} \end{bmatrix}\right) \tag{2.23}$$

where $\Phi \equiv \Phi_2 \Phi_2'$. In matrix notation, the above equation reads as

$$Z\zeta = \tilde{\epsilon} \quad , \quad \tilde{\epsilon} \sim N(0_{n_\zeta n_q}, K_{\tilde{\epsilon}}^{-1}) \tag{2.24}$$

where $\tilde{\epsilon} \equiv [\tilde{\epsilon}_1', \tilde{\epsilon}_2' \dots]'$ is the $(n_\zeta n_q) \times 1$ vector of errors, and $K_{\tilde{\epsilon}}$ is the sparse and block-banded precision of the latter. A change of variable transformation yields the prior state distribution, $P(\zeta|\Theta)$, with $\zeta|\Theta \sim N(\zeta_0, K^{-1})$ and $\zeta_0 = 0_{n_\zeta n_q}$. The precision $K = Z' K_{\tilde{\epsilon}} Z$ is also 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 $(\widehat{\zeta})$ is computed based on the efficient simulation of Chan and Jeliazkov who use forward and backward substitution in (3.32) exploiting the nature of P:

$$P\widehat{\zeta} = K\zeta_0 + H'\Sigma_M^{-1}(\Upsilon - \Gamma) \tag{2.25}$$

The integrated log-likelihood (the likelihood of the data 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 states: $lnP(\Upsilon|\Theta) = lnP(\Upsilon|\Theta, \widehat{\zeta}) + lnP(\widehat{\zeta}|\Theta) - lnP(\widehat{\zeta}|\Upsilon, \Theta)$, where all terms are computed fast using the banded nature of the precisions.

Zero Lower Bound.

To study the post-2008 determinants of the labor share, I extract the shocks by simulating the model, evaluated at the posterior parameter mean and with the ZLB binding, on the 2009-2016 data. As shown in Hirose and Inoue (2016), although the shocks are sensitive to the incorporation of the ZLB, the parameter estimates become biased only with a lengthy zero interest rate duration. Given the large model dimension, I do not adopt a fully non-linear solution. Instead, I adopt the perfect foresight approach of Chen et al. (2012), examined in Del Negro et al. (2015) and Lindé et al. (2016). In a similar vein, Cagliarini and Kulish (2013) examine solutions with anticipated structural changes.

The rational expectations solutions is viewed as the absorbing state in 2016Q1 – the first interest rate hike took place in December 2015 – and onwards up to end of the sample in 2016Q4. The agents incorporate in their expectations the duration of the ZLB[6]. During the ZLB period, $\tau = zlb$, and $\{\Phi_{1,t}, \Phi_{2,t}\}$ in (3.26) are time-varying and pinned down by

[6] I take a shortcut. As in Del Negro et al. (2015), the agents are myopic and do not forecast changes in the duration of the ZLB. Contrary, though, to those authors who exogenously pin down the expected duration of the ZLB through overnight index swap rates, the duration is entirely exogenous in the present paper in order to speed up computations and given that the ZLB is not the main focus of the paper. Kulish et al. (2017) find variation in the expected duration of the ZLB.

$$\Phi_{1,t} = [\Gamma_{0,zlb} + \Gamma_{2,zlb}\Phi_{1,t+1}]^{-1}\Gamma_{1,zlb} \tag{2.26}$$

$$\Phi_{2,t} = [\Gamma_{0,zlb} + \Gamma_{2,zlb}\Phi_{1,t+1}]^{-1}\Psi_{zlb} \tag{2.27}$$

with Φ_{t+1} being the rational expectations solution in 2016Q1.

2.1.11 Sampler And Estimated Models.

The Random Walk Metropolis-Hastings algorithm is used to simulate draws from the non-tractable posterior[7]. To deepen the understanding, I estimate the model with and without labor share series and automation shocks.

2.1.12 Priors.

The priors are conventional and reported in Table (D.1)[8]. The persistence of automation shocks is drawn from a Beta distribution centered at 0.5 with a 0.2 standard deviation (std). The std of the associated innovations and measurement errors is drawn from the Inverse Gamma distribution centered at 0.15 (1 std). The loading factors (Ψ_w, Ψ_c) are sampled from a disperse Normal distribution around 1 (0.5 std).

[7]The covariance of the jumping distribution is initialized at the prior and updated every 100k draws.

[8] δ and g are set at the values chosen in Smets and Wouters (2007). β is fixed at 0.998. The std of measurement errors associated with series other than wages and the labor share are drawn from a tight Inverse Gamma centered at 0.01 (0.001 std).

2.2 Findings

The presentation of the findings starts with the parameter estimates. It then delves into the determinants of the labor share swings and their implications. The latter features the impact of automation shocks, and sheds light on the model behavior that is heavily influenced by the properties of the labor income share. Robustness checks are discussed at the end.

2.2.1 Posterior.

Table (D.1) collects the posterior parameter distribution[9] – the four blocks display, in order, the parameters associated with the micro foundations of the model, the stochastic structure, the labor market, and the automation shocks. Most parameters obtain about the same value in both model configurations, and are aligned with what is commonly found in the literature. Nonetheless, some shift away from their values in the model without the LS to capture the properties of the labor share swings.

Disturbances in production automation are persistent (0.9) and volatile (1.78). The loading factor Ψ_α differs from one and implies that the two LS series exhibit distinct features that the model disentangles. In fact, it is below one (0.55), suggesting that the model weighs the fluctuations in the non-farm business sector more than the fluctuations in the non-financial corporations. This finding is corroborated by the fact that the latter series is loaded with a higher measurement error (0.62) than the former series is (0.46).

Some parameters associated with the labor market change fundamentally across the two model configurations. Shifting from the model without the LS to that including the LS amplifies the endogenous mechanisms of persistence and, in particular, wage indexation from 0.07 to 0.76. As it is seen in later sections, this change play a pivotal role in the model

[9]The std of measurement errors for variables with a single observable series is relegated to the Appendix.

behavior. Contrary to the model without the LS, in the model with the observed LS, the loading factor for the compensation index exceeds 1 and implies that more weight is put on that index than on the survey-based earnings which are loaded with sizable measurement error. It is important to point out that although Ψ_w exceeds 1, it does so by a small margin (0.19). The latter suggests that although the model weighs the compensation index more than the earnings series, the earnings series still remains influential to the wage component that is extracted from the data (in the opposite case, the loading factor would obtain higher values). Furthermore, the persistence of wage markup shocks rises a tad from 0.98 to 0.99, and the volatility of those shocks almost doubles. Wage stickiness decreases a tad.

Two shifts in the stochastic structure are noteworthy. First, the persistence of MEI shocks decreases by about a half, from 0.91 to 0.48, despite a small increase in the volatility of those shocks from 7.35 to 8.21. These changes have implications for the explanatory power of MEI shocks that become apparent in the analysis that follows. Second, the parameters associated with pricing change a tad. The highly persistent price markup shock of the model without the LS, obtains a highly disperse distribution in the model with the LS. This result is in line with the literature: price markup shocks are highly persistent and not volatile when the relative price of investment in included in the model as in Justiniano et al. (2011), but become less persistent and more volatile in models featuring a factor approach to labor market observables as in Justiniano et al. (2013). The attenuated exogenous persistence of price dynamics in the model with the LS is compensated with increases in price indexation, as well as in the steady state inflation and price markup.

2.2.2 The Determinants of the Labor Share Swings.

In this section, I study the origins of the fluctuations in the U.S. labor income share.

Table 2.1: Posterior Distribution

		Prior	**Posterior** Mean [5-95%]	
			Without LS	**With LS**
capital share	α	N (0.30, 0.05)	0.17 [0.16, 0.18]	0.18 [0.17, 0.19]
habit	η	B (0.70, 0.10)	0.88 [0.83, 0.93]	0.83 [0.73, 0.90]
inv. Frisch elast.	χ	N (2.00, 1.00)	3.87 [2.77, 5.11]	3.91 [2.68, 5.16]
util. cost elast.	ψ	B (0.50, 0.10)	0.40 [0.27, 0.55]	0.47 [0.34, 0.61]
adj. cost elast.	S	N (4.00, 1.00)	5.18 [3.23, 6.96]	3.51 [1.78, 4.94]
price stickiness	ζ_p	B (0.60, 0.10)	0.73 [0.69, 0.78]	0.55 [0.48, 0.62]
price indexation	ι_p	B (0.50, 0.15)	0.13 [0.06, 0.22]	0.19 [0.08, 0.34]
MP resp. to int.rate	ρ_r	B (0.75, 0.10)	0.81 [0.77, 0.84]	0.82 [0.78, 0.85]
MP resp. to inflation	ψ_π	N (1.70, 0.25)	1.67 [1.39, 1.95]	1.91 [1.64, 2.18]
MP resp. to gap	ψ_y	N (0.12, 0.05)	0.04 [0.01, 0.07]	0.08 [0.04, 0.12]
MP resp. to growth	$\psi_{\Delta y}$	N (0.12, 0.05)	0.23 [0.15, 0.31]	0.23 [0.15, 0.31]
composite growth	γ	N (0.40, 0.03)	0.41 [0.37, 0.45]	0.41 [0.36, 0.45]
inv. price growth	γ_ω	N (0.30, 0.03)	0.30 [0.26, 0.35]	0.30 [0.26, 0.35]
inflation	π	N (0.62, 0.10)	0.65 [0.52, 0.81]	0.96 [0.82, 1.09]
st.st. wage markup	υ_w	N (0.50, 0.05)	0.50 [0.41, 0.58]	0.50 [0.42, 0.58]
st.st. price markup	υ_p	N (0.30, 0.05)	0.29 [0.22, 0.36]	0.41 [0.34, 0.48]
AR risk premium	ρ_b	B (0.50, 0.20)	0.62 [0.34, 0.84]	0.63 [0.36, 0.87]
std risk premium	σ_b	IG (0.15, 1.00)	0.09 [0.05, 0.15]	0.10 [0.05, 0.14]
AR MEI	ρ_i	B (0.50, 0.20)	0.91 [0.82, 0.99]	0.48 [0.22, 0.66]
std MEI	σ_i	IG (0.50, 1.00)	7.35 [5.62, 9.29]	8.21 [5.00, 11.11]
AR IST	ρ_ω	B (0.20, 0.10)	0.14 [0.06, 0.24]	0.14 [0.06, 0.22]
std IST	σ_ω	IG (0.50, 1.00)	0.74 [0.68, 0.81]	0.74 [0.68, 0.80]
AR technology	ρ_z	B (0.40, 0.20)	0.11 [0.03, 0.20]	0.23 [0.08, 0.37]
std technology	σ_z	IG (0.50, 1.00)	0.97 [0.88, 1.07]	0.72 [0.62, 0.82]
AR price markup	ρ_p	B (0.50, 0.20)	1.00 [1.00, 1.00]	0.52 [0.09, 0.98]
std price markup	σ_p	IG (0.15, 1.00)	0.13 [0.10, 0.17]	0.24 [0.18, 0.30]
std MP	σ_{mp}	IG (0.15, 1.00)	0.24 [0.22, 0.26]	0.25 [0.22, 0.27]
AR govt spending	ρ_g	B (0.50, 0.20)	0.98 [0.96, 0.99]	1.00 [0.99, 1.00]
std govt spending	σ_g	IG (0.15, 1.00)	0.28 [0.25, 0.30]	0.28 [0.26, 0.31]
tech. resp. to govt	ρ_{gz}	B (0.50, 0.20)	0.08 [0.04, 0.11]	0.09 [0.05, 0.13]
wage stickiness	ζ_w	B (0.60, 0.10)	0.72 [0.68, 0.76]	0.63 [0.52, 0.71]
wage indexation	ι_w	B (0.50, 0.15)	0.07 [0.04, 0.11]	0.76 [0.64, 0.87]
AR wage markup	ρ_w	B (0.50, 0.20)	0.98 [0.97, 0.99]	0.99 [0.97, 1.00]
std wage markup	σ_w	IG (0.15, 1.00)	0.04 [0.02, 0.05]	0.07 [0.03, 0.16]
factor for wages	Ψ_w	N (1.00, 0.50)	0.56 [0.43, 0.70]	1.19 [1.09, 1.29]
std m.e. earnings	μ_w^e	IG (0.15, 1.00)	0.32 [0.28, 0.37]	0.71 [0.65, 0.79]
std m.e. compensation	μ_w^c	IG (0.15, 1.00)	0.66 [0.60, 0.72]	0.25 [0.17, 0.33]
AR labor share	ρ_α	B (0.50, 0.20)	[,]	0.90 [0.81, 0.98]
std labor share	σ_α	IG (0.15, 1.00)	[,]	1.78 [1.50, 2.11]
factor for labor share	Ψ_α	N (1.00, 0.50)	[,]	0.55 [0.43, 0.66]
std m.e. non farm ls	μ_{ls}^{nf}	IG (0.15, 1.00)	[,]	0.46 [0.41, 0.51]
std m.e. corporate ls	μ_{ls}^c	IG (0.15, 1.00)	[,]	0.62 [0.57, 0.67]
Marginal Likelihood			-1484	-1863

Notes: "Without/With LS": without/with multiple labor income share observables.

Business Cycles.

The *last* column of Table (2.2) quantifies the autonomous effect of the model's disturbances on the fluctuations of the labor share by displaying its forecast error variance decomposition (FEVD) at different horizons (2 and 20 years ahead). Table (2.3) reports the same decomposition in the model without the LS.

The lion's share of the fluctuations in the labor share (ls_t) is attributed to automaton shocks (66%) in the short run. Their influence, however, decreases to 31% in the long run. The decrease stems from a weakening in the influence of automation shocks on output (from 29% to 9%), because their influence on the real wage (about a third) and labor remains largely unchanged across different horizons. In contrast, wage markup shocks, mirroring stochastic variations in workers' market power and, in turn, in labor market competitiveness, are the main determinant of long-run fluctuations in the LS (62%) despite their moderate short-run influence (19%). The long-run influence of wage markup shocks reflects their prominent role in economy wide fluctuations. Their prominence contradicts the findings in the model without the LS (Table 2.3) where MEI shocks are the most prominent force behind output fluctuations. The introduction of the LS observables, hence, attenuates the impact of MEI shocks and amplifies the impact of wage markup shocks. Put differently, the influence of MEI shocks on output is sensitive to observables associated with the labor market.

Demand side disturbances have a limited influence on the labor share at all horizons. A result that stands out in the model without the LS is that the LS fluctuations are entirely explained by supply side disturbances and, in particular, by the persistent price markup shocks. With the introduction of observables for the labor share, the explanatory power of price markup shocks falls drastically at all horizons, and that of wage markup shocks rises. Furthermore, the fact that MEI and IST disturbances, that are tightly linked to the evolution of the relative investment price, account for a negligible part of the labor income share (3/1%) suggests a limited interaction between the evolution of the relative investment price and the labor share that differs from the evidence of Karabarbounis and Neiman (2014).

Table 2.2: Business Cycles – with LS

	variable						
shock	y_t	i_t	π_t	r_t	L_t	w_t^r	ls_t
technology	2/0	1/1	9/5	4/3	1/1	32/21	5/2
price markup	1/0	1/0	20/12	7/4	1/0	17/10	5/2
wage markup	38/83	15/47	33/60	23/58	57/89	3/8	19/62
IST	1/0	1/1	0/0	0/1	0/0	8/9	0/0
supply side	43/84	17/50	62/77	35/65	60/90	60/48	29/66
risk premium	9/2	2/1	14/8	27/14	12/2	1/1	1/0
MEI	15/3	61/33	5/3	10/6	17/3	6/13	3/1
govt spending	2/1	0/0	0/0	0/0	3/2	0/0	1/1
policy	2/0	1/0	7/4	18/9	3/1	0/0	0/0
demand side	28/7	64/35	27/16	55/29	35/8	8/14	5/3
automation	29/9	19/15	11/6	11/6	5/1	32/38	66/31

Table 2.3: Business Cycles – without LS

	variable						
shock	y_t	i_t	π_t	r_t	L_t	w_t^r	ls_t
technology	2/1	0/0	8/6	6/3	2/1	8/1	6/0
price markup	21/42	6/15	33/33	16/14	17/26	87/96	90/98
wage markup	8/26	1/4	8/16	4/12	11/39	0/0	3/1
IST	0/0	0/0	0/0	0/0	0/0	1/0	0/0
supply side	32/69	8/19	50/55	27/29	30/66	96/96	98/100
risk premium	9/2	1/0	4/3	7/5	11/4	0/0	0/0
MEI	56/28	91/80	44/41	55/60	56/29	3/4	1/0
govt spending	1/0	0/0	0/0	0/0	1/1	0/0	0/0
policy	2/0	0/0	2/1	11/6	2/1	0/0	0/0
demand side	68/31	92/81	50/45	73/71	70/34	4/4	2/0

Notes: FEVD at the posterior mean 8/80 quarters ahead.

Historical Fluctuations and the Downward Trend.

Have the forces behind the evolution of the labor share varied over time? The structural perspective of the present paper allows to answer that question. Fig.(2.2) reveals an affirmative answer by displaying the historical decomposition of the fluctuations in the labor share across the model's innovations grouped in demand and supply side shocks – automation shocks are not included in any of those groups. The influence of automation shocks evolves in *waves*. During 1970-1985, automation shocks push the LS downwards. Their influence changes during 1985-2000, when they exert an upward effect on the LS. The post-2000 tumble of the LS, before and during the zero lower bound period, is largely shaped by the influence of automation shocks. This finding suggests that technical advances during that period largely favored capital over labor in the production process. The post-2000 profound influence of automation shocks on the LS decline is consistent with the evidence of Dao et al. (2017) and Abdih and Danninger (2017) on the influence of automation on the downward trend of the labor share.

Demand side shocks exert a small influence throughout the sample period, suggesting that the forces driving the labor share rest outside the demand side of the economy. Furthermore, during the 1970-1985 wave, supply side shocks balance out the influence of automation shocks and sustain the labor share relative stable. During 1985-2000, supply side shocks edge out automation shocks resulting in a gradually declining labor share. The decline is temporarily reversed around 2000 before the subsequent tumble of the LS. During the latter, supply side shocks are aligned with automation shocks.

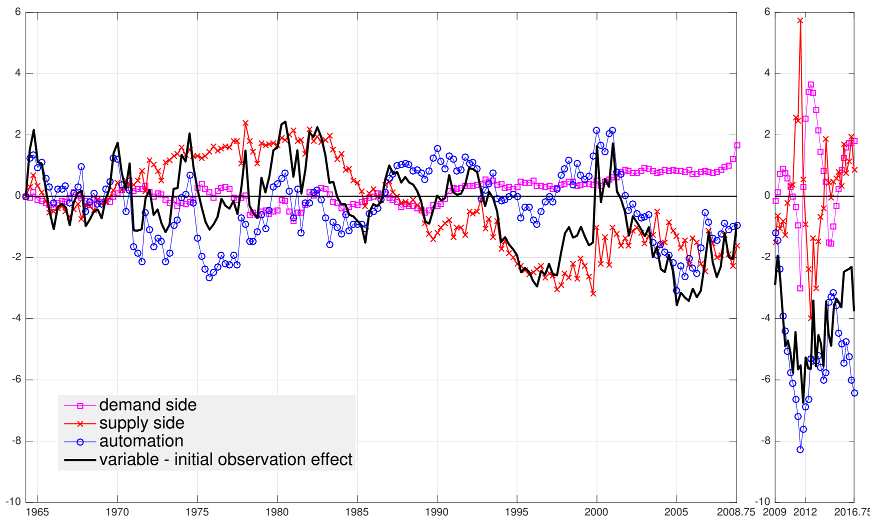
2.2.3 Implications.

I investigate the implications of incorporating the labor share swings in the observation set across several dimensions.

Economic Cycles.

As briefly mentioned in the above section, automation shocks influence business cycles. They explain 29% and 9% of output cycles in the short and long run, respectively, about a third

Figure 2.2: U.S. Labor Income Share



Notes: Historical Decomposition of the deviation of the smooth Labor Income Share from its steady state. 1964Q2–2008Q4: Posterior mean influence of structural shocks. 2009Q1-2016Q4 simulated influence of structural shocks at the posterior parameter mean. The categorization of shocks follows Table (2.2).

of real wage fluctuations, and about 20% of short-run investment. They exhibit a moderate influence (about 10%) on inflation and the interest rate. Although their influence on labor is small (5%), matching LS observables and allowing for automation shocks, decreases massively the influence of MEI shocks on labor – from 56/29 to 17/3 – in favor of wage markup shocks. Thus, labor is freed from being determined by investment demand innovations in favor of innovations associated with the labor market.

According to Table (2.2), there are three major shifts in the determinants of aggregate variables when matching the LS series. First, demand side shocks no longer are the main determinant of the business cycle; they explain 68/31 and 28/7 of output cycles in the model without and with LS series, respectively. Their attenuated role stems from a reduction in the influence of MEI shocks which, for example, falls from 56/28 to 15/3 in terms of ouput, and is mirrored in a moderate persistence parameter in Table (D.1). MEI shocks, however, retain a large influence on investment (61/33), which is intuitive since those shocks are investment demand shocks as argued in Moura (2018) as well. The fact that the MEI shock is the main driver of the business cycle in the model without the LS suggests that the findings of Justiniano et al. (2011) are robust to the inclusion of multiple wage indicators in the estimation. Nevertheless, the findings of the present paper demonstrate that when the wage extracted from multiple wage series is disciplined by the labor share data, the determinants of the business cycle change. With wages and the labor share sampled *jointly*, the influence of MEI shocks declines in an analogous way to that found in Kaihatsu and Kurozumi (2014) who study financial shocks in conjunction with MEI shocks and match financial data.

Second, the explanatory power of price markup shocks is attenuated for all variables, and reflected in their moderate persistence. Third, wage markup shocks obtain an elevated role associated with an increase in their persistence and volatility. Jointly sampling wages and the LS, therefore, attributes a pronounced role to wage markup disturbances – this role is in line with the evidence of Galí et al. (2012b, 2012a).

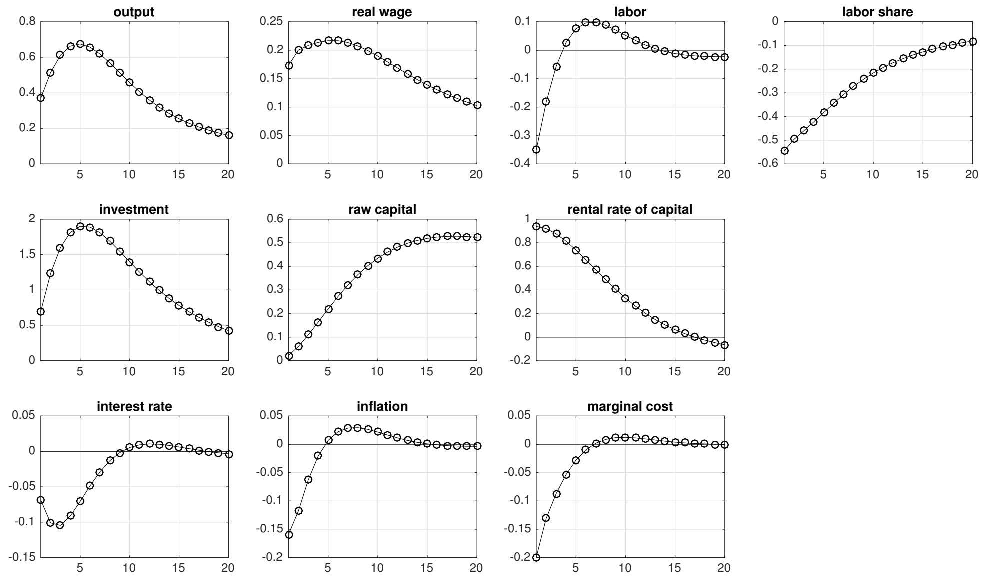
Automation Shocks.

How are, though, automation disturbances diffused in the economy? What are their economy wide effects? For example, automation shocks may lead to a production increase for a given capital-to-labor ratio or to a substitution of labor with capital for no change in production. I tackle those questions in Fig.(2.3). In response to automation shocks, output and capital increase, whereas marginal cost, labor, and the labor share decrease[10]. Therefore, automation shocks trigger both an output rise and a substitution of labor with capital. The labor share decreases since the wage increase associated with the economic stimulus is small and cannot compensate the combined effect of the employment decline and output expansion. The lowered marginal cost generates downward pressure to inflation and, in turn, to the interest rate through the monetary policy rule. The influence of automation disturbances persists

[10]These responses can be understood from eq. (2.3 –2.5) in the paper, the associated equations in the Appendix, and the fact that the steady state implies $k/L > 1$, where $k = K/(A\Omega)$.

for several quarters, and only gradually raises capital.

Figure 2.3: Automation Shocks



Notes: Impulse response functions evaluated at the posterior mean.

How are the automation disturbances disentangled from the other disturbances? Worth emphasizing is the fact that labor and inflation exhibit counter-cyclical responses. As a result of the labor counter-cyclicality, labor and capital move in opposite directions due to the substitution of the former with the latter. Over time, labor overshoots its steady state and demonstrates a pro-cyclicality – albeit a quantitatively small one compared to its drop on impact. A counter-cyclical response of labor hours cannot be generated by any other shock as it is seen in Fig.(2.6,2.7). This distinctive response, therefore, disentangles automation shocks from all other shocks. On top of that response, automation innovations are disentangled from demand side innovations on an additional ground, namely the inflation response. They trigger counter-cyclical inflation through their effect on production cost, which is at odds with the pro-cyclical inflation response after all demand side disturbances – see Fig.(2.6). Moreover, they differ from all supply disturbances but wage markup shocks in terms of their pro-cyclical wage response and their counter-cyclical LS response.

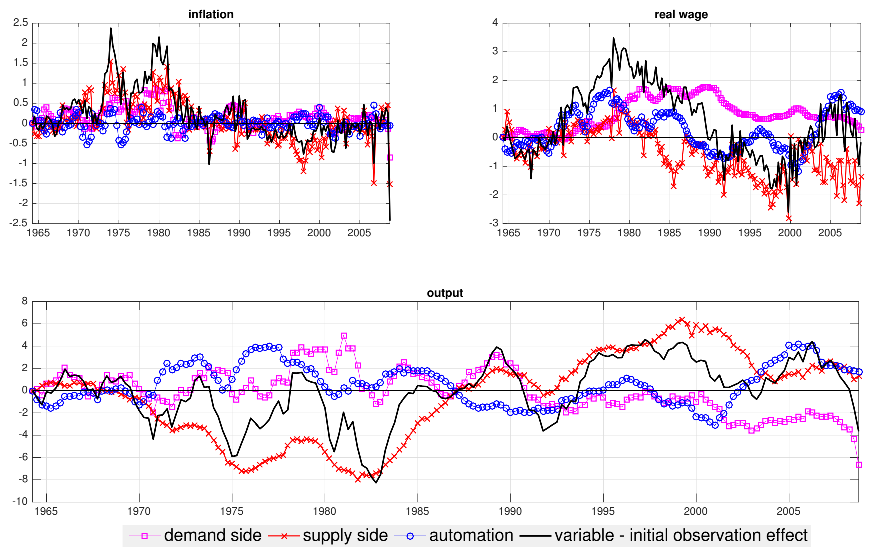
Furthermore, the equilibrium drop of labor shows that the model is not susceptible to the critique of Acemoglou and Restrepo (2018) according to which production automation generates a drop in labor demand that cannot be matched by models featuring various forms of capital-augmenting processes. It is important to add to the above that the fall in labor cannot be obtained by other exotic shocks affecting capital, namely utilization and depreciation shocks – Furlanetto and Seneca (2014) show that those shocks spur a pro-cyclical labor response in a New Keynesian DSGE model.

Fig.(2.4) gauges the autonomous effect of exogenous shifts in automation on the evolution of U.S. output, inflation, and the real wage. The figure suggests persistent waves of influence on output and the real wage, and a small impact on inflation. During 1970-1985, while they have a negative influence on the labor share, automation shocks boost output and the real wage. In contrast, during 1985-2000, while they favor labor and the labor income share, automation shifts have a negative effect on output and the real wage on average. During the post-2000 tumble of the labor income share, those disturbances trigger a rather steep upward effect on output and the real wage. The fact that those shocks do not strongly commove with either demand side or supply side shocks corroborates earlier evidence on the unique features of those shocks that disentangle them from other aggregate innovations.

The Cyclicality of the Labor Income Share.

Is the labor share pro-cyclical, counter-cyclical, or a-cyclical? RBC models using U.S. data over the 1970s-1990s found a counter-cyclical labor income share [Young, 2004; Boldrin and Horvath, 1995; Gomme and Greenwood, 1995]. In accordance with those papers, the findings of Table (2.4) suggest a counter-cyclical share in the 1964-2008 U.S. data; -0.5 and -0.3 are the correlations in the non-farm business sector and the non-financial corporations, respectively.

Figure 2.4: U.S. Output, Inflation, and the Real Wage



Notes: Historical decomposition of cyclical fluctuations in output, inflation, and the real wage. The posterior effect of innovations is displayed.

Table (2.4), in fact, reveals a weakness of the DSGE model estimated on multiple wage indicators but not multiple LS series: the model implies a pro-cyclical labor share (0.6) that is at odds with the data. The model-implied pro-cyclicality is associated with overstated comovements between the labor share and the real wage (1.0), as well as between the labor share and employment (0.4), compared to the moderate comevement between wages and the LS in the data (0/0.5 and -0.1/0.3 for the non-farm business sector and the non-financial corporations, respectively) and the weak comevement between labor and the LS in the data (-0.1). The present paper, therefore, demonstrates that including multiple wage indicators in the canonical NK DSGE model – an approach undertaken in several papers [Galí et al., 2012a; Justiniano et al., 2013; Lindé et al., 2016; Charalampidis, 2018] aiming to strengthen the identification of wage markup shocks – spurs model-implied comovements that are at odds with the data. It is important to clarify, though, that the pro-cyclical LS emerges only when the model is matched to multiple wages. It does not emerge in Smets and Wouters (2007) where the counter-cyclicality of the model-implied LS is -0.5 and replicates that in the data shown in Table (2.4) since only the compensation index is included therein.

In contrast, when the estimation features observables for the labor share, on top of multiple wage indicators, the model-implied cyclicality of the labor share is disciplined to follow that in the data. The evidence of Table (2.4) corroborates this argument by revealing a counter-cyclical LS (-0.6), a moderate comevement between the LS and the real wage (0.3), and a low comovement between the LS and employment. The comovement of the LS with either the nominal interest rate or inflation is aligned with that in the data in both models. Therefore, including information reflecting salient features of the labor share entails an improvement in the model performance in a similar spirit to Rios-Rull and Santaeulàlia-Llopis (2010). Fig.(2.5) displays the smooth swings of the extracted labor share in the model with and without observables for it. The figure confirms the existence of differences in their evolution. In the Appendix, I provide similar evidence pertaining to the extracted wage.

Table 2.4: Cyclical Properties of the Labor Income Share

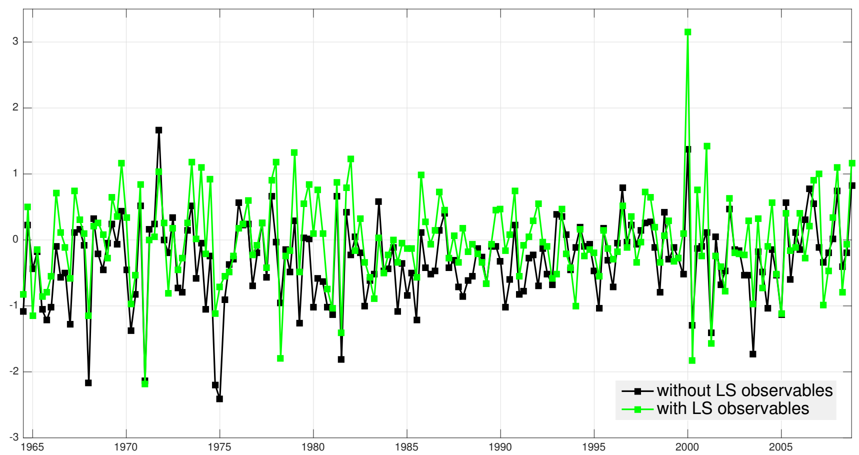
correlation	$\Delta ls_t, \Delta y_t$	$\Delta ls_t, \Delta w_t^r$	$\Delta ls_t, \Delta L_t$	$\Delta ls_t, \pi_t$	$\Delta ls_t, r_t$
model					
without LS	0.6	1.0	0.4	-0.2	-0.1
with LS	-0.5	0.3	0.0	0.0	0.1
data					
non farm LS	-0.5	-0.0/0.5*	-0.1	-0.0	0.1
non fin. corp. LS	-0.3	-0.1/0.3*	-0.1	-0.0	0.1

Notes. Model correlations are computed at the posterior mean of smooth states. *with earnings/compensation series.

Explaining the Changes in Aggregate Shocks.

Why do demand side and price markup shocks lose influence while wage markup shocks gain influence when LS series are matched? Although demand side and, in particular, MEI shocks trigger a counter-cyclical LS response (fig.2.6), the response is of a moderate magnitude compared to that triggered by wage markup and automation shocks. Furthermore, that response rests on the elevated wage indexation (0.76, Table D.1) in the model with the LS compared to the model without the LS observables (0.07, Table D.1). Due to index-

Figure 2.5: Labor Income Share Swings



Notes: The figure displays the (posterior mean of the smooth) swings in the labor share in the model with and without labor income share observables.

ation, wage inflation remains tightly linked to inflation and less responsive to the general equilibrium effects of disturbances taking place outside of the labor market. As a result of the tightly linked wages to inflation, the response of the real wage is attenuated (fig.2.6,2.7) and the labor share is counter-cyclical despite the pro-cyclical response of labor and the real wage to demand side shocks. This attenuated wage response explains the low comovement between the labor share and real wages (0.3) in Table (2.2) which differs from their high comevement (1.0) in the model without the LS series. This evidence suggests that the wage response plays a catalytic role in shaping the response of the labor share.

Price markup shocks lose influence because they spur a pro-cyclical response in the labor share, displayed in Fig.2.7, which is at odds with the counter-cyclical LS in the data. In contrast, wage markup shocks generate a counter-cyclical LS response (fig.2.7) that is aligned with the data and, hence, favored by the model. Therefore, exogenous shifts in the demand side are attenuated in favor of shifts in labor market in the model with the LS.

Figure 2.6: Demand Side Disturbances

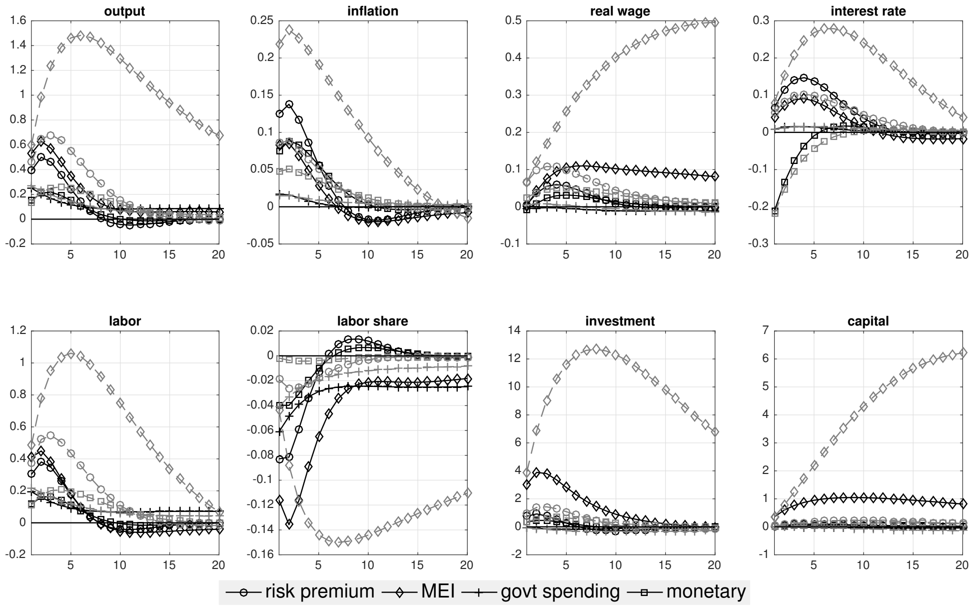
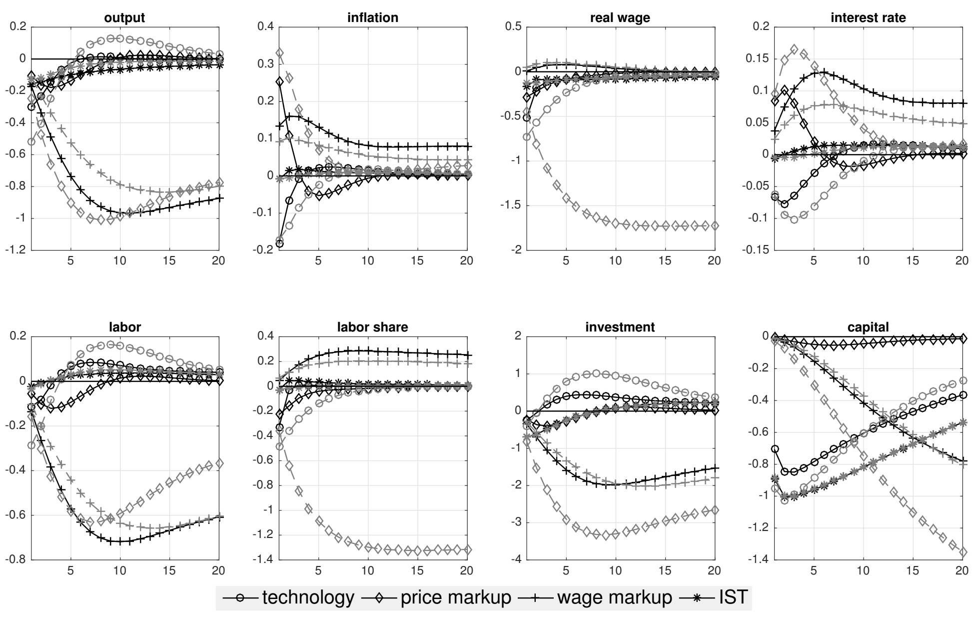


Figure 2.7: Supply Side Disturbances



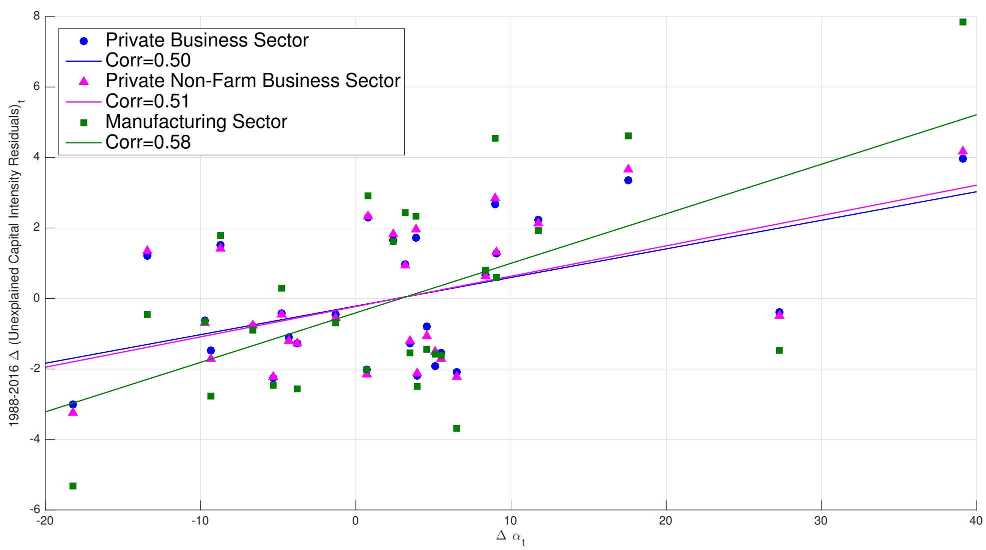
Notes: IRFs evaluated at the posterior mean. Black/Grey: model with/without labor share observables.

2.2.4 Robustness Checks.

Despite that the prior specification is in line with what is commonly considered in the literature, I investigate the robustness of the results to it. The forecast error variance decomposition at the prior mean shows a substantially smaller influence of automation shocks than that obtained at the paper; these shocks account for about 1% of economy wide fluctuations and 10% of the LS swings; see Appendix. These results suggest that the prior is not dogmatic. Although the long-run influence of automation shocks on the LS at the prior is close to that obtained at the posterior mean, there are considerable differences in the influence of the other shocks. In particular, computations at the prior mean weigh price markup and technology shocks considerably more than wage markup shocks compared to the weighting associated with the computations at the posterior mean. In addition, computations at the prior mean suggest zero influence of demand side shocks on the LS which differs from the 5/3% influence at the posterior mean shown in Table (2.2).

Moreover, I undertake some steps towards an external validation of the model-implied automation shocks. In particular, I examine whether these shocks exhibit an association with measures of capital intensity which can be viewed as proxies of the degree of routinization of production. Although using proxies is not fully satisfactory due to the fact that they may be influenced by several factors and due to their availability in an annual frequency since 1988, they provide a viable way to examine the properties of automation shocks because the empirical papers studying automation that were mentioned in the introduction use survey data at various years which, however, are not consecutive and not enough to run time series regressions. I use the (growth rate of) the capital intensity index in the private and non-farm business sectors, as well as in manufacturing, compiled by the BLS. Following Milani (2017) who uses the same identification approach on expectational shocks, I obtain the unexplained part of the capital intensity indices from their regression on output, inflation, and the interest rate, and examine its association with the model-implied automation shocks (α_t). I conduct the analysis during 1989-2016 to exploit the largest possible time span – the results for the 1989-2008 window are relegated to the Appendix. Fig.(2.8) shows that the model-implied automation shocks commove with the unexplained part of the capital intensity indices (about 0.5 correlation)[11]. This result implies that the automation shocks are connected to capital intensity and, in turn, to the degree of automation in the private sector.

Figure 2.8: Capital Intensity and Automation Shocks, 1988-2016



Notes: Author's computations. *Data Sources:* Bureau of Labor Statistics.

In addition, I consider the case in which shifts in the relative price of investment spur shifts in production automation. To this end, I re-estimate the model by including correlated disturbances and, more specifically, the following specification for automation shocks

$$\widehat{\alpha}_t = \rho_\alpha \widehat{\alpha}_{t-1} + \nu_\omega \widehat{\upsilon}^{\omega}_{t-1} + \sigma_\alpha \epsilon^{\alpha}_t \tag{2.28}$$

where a Beta prior centered around 0.5 (0.2 std) is assigned to ν_ω. The data do not favor the above specification – the posterior mean of ν_ω is 0.12.

[11]During the 1989-2008 window the comovement is weaker (about 0.2); see the Appendix.

2.3 Concluding Remarks

The present paper is the first that brings series for the labor income share into the workhorse medium-scale NK DSGE model through a latent factor approach, and examines their drivers and their implications, while extracting automation shocks that capture exogenous shifts in routine-biased technology from a macroeconomic perspective. The paper shows that wage markup shocks and automation shocks account for the lion's share of fluctuations in the labor income share, whereas disturbances associated with the investment side of the economy, such as shocks to the marginal efficiency of investment and investment-specific technology shocks, have limited influence. Automation shocks, in particular, play a large role during the post-2000 tumble of the labor share, generate a distinctive counter-cyclical response in labor that cannot be matched by any other disturbance, and explain 29/9% of output fluctuations in the short/long run. In order to match the counter-cyclical evolution of the labor share, the model attenuates the influence of MEI shocks in favor of wage markup and automation shocks, and yields a high degree of wage indexation that renders the real wage less affected by general equilibrium effects generated by disturbances outside of the labor market.

This paper sets the stage for future explorations across different dimensions. First, the labor income share can be used to inform the underlying mechanisms in papers featuring heterogeneous agents, such as workers and capitalists, as well as high- and low-skill workers. Second, shifting away from the Cobb-Douglas production function to alternative specifications such a CES [Cantore et al., 2015; Di Pace and Villa, 2016] or task-based approaches [Acemoglou and Restrepo, 2018, 2017a, 2017b], albeit challenging, can potentially illustrate further the role of automation. Third, enriching the observation set with additional indicators capturing automation may deepen the understanding of its macroeconomic effects.

Chapter 3

On Unemployment And Wage Cycles: Euro Area, 1999–2016

3.1 Introduction

The financial collapse that plunged the Euro Area into the Great Recession led to a turmoil that unveiled fundamental problems in labor, goods, and financial markets. It resulted in an output trough and an unemployment spike in the whole Euro Area and, especially, in the southern periphery from about 6-9% in 2008 to about 12% in Italy, 17% in Portugal, and more than 25% in Spain and Greece in 2013. Despite these sizable swings, still little is known about the cyclical drivers of unemployment in those economies.

This lack of evidence on the sources of unemployment fluctuations in those economies is at odds with the accumulating evidence pertaining to unemployment in U.S. [Galí et al., 2012a, 2012b; Canova et al., 2013; Casares et al., 2014; Furlanetto and Groshenny, 2016]. Even analyses investigating various dimensions of the Great Recession in the southern periphery [Eggertsson et al., 2014; in 't Veld et al., 2014; Gourinchas et al., 2016; Kollmann et al., 2016;

Albonico et al., 2016] abstract from unemployment, and ultimately preclude understanding the factors that shaped its spike during that tumultuous period. This abstraction relates to the fact that models tailored to explain business cycles in small open economies [Justiniano and Preston, 2010; Adolfson et al., 2005, 2007] do not feature unemployment. Christiano et al. (2011) is an exception that incorporates labor search in a model for Sweden. Shedding light on the drivers of unemployment, though, can inform policy making since growing unemployment raises the pressure for a policy reaction [Draghi, 2014], labor market conditions influence policy decisions [Gerlach and Stuart, 2016] and price dynamics [Rudebusch and Williams, 2016], and monetary policy can have desirable stabilization properties depending on the origins of unemployment cycles [Galí, 2011].

The present paper fills the above void by shedding light on the recurrent sources of unemployment cycles in the Euro Area and the southern economies (Greece, Italy, Portugal, Spain) during 1999Q1–2016Q4. It does so through the lens of an estimated structural model and by extracting information from a plethora of wage indicators. I elaborate on those features below.

Unemployment in the model stems from a wage markup above the competitive market-clearing wage. This perspective on unemployment is relevant for the southern economies where labor markets are notoriously rigid and involve staggered wage setting. The approach is along the lines of Gali (2011) who introduces the extensive margin of labor supply and heterogeneous labor disutility across workers in Erceg et al. (2000). In a similar vein, Casares (2010) studies labor supply and demand mismatches due to wage stickiness. A closed-economy model similar to that of Galí et al. (2012b) is considered for the Euro Area. To model business cycle in the southern economies, unemployment is introduced in the small open economy model of Justiniano and Preston (2010), which is the limit of Galí and Monacelli (2005) as shown in De Paoli (2009), featuring fixed exchange rates, union wide monetary policy, imperfect insurance across economies, and nominal rigidities.

The time-varying wage markup triggering unemployment entails an endogenous component that responds to economy wide conditions, as well as an exogenous component defined as the wage markup disturbance. The disturbance, modeled as exogenous shifts in the elasticity of substitution across labor types, generates movements in workers' market power which, in turn, mirror changes in labor market competitiveness. Following the approach of Galí et al. (2012b, 2012a) in addressing the critique of Chari et al. (2009), I identify those disturbances and disentangle them from labor disutility shocks capturing developments in labor supply, by postulating an autoregressive structure for both, and by using the unemployment rate and multiple wage indicators as observables. Three wage measures based on administrative data and a survey-based measure are used in the estimation. Justiniano et al. (2013) use two wage indicators, but postulate white noise wage markup shocks.

The first set of results involves four observations. First, consistently with the U.S. evidence of Galí et al. (2012b), persistent shifts in labor market competitiveness, with a volatility that is smaller than that of the other disturbances, constitute the main source of *long-run* unemployment cycles: they explain 80–97% and 65% of those cycles in the periphery and the Euro Area, respectively. Second, the *short-run* impact of those shifts depends on the comovement – captured by the correlation – between the latent wage series and unemployment: the higher that comovement is, the lower the impact and volatility of wage markup shocks are. Thus, in Greece and Italy, that are characterized by low comovement, shifts of moderate volatility in labor market competitiveness play the dominant role in the short-run unemployment cycles by explaining 72% and 88% of them, respectively. Conversely, in the Euro Area, Spain, and Portugal, that are characterized by high comovement, the influence of low-volatility shifts in labor market competitiveness is attenuated and accounts for a moderate share of unemployment cycles. In particular, the combination of demand and supply side shocks is about equal to the contribution of wage markup shocks in Portugal (25% + 20% vs 42%) and Spain (18% + 17% vs 49%), and even exceeds it in the Euro Area (50% + 26% vs 24%). Third, the importance of labor market innovations (wage markup and labor disutility shocks) is larger in the periphery than in the Euro Area for *short-run* unemployment (54-90% vs 25%), as well as for nominal wage inflation (53-85% vs 13%) and price inflation (22-53% vs 7%). In fact, in the Euro Area, demand side shocks exert a sizable influence on those variables. Fourth, unemployment cycles in the periphery are entirely ignited by domestic rather than euro-area disturbances.

After having examined the determinants of unemployment over the whole sample, the present paper zooms in the episode of the Great Recession, and pins down the factors – the mix of demand, supply, and labor market disturbances – that shaped the unemployment spike, in a similar spirit to Ireland (2011) and Galí et al. (2012a). It shows that, in the Euro Area, the two unemployment humps, as well as the output troughs, during the two phases of the recession – the onset (2008-11) and the sovereign debt crisis (2011-14) – are largely attributed to two factors: an exogenous contraction in demand, and an adversarial shift in wage markups. The sizable influence of wage markup shocks emerges only during the recession. In contrast, in the pre-2008 period, demand side disturbances account for unemployment cycles. Although wage markup shocks negatively affect unemployment and output, they slow down the fall in wages and prices stemming from the demand contraction.

In the southern economies, adversarial shifts in labor market competitiveness contribute to the unemployment spike to a larger extent than they do in the Euro Area. In fact, they are the main determinant of unemployment during the Great Recession. The large influence of wage markup shocks during that tumultuous period is associated with a drastic weakening of the unemployment–wage comovement. As for the contribution of the other disturbances, during the first phase of the recession, unemployment rises due to different causes across countries, likely reflecting asynchronous business cycles: due to negative demand side shocks in Spain and Italy, and due to supply side shocks in Greece and Portugal. During the second phase, a demand-side contraction that encapsulates the sovereign debt crisis, as well as an abrupt decrease in labor disutility that raises the labor force, increase unemployment.

Euro-area shocks have a persistently adversarial, albeit small in magnitude, contribution throughout the two phases.

Turning to wage cycles, the present paper documents the phenomenon of subdued wage growth, observed in advanced economies [Hee Hong et al., 2018; Bell and Blanchflower, 2018; European Commission, 2017; Ciccarelli and Osbat, 2017], for the Euro Area and the southern economies. During 2014Q3–16Q4 – a period of positive detrended output growth in the Euro Area – the cumulative growth rate of real wages is smaller than that of output, negative, and on average smaller in the periphery than in the Euro Area. The driving factors of the output–wage differential paint a picture of a certain degree of country heterogeneity that is aligned with the findings of the aforementioned papers. Despite that heterogeneity, the results suggest that in all the economies, except for Italy, a sizable weakening of workers' market power is a catalytic factor in the subdued wage growth.

To asses the robustness of the model's empirical performance, I compare the model-implied unemployment gap, defined as the deviation of unemployment from its natural counterpart, to its reduced-form estimates. The two measures are remarkably well aligned in the Euro Area and Portugal. In Spain and Italy, the alignment is qualitatively good despite some quantitative differences. In Greece, the model-implied gap is aligned to the empirical estimates up to 2008, but becomes at odds with them thereafter. Thus, the alignment is better in economies with high unemployment–wage comovement. Overall, the gaps suggest a lengthy economic slack during the Great Recession, as well as an economic "over-heating" in the pre-2008 period.

Additional sensitivity checks suggest that altering some dimensions may boost a tad the short-run impact of shifts in worker's market power: matching the euro-area medium-term private sector unemployment forecasts, or allowing for time variation in the deep parameters associated with wage setting, strengthens the influence of those shifts over that of demand side shocks. Including a shadow rate to capture the effect of unconventional policies has a negligible effect.

Finally, the paper contributes in the literature of Bayesian estimation of Dynamic Stochastic General Equilibrium models [An and Schorfheide, 2006] by being the first that operationalizes the efficient simulation of states of Chan and Jeliazkov (2009) in the Bayesian estimation of a structural model. These authors consider reduced-form models, and provide an alternative state space approach to the filtering recursions that exploits the sparse and block-banded nature of precision matrices, leads to computational gains of 20-40% in running time, and does not require the prediction error decomposition of the likelihood. Applying that approach in the present paper is a fruitful enterprise to cope with the structural model's large state space dimensionality that stems from including both a peripheral economy and the core of the Euro Area, and renders the exploration of the posterior surface time-demanding.

In closing, it is worth mentioning that the above results are based on a linear solution of the structural model. Thus, the case of downward nominal wage rigidities (DNWR), that hinges on a non-linear solution of the model, cannot be examined and remains outside the scope of the paper. A connection of the paper's results on the comovement of wages and unemployment to the DNWR without further examination is not warranted because recent studies using high-quality administrative data find no DNWR before and during the Great Recession in several Eurozone economies [Verdugo, 2016] and Ireland [Doris et al., 2015][1], and challenge previous survey-based studies [Fabiani et al., 2010; Babecký et al., 2010].

Section 2 discusses the structural model. Section 3 develops the estimation approach. Section 4 presents the results. Section 5 conducts the sensitivity analysis. Section 6 concludes.

[1] Kurmann and McEntarfer (2017) and Elsby et al. (2016) find similar evidence for the U.S.A.

3.2 Structural Model

The model for the Euro Area is a closed-economy DSGE model with unemployment as in Galí et al. (2012b) but without capital. The model for a peripheral economy is a small open economy model [Justiniano and Preston, 2010], featuring nominal rigidities, indexation, monopolistic competition, staggered price setting, linear production, imperfect exchange rate pass-through [Monacelli, 2005] and cross-country insurance [Schmitt-Grohé and Uribe, 2003]. In that structure, I integrate unemployment stemming from staggered wage setting and the market power of labor unions à la Gali (2011), and a regime of fixed nominal exchange rates. Each economy is populated by a large number of identical families consisted of individuals who differ in terms of their labor type and disutility, supply labor along the extensive margin, and are perfectly insured. There is no immigration.

I describe the log-linearized equilibrium conditions below, and relegate their derivation to the Appendix. Lower-case letters denote log-deviations from a non-stochastic zero growth steady state. Starred (non-starred) variables and parameters pertain to the Euro Area (periphery). I focus on the periphery when describing equations and parameters that are isomorphic in all the economies.

According to the Euler equation (3.1/3.2), consumption (c_t) depends on a weighted average of its past and future values, on an interest rate, on expected inflation ($E_t\pi_{t+1}$), and on an AR(1) demand (preference) shock ($\upsilon_{d,t}$) with associated parameters $\{\rho_d, \sigma_d\}$. The composite parameters are given by $c_1 = 1/(1+\eta)$ and $c_2 = (1-\eta)/(1+\eta)$, where η is the external habit. The coefficient of relative risk aversion is unitary as in Galí et al. (2012b). Rational expectational operators are defined over all states of nature. The interest rate in the Euro Area (i_t^*) is set by monetary policy (3.3) in response to its last period's value, inflation ($\pi_{p,t}^*$), and the output gap ($y_t^* - y_t^{*,f}$), with the associated reaction coefficients being ρ^*, ψ_π^*, and ψ^*, respectively. $y_t^{*,f}$ stands for output in the flexible price and wage allocation that does not feature wage and price markup shocks. $\varepsilon^*_{mp,t}$ denotes a white noise policy innovation with standard deviation (std) σ^*_{mp}. The interest rate in the periphery (i_t) is determined in the uncovered interest rate parity (3.4) as a function of the union wide rate and a debt elastic premium with elasticity ϕ, capturing the cross-country financial market incompleteness. The asset position (d_t) of the periphery is traced out by the budget constraint (3.5) that involves the real exchange rate (q_t), the terms of trade (s_t), and output (y_t).

Turning to the labor market, workers endogenize the market clearing wage and participate in the market as long as that wage exceeds their disutility of work. In the equilibrium, the labor force (l_t) is defined as the mass of workers whose labor disutility lies below that of the worker who is indifferent between participating in and staying out of the market. It is pinned down by condition (3.13/3.18) that implies an equalization of the real wage, w_t, to the labor disutility (expressed in consumption units) of the workers who participate in the market. χ stands for the inverse Frisch elasticity along the extensive margin. z_t is a smooth consumption trend determined in (3.14/3.19) as a weighted average of its past value and the inverse marginal consumption utility. ω regulates the consumption wealth effects on labor supply and is added by Galí et al. (2012b) to address the pro-cyclicality of labor supply in response to monetary policy innovations. It reconciles a balanced growth path with an arbitrarily small wealth effect in separable preferences. $\upsilon_{\chi,t}$ captures changes in labor disutility and is modeled as an AR(1) process with associated parameters $\{\rho_x, \sigma_x\}$.

Once in the market, workers of different types form monopolistically competitive unions that sell labor to a perfectly competitive labor aggregator and set wages in a staggered fashion, leading to the wage Phillips curve (3.16/3.21). The latter determines wage inflation as a function of its future value, of past and current price inflation rates stemming from wage indexation to past price inflation according to parameter γ_w, and of the wage markup given by the deviation of unemployment from its natural level (u^n_t). The latter is obtained from the same model solved under flexible prices and wages, and is given by $u^n_t = \upsilon_{w,t}/\chi$. $\upsilon_{w,t}$ stands for the AR(1) wage markup shock with parameters $\{\rho_w, \sigma_w\}$. It stems from the exogenous time-varying elasticity of substitution across labor types, and leads to changes in the market power of workers and, thus, in the competitiveness of the labor market [Justiniano et al., 2013; Galí et al., 2012b]. The slope coefficient reads as $\kappa_w = (1-\beta\theta_w)(1-\theta_w)/[\theta_w(1+\chi\epsilon_w)]$, where ϵ_w is the steady state elasticity of substitution across labor types, and θ_w governs the frequency of wage adjustments. Each union provides the labor that is associated with the equilibrium wage. The latter, however, exceeds the competitive wage due to the staggered wage setting. The resulting wage markup leads to unemployment since employment is lower than what would otherwise prevail in an economy of perfectly flexible wages. Unemployment is defined as the difference between the labor force and employment (n_t) in (3.15/3.20). (3.12/3.17) is an identity defining the real wage as the inflation differential between nominal wages and prices.

In the supply side, production (3.7/3.11) is linear and includes an AR(1) technology shock ($\upsilon_{a,t}$) with associated parameters $\{\rho_a, \sigma_a\}$. In the Euro Area, prices are set in a staggered way and partially indexed to past inflation according to γ_p^*. Inflation is determined by the Phillips curve (3.6) as function of its past and future value, the wage, the AR(1) price markup shock $\upsilon_{p,t}^*$ with associated parameters $\{\rho_p^*, \sigma_p^*\}$, and technology. The composite parameters are: $\pi_1^* = \beta/(1+\beta\gamma_p^*)$, $\pi_2^* = \gamma_p^*/(1+\beta\gamma_p^*)$, and $\kappa_p^* = (1-\theta_p^*)(1-\theta_p^*\beta)/[\theta_p^*(1+\beta\gamma_p^*)]$. θ_p^* captures the degree of price stickiness. β is the common discount factor across economies. (3.8) yields price inflation ($\pi_{p,t}$) in a peripheral economy as the weighted average of domestic-good ($\pi_{h,t}$) and imported-good ($\pi_{m,t}$) inflation rates. $1-\tau \in [0,1]$ is the share of domestic goods in the consumption basket (home bias).

Intermediate good producers hire workers from the labor aggregator that packages heterogeneous labor supplied by unions, set prices in a staggered way, and sell goods in domestic and euro-area markets. The inflation of the domestically produced goods is determined by the forward-looking Phillips curve (3.9), where $\pi_{h1} \equiv \beta/(1+\beta\gamma_h)$, $\pi_{h2} \equiv \gamma_h/(1+\beta\gamma_h)$, and

$\kappa_h \equiv (1-\theta_h)(1-\theta_h\beta)/[\theta_h(1+\beta\gamma_h)]$. It is, thus, sensitive to real marginal costs given by the real wage and the terms of trade after accounting for technology and AR(1) price markup ($\upsilon_{h,t}$) shocks with associated parameters $\{\rho_h, \sigma_h\}$. The price markup shocks stem from a time-varying elasticity of substitution across domestic varieties. θ_h governs the frequency of price adjustments, and γ_h reflects indexation to past inflation. Monopolistically competitive importers buy goods at the euro-area price, and sell them in a peripheral market by setting prices in a staggered way. The imported-good inflation rate (3.10) depends on its past and future values, as well as on deviations from the law of one price, captured in the difference between the real exchange rate and the terms of trade (weighted by the home bias), where $\pi_{m1} \equiv \beta/(1+\beta\gamma_m)$, $\pi_{m2} \equiv \gamma_m/(1+\beta\gamma_m)$, and $\kappa_m \equiv (1-\theta_m)(1-\theta_m\beta)/[\theta_m(1+\beta\gamma_m)]$. $\upsilon_{m,t}$ is an AR(1) import price shock with parameters $\{\rho_m, \sigma_m\}$, and stems from a time-varying elasticity of substitution across imported varieties. θ_m governs the frequency of price adjustments, and γ_m reflects indexation to past inflation.

(3.22) and (3.23) yield the market clearing conditions in the Euro Area and the periphery, respectively. Both conditions include a government spending shock ($\upsilon_{g,t}$) with associated parameters (ρ_g, σ_g). $\nu > 0$ is the trade elasticity between domestic and imported goods. The real exchange rate and the terms of trade are pinned down by the cross-country inflation differential in (3.24) and the differential between imported- and domestic-good inflation rates in (3.25), respectively.

Two remarks are in oder. First, the policy rule is stylized and does not account for the possibility of a binding zero lower bound (ZLB). The ZLB applies since 2014Q4 and, thus, affects only a small part of the sample. I return to this issue in the robustness analysis. Second, neither block features capital accumulation, precluding the identification of an investment shock. Abstracting from that shock, though, is innocuous since the response of labor market variables to it is similar to that generated after other demand-side shocks like those already included; see Galí et al. (2012b).

The ten equations in the first column of Table (3.1) describe the equilibrium dynamics of the euro-area model for the variables $\{c_t^*, y_t^*, z_t^*, l_t^*, w_t^*, n_t^*, u_t^*, \pi_{w,t}^*, \pi_{p,t}^*, i_t^*\}$. The fifteen equations in the second column describe the equilibrium dynamics in a peripheral economy for the variables $\{c_t, y_t, z_t, l_t, w_t, n_t, u_t, \pi_{w,t}, \pi_{p,t}, \pi_{h,t}, \pi_{m,t}, i_t, d_t, q_t, s_t\}$.

Both blocks feature seven structural innovations. Six of them are common to both blocks: price and wage markup, demand, technology, spending, and labor disutility shocks. The euro-area block also features a policy innovation, and the peripheral block an import price markup innovation.

3.3 Estimation

3.3.1 Efficient simulation.

The present paper operationalizes the efficient simulation of states of Chan and Jeliazkov (2009) in a full-fledged structural framework. Those authors provide an alternative approach to the Kalman filtering [Durbin and Koopman, 2001] that exploits the insights of Fahrmeir and Kaufmann (1991) on the nature of sparse and block-banded precision matrices.

The equilibrium conditions are casted in the form: $\Gamma_0(\Theta)\xi_t = \Gamma_1(\Theta)\xi_{t-1} + \Psi(\Theta)\epsilon_t + \Pi\eta_t$, where the matrices $\{\Gamma_0, \Gamma_1, \Psi\}$ are functions of the parameter vector Θ, ξ_t is the $(n_q \times 1)$ state vector, and η_t collects the expectational errors. The structural shocks are grouped in the $(n_\epsilon \times 1)$ vector ϵ_t. (3.26) gives the VAR(1) representation of the rational expectations solution of Sims (2002).

$$\xi_t = \Phi_1(\Theta)\xi_{t-1} + \Phi_2(\Theta)\epsilon_t \ , \quad \epsilon_t \sim N(0_{n_\epsilon}, I_{n_\epsilon}), \quad \forall t \geq 2 \tag{3.26}$$

Table 3.1: Log-Linearized Equilibrium

Euro Area Block	**Small Open Economy Block**
Demand	Demand
$c^*_t = c^*_1 E_t c^*_{t+1} + (1-c^*_1)c^*_{t-1} - c^*_2[i^*_t - E_t\pi^*_{t+1} - (1-\rho^*_d)\upsilon^*_{d,t}]$ (3.1)	$c_t = c_1 E_t c_{t+1} + (1-c_1)c_{t-1} - c_2[i_t - E_t\pi_{t+1} - (1-\rho_d)\upsilon_{d,t}]$ (3.2)
Policy	Financial Structure
$i^*_t = \rho^* i^*_{t-1} + (1-\rho^*)[\psi^*_\pi \pi^*_{p,t} + \psi^*(y^*_t - y^{*,f}_t)] + \varepsilon^*_{mp,t}$ (3.3)	$i_t = i^*_t - \phi d_t$ (3.4) $c_t + \tau(\tau s_t + q_t) + d_t = \beta^{-1} d_{t-1} + y_t - \upsilon_{g,t}$ (3.5)
Supply	Supply
$\pi^*_{p,t} = \pi^*_1 E_t \pi^*_{p,t+1} + \pi^*_2 \pi^*_{p,t-1} + \kappa^*_p[w^*_t - \upsilon^*_{a,t} + \upsilon^*_{p,t}]$ (3.6) $y^*_t = n^*_t + \upsilon^*_{a,t}$ (3.7)	$\pi_{p,t} = (1-\tau)\pi_{h,t} + \tau\pi_{m,t}$ (3.8) $\pi_{h,t} = \pi_{h1} E_t \pi_{h,t+1} + \pi_{h2}\pi_{h,t-1} + \kappa_h\left[w_t - \upsilon_{a,t} + \upsilon_{h,t} + \tau s_t\right]$ (3.9) $\pi_{m,t} = \pi_{m1} E_t \pi_{m,t+1} + \pi_{m2}\pi_{m,t-1} + \kappa_m\left[q_t - (1-\tau)s_t + \upsilon_{m,t}\right]$ (3.10) $y_t = n_t + \upsilon_{a,t}$ (3.11)
Labor Market	Labor Market
$w^*_t = w^*_{t-1} + \pi^*_{w,t} - \pi^*_{p,t}$ (3.12) $w^*_t = \chi^* l^*_t + z^*_t + \upsilon^*_{\chi,t}$ (3.13) $z^*_t = (1-\omega^*)z^*_{t-1} + (\omega^*/(1-\eta^*)) * (c^*_t - \eta^* c^*_{t-1})$ (3.14) $u^*_t = l^*_t - n^*_t$ (3.15) $\pi^*_{w,t} = \gamma^*_w \pi^*_{p,t-1} + \beta[E_t\pi^*_{w,t+1} - \gamma^*_w \pi^*_{p,t}] - \kappa^*_w \chi^*(u^*_t - u^{*,n}_t)$ (3.16)	$w_t = w_{t-1} + \pi_{w,t} - \pi_{p,t}$ (3.17) $w_t = \chi l_t + z_t + \upsilon_{\chi,t}$ (3.18) $z_t = (1-\omega)z_{t-1} + (\omega/(1-\eta))(c_t - \eta c_{t-1})$ (3.19) $u_t = l_t - n_t$ (3.20) $\pi_{w,t} = \gamma_w \pi_{p,t-1} + \beta\left(E_t \pi_{w,t+1} - \gamma_w \pi_{pt}\right) - \kappa_w \chi(u_t - u^n_t)$ (3.21)
Market Clearing	Market Clearing
$y^*_t = c^*_t + \upsilon^*_{g,t}$ (3.22)	$y_t = (1-\tau)c_t + \tau\nu(q_t + s_t) + \tau c^*_t + \upsilon_{g,t}$ (3.23)
	International Prices
	$q_t = q_{t-1} + \pi^*_{p,t} - \pi_{p,t}$ (3.24) $s_t = s_{t-1} + \pi_{m,t} - \pi_{h,t}$ (3.25)

$\{\Phi_1, \Phi_2\}$ are non-linear functions of Θ. ξ_1 is initialized at the observed data for observed variables and at zero otherwise, with a covariance D being the steady state covariance of the state vector evaluated at the prior mean of Θ. Defining the reduced-form errors, $\tilde{\epsilon}_t = \Phi_2 \epsilon_t$ for $t > 1$ and $\tilde{\epsilon}_1 = \epsilon_1$, and stacking (3.26) across time yields:

$$\begin{bmatrix} I_{n_q} & \dots & \dots & \dots \\ -\Phi_1 & I_{n_q} & \dots & \dots \\ \dots & \ddots & \ddots & \dots \\ \dots & \dots & -\Phi_1 & I_{n_q} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_T \end{bmatrix} = \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix} , \qquad \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix} \sim N \left(0_{Tn_q}, \begin{bmatrix} D & \dots \\ \vdots & \Omega \otimes I_{T-1} \end{bmatrix} \right) \tag{3.27}$$

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

$$Z\xi = \tilde{\epsilon} \qquad , \qquad \tilde{\epsilon} \sim N(0_{Tn_q}, K_{\tilde{\epsilon}}^{-1}) \tag{3.28}$$

where $\xi \equiv [\xi_1', \xi_2' \dots, \xi_T']'$ is the $(Tn_q \times 1)$ vector of states, $\tilde{\epsilon} \equiv [\tilde{\epsilon}_1', \tilde{\epsilon}_2' \dots, \tilde{\epsilon}_T']'$ is the $(Tn_q \times 1)$ vector of errors, and $K_{\tilde{\epsilon}}$ is the sparse and block-banded precision of the latter. A change of variable transformation yields the prior state distribution, $P(\xi|\Theta)$, with $\xi|\Theta \sim N(\xi_0, K^{-1})$ and $\xi_0 = 0_{Tn_q}$. The precision $K = Z'K_{\tilde{\epsilon}}Z$ is also sparse and block-banded [Chan and Jeliazkov, 2009].

To accommodate the approach of Chan and Jeliazkov, I include white noise measurement error to all observed series appearing in the observation equation:

$$Y_t = H_0 \xi_t + H_1 \xi_{t-1} + M_t \quad , \quad M_t \sim N(0_m, \Sigma_M) \tag{3.29}$$

Y_t is the $(m \times 1)$ observation vector, with $m > n_\epsilon$; $\{H_0, H_1\}$ are $(m \times n_q)$ matrices linking observables to states; $H_1\xi_{t-1}$ allows for state augmentation; and M_t is a $(m \times 1)$ vector of measurement errors with diagonal covariance Σ_M. Stacking (3.29) over time yields:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_T \end{bmatrix} = \begin{bmatrix} H_0 & \dots & \dots & \dots \\ H_1 & H_0 & \dots & \dots \\ \dots & \ddots & \ddots & \dots \\ \dots & \dots & H_1 & H_0 \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_T \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_T \end{bmatrix}, \quad \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_T \end{bmatrix} \sim N\left(0_{Tm}, I_T \otimes \Sigma_M\right) \tag{3.30}$$

Or, in matrix notation,

$$Y = H\xi + M \qquad , \qquad M \sim N(0_{Tm}, I_T \otimes \Sigma_M) \tag{3.31}$$

H is $(Tm \times Tn_q)$, $Y \equiv [Y_1', Y_2', \dots, Y_T']'$ and $M \equiv [M_1', M_2', \dots, M_T']'$ are $(Tm \times 1)$ vectors. Thus, the likelihood of the data given Θ and the hidden states ξ, is $P(Y|\Theta, \xi)$, where $Y|\Theta, \xi \sim N(H\xi, I_T \otimes \Sigma_M)$.

Bayes rule, $P(\xi|Y, \Theta) \propto P(Y|\Theta, \xi)P(\xi|\Theta)$, yields the block-banded posterior precision: $P = K + H'(I_T \otimes \Sigma_M^{-1})H$. The posterior state $(\widehat{\xi})$ is computed based on the efficient simulation of Chan and Jeliazkov who use forward and backward substitution in (3.32) exploiting the nature of P:

$$P\widehat{\xi} = K\xi_0 + H'(I_T \otimes \Sigma_M^{-1})Y \tag{3.32}$$

The integrated log-likelihood (the likelihood of the data 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: $\log P(Y|\Theta) = +logP(Y|\Theta,\widehat{\xi}) + logP(\widehat{\xi}|\Theta) - logP(\widehat{\xi}|Y,\Theta)$, where all terms can be computed fast using the block-banded nature of the precision matrices.

The Random Walk Metropolis-Hastings algorithm is used to simulate draws from the non-tractable posterior[2]. I partition the parameter space into two sets reflecting the two economic blocks: a set collecting the parameters that pertain to the euro-area block and another one collecting those that pertain to a small open economy. Since there is no feedback from a peripheral economy to the Euro Area and in order to guarantee that the euro-area parameters are the same in all the runs for the small open economies, I estimate the euro-area block in an independent run.

3.3.2 Observables.

To identify the seven structural shocks in each economy, I use ten quarterly data series spanning the period 1999Q1–2016Q4[3], all obtained from the OECD, ECB, and Eurostat – a detailed description of the data sources and transformations is relegated to the Appx. Nine series are common to all economies: real private consumption and GDP growth, the unemployment rate, the growth rate of employment, CPI inflation, and four measures of nominal wage inflation from administrative and survey data, namely (i) economy-wide wages and salaries; (ii) an hourly compensation index; (iii) compensation per employee; (iv) a survey-based hourly earnings index in the private sector (not available for Greece). The four measures are incorporated through a factor specification. The loading factor of wages and salaries is unity and that of the remaining measures is denoted by $\{\alpha^{hr}, \alpha^{comp}, \alpha^{earn}\}$ and ordered according to the order of the presentation of the measures above. All series are entered with

[2]The covariance of the jumping distribution is initialized at the prior, and updated every 200,000 draws.

[3]Although the inclusion of the Great Recession in the sample influences the estimates, that period accounts for an important part of Eurozone's history. Since Greece enters the Eurozone late, its data start in 2001Q1.

a white noise measurement error with associated std denoted by $\{\mu_w^{wns}, \mu_w^{hr}, \mu_w^{comp}, \mu_w^{earn}\}$. Thus, the present paper includes more wage measures than Justiniano et al. (2013) and Galí et al. (2012b). For each peripheral economy, I also match the inflation rate of the GDP deflator. In the Euro Area, I also match the money market interest rate. In the robustness checks, the set of observables is augmented by the shadow rate of Wu and Xia (2017), and by the quarterly rolling two-year-ahead private sector unemployment forecasts.

As in Christiano et al. (2011), and in order to avoid imposing a balanced growth path that would need to be common in all economies and, thus, entail a stringent assumption given the short sample length, I opt into an empirically oriented approach and allow for different trends across variables by detrending the series outside the model. All inflation and growth rates are demeaned. The interest rate is demeaned instead of subtracting the steady state interest rate from it, for the latter approach yields a lengthier time period of negative rates than the former does due to the low interest rates during the Great Recession. As in Galí et al. (2012b) and Casares et al. (2014), I match the unemployment rate. All measurement equations are relegated to the Appendix.

3.3.3 Prior.

A conventional prior is considered[4] and reported in Table (3.2). Indexation parameters and autoregressive coefficients are drawn from the Beta distribution (B) centered at 0.5 (0.15 std) and 0.6 (0.2 std), respectively; the std of structural shocks and measurement errors associated with wages is sampled from the inverse-gamma distribution (IG) centered at 0.15 (1 std)[5]. The policy responses to inflation and the output gap have a normal (N) prior centered at 1.5 (0.25 std) and 0.125 (0.05 std), respectively. The interest rate smoothing,

[4] β is fixed at 0.9995. As in Galí et al.(2012b, 2012a), the persistence of labor disutility shocks (ρ_x) is set at 0.999.

[5] The std of all other measurement errors is tight (IG around 0.01; 0.001 std) since they pertain to a single observable. Their posterior std is shown in the Appendix.

the habit, and the debt premium elasticity are sampled from B centered at 0.75 (0.1 std), 0.7 (0.1 std), and 1% (0.5% std), respectively. The inverse Frisch elasticity and the loading factors have disperse N priors centered at 2 (1 std) and 1 (0.5 std), respectively. The wealth effect follows a B centered at 0.5 (0.15 std). The N prior mean of the elasticity of substitution across labor types (ϵ_w) is set at 3 (0.5 std), implying a prior steady state wage markup of 1.5. The prior for the trade share is a B centered at 0.3 (0.02 std), which is in the ballpark of what is considered in calibrations [Adolfson et al. 2005, 2007]. The trade elasticity has a disperse N prior around 1.2 (0.15 std) since it is notoriously identified. All Calvo parameters are sampled from B, centered at 0.5 (0.1 std); for θ_w in Spain, Italy, and Greece, however, I use a tad lower std (0.05)[6] because the sampler spends lengthy periods in a region of high wage stickiness and low persistence of wage markup shocks, demonstrating a swing between those parameters that is likely influenced by the scaling of shocks discussed below. A tighter prior avoids that region that is at odds with the evidence of Fabiani et al. (2010) and Lopez-Villavicencio and Saglio (2017), and speeds up convergence. The markup shocks in prices (3.6,3.9,3.10) and wages (3.16,3.21), as well as the demand shocks (3.1,3.2), are scaled to enter with an unitary coefficient. The scaling induces correlated priors and makes easier to set priors for the disturbances.

3.4 Findings

3.4.1 Posterior.

I discuss below aspects of the estimates reported in Table (3.2), that pertain to wages and unemployment, while putting less emphasis on estimates that are in line with those in the literature. In all the economies, the shifts in workers' market power are highly persistent

[6]The same tweak is used for θ_h in the case of Spain. The prior std for θ_w in Greece, Italy, and Spain, as well as that for θ_h in Spain, is 0.05.

(ρ_w is above 0.9) and characterized by a volatility (σ_w) that is on average smaller than that of the other disturbances. To facilitate the presentation of several findings, I distinguish two country groups: Greece and Italy on the one hand, and the Euro Area, Portugal, and Spain on the other hand.

The volatility of wage markup shocks in the Euro Area, Spain, and Portugal is remarkably low compared to that in Greece and Italy. The loading factors and the std of the associated measurement errors, that play a quintessential role in the identification of wage markup shocks, are heterogeneous across both countries and wage series. In Greece and Italy, the factors do not move far from unity, mirroring a high correlation among the wage series. A high correlation implies that an additional wages series does not bring in much novel information, and that the model might not be able to extract an accurate measure of wage inflation. In contrast, the factors move away from unity in the Euro Area, Spain, and Portugal. Thus, in those economies, the alternative wage series are not highly correlated, and encapsulate novel information that the model incorporates. The three wage series based on administrative data have a high loading factor in Greece and Italy, but a moderate or low one elsewhere. In Italy, the survey-based earnings index has an approximately zero loading factor, suggesting a negligible comovement of that series with the other wage series as well as with the other observables. In contrast, that factor is moderate in the other economies, implying that the survey-based index provides useful information on the wage structure.

The std of all measurement errors associated with wage series implies sizable errors that the models washes out through the factor specification. Despite the calibrated large persistence of labor disutility shocks, those shocks are volatile (σ_x). Consistently with the U.S. evidence of Galí et al. (2012b), weak wealth effects on labor supply are favored according to the value of ω. Contrary to them, however, who find an inverse Frisch elasticity of about 4, the elasticity (χ) is in the ballpark of 1.75–2.02 in the Euro Area and the peripheral economies – only in Greece that elasticity is 4.65. Wage stickiness is moderate; in the Euro Area, it is a tad lower than what is found in Smets and Wouters (2003). It implies a two-quarter duration of wage contracts and a certain degree of steepness in the wage Phillips curve. This finding is corroborated by a reduction in U.S. wage stickiness when unemployment is included in the observation set [Galí et al., 2012b].

All shock processes and the habit are a tad more persistent than what is usually obtained in the literature due to the inclusion of the Great Recession. Country heterogeneity is not pronounced in terms of wage stickiness, price and wage indexation, the debt elastic premium, the trade share, the trade elasticity, the steady state wage markup, and the highly volatile import-price shock. The price stickiness is higher in Greece than in the other economies, but it is associated with a low persistence of price markup shocks. Some country heterogeneity is detected in terms of the persistence and volatility of the remaining structural shocks. The implications of that heterogeneity appear in the forecast error variance decomposition (FEVD) of the following section.

Table 3.2: Posterior Estimates

			Greece	Italy	Portugal	Spain	Euro Area
		Prior	Mean [5-95%]	Mean [5-95%]	Mean [5-95%]	Mean [5-95%]	Mean [5-95%]
habit	η	B (0.7, 0.1)	0.95 [0.90, 0.98]	0.92 [0.88, 0.95]	0.90 [0.83, 0.94]	0.87 [0.81, 0.93]	0.96 [0.94, 0.98]
inverse Frisch elast.	χ	N (2, 1)	4.65 [3.78, 5.56]	2.02 [1.86, 2.17]	1.75 [1.41, 2.08]	1.71 [1.55, 1.86]	1.74 [1.51, 2.04]
wealth effect	ω	B (0.5, 0.2)	0.04 [0.01, 0.09]	0.05 [0.02, 0.08]	0.02 [0.01, 0.05]	0.02 [0.01, 0.03]	0.02 [0.01, 0.04]
domestic price indexation	γ_h/γ_p^*	B (0.5, 0.15)	0.18 [0.07, 0.33]	0.19 [0.08, 0.34]	0.22 [0.09, 0.39]	0.68 [0.49, 0.85]	0.38 [0.17, 0.64]
domestic price stickiness	θ_h/θ_p^*	B (0.5, 0.1*)	0.93 [0.89, 0.96]	0.62 [0.44, 0.75]	0.65 [0.46, 0.83]	0.60 [0.53, 0.67]	0.78 [0.69, 0.87]
wage indexation	γ_w	B (0.5, 0.15)	0.44 [0.21, 0.67]	0.31 [0.13, 0.55]	0.34 [0.16, 0.56]	0.39 [0.19, 0.60]	0.16 [0.07, 0.26]
wage stickiness	θ_w	B (0.5, 0.1*)	0.48 [0.41, 0.57]	0.52 [0.47, 0.58]	0.52 [0.44, 0.61]	0.52 [0.48, 0.57]	0.49 [0.45, 0.54]
subst. elast. wages	ϵ_w	N (3, 0.5)	2.91 [2.14, 3.72]	3.09 [2.29, 3.83]	3.11 [2.33, 3.86]	3.10 [2.40, 3.84]	3.02 [2.28, 3.81]
import price indexation	γ_{im}	B (0.5, 0.15)	0.31 [0.12, 0.53]	0.26 [0.11, 0.48]	0.26 [0.11, 0.48]	0.28 [0.12, 0.47]	[,]
import price stickiness	θ_{im}	B (0.5, 0.1)	0.37 [0.23, 0.54]	0.24 [0.15, 0.37]	0.36 [0.23, 0.50]	0.50 [0.38, 0.62]	[,]
trade elasticity	ν	N (1.2, 0.3)	0.64 [0.51, 0.81]	0.53 [0.47, 0.60]	0.50 [0.43, 0.57]	0.47 [0.43, 0.51]	[,]
trade share	τ	B (0.3, 0.02)	0.35 [0.32, 0.39]	0.38 [0.34, 0.41]	0.37 [0.34, 0.40]	0.35 [0.31, 0.39]	[,]
debt elastic premium	ϕ	B (0.01, 0.005)	0.00 [0.00, 0.00]	0.01 [0.00, 0.02]	0.01 [0.00, 0.01]	0.00 [0.00, 0.00]	[,]
AR wage markup	ρ_w	B (0.6, 0.2)	0.92 [0.85, 0.98]	0.98 [0.95, 1.00]	0.99 [0.98, 1.00]	1.00 [1.00, 1.00]	0.99 [0.99, 1.00]
std wage markup	σ_w	IG (0.15, 1)	1.15 [0.76, 1.61]	0.28 [0.19, 0.38]	0.11 [0.06, 0.17]	0.12 [0.08, 0.16]	0.05 [0.03, 0.06]
std labor disutility	σ_x	IG (0.15, 1)	4.24 [3.37, 5.12]	1.02 [0.87, 1.20]	1.06 [0.81, 1.32]	0.87 [0.72, 1.04]	0.20 [0.15, 0.25]
factor compensation	α^{hr}	N (1, 0.5)	1.26 [1.05, 1.51]	0.93 [0.70, 1.13]	0.69 [0.16, 1.22]	0.48 [0.30, 0.65]	0.22 [0.07, 0.38]
factor comp. per employee	α^{comp}	N (1, 0.5)	0.97 [0.79, 1.19]	0.74 [0.52, 0.94]	1.03 [0.61, 1.43]	0.45 [0.32, 0.60]	0.39 [0.28, 0.49]
factor hourly earnings	α^{earn}	N (1, 0.5)	[,]	0.03 [-0.16, 0.22]	0.71 [0.26, 1.15]	0.29 [0.19, 0.40]	0.33 [0.22, 0.44]
meas. er. wages and salaries	μ_w^{wns}	IG (0.15, 1)	1.82 [1.47, 2.21]	0.39 [0.21, 0.51]	1.05 [0.89, 1.23]	0.81 [0.68, 0.96]	0.24 [0.20, 0.29]
meas. er. hourly comp.	μ_w^{hr}	IG (0.15, 1)	1.23 [0.93, 1.54]	0.58 [0.48, 0.69]	1.75 [1.54, 2.01]	1.02 [0.89, 1.18]	0.29 [0.25, 0.33]
meas. er. comp. per employee	μ_w^{comp}	IG (0.15, 1)	1.36 [1.08, 1.64]	0.55 [0.46, 0.64]	0.91 [0.74, 1.07]	0.67 [0.57, 0.78]	0.19 [0.17, 0.22]
meas. er. hourly earnings	$\mu_{w^*}^{earn}$	IG (0.15, 1)	[,]	0.70 [0.61, 0.80]	1.37 [1.20, 1.58]	0.52 [0.45, 0.60]	0.22 [0.19, 0.25]
AR demand	ρ_d	B (0.6, 0.2)	0.35 [0.17, 0.55]	0.30 [0.17, 0.42]	0.45 [0.26, 0.64]	0.33 [0.20, 0.46]	0.38 [0.28, 0.47]
std demand	σ_d	IG (0.15, 1)	0.73 [0.54, 0.94]	0.18 [0.15, 0.22]	0.28 [0.20, 0.37]	0.26 [0.20, 0.31]	0.11 [0.09, 0.13]
AR spending	ρ_g	B (0.6, 0.2)	0.99 [0.97, 1.00]	0.99 [0.97, 1.00]	0.98 [0.96, 1.00]	0.99 [0.98, 1.00]	0.93 [0.88, 0.97]
std spending	σ_g	IG (0.15, 1)	1.25 [1.07, 1.47]	0.48 [0.42, 0.55]	0.48 [0.42, 0.56]	0.46 [0.40, 0.52]	0.48 [0.42, 0.55]
AR technology	ρ_a	B (0.6, 0.2)	0.97 [0.96, 0.98]	0.89 [0.84, 0.94]	0.92 [0.87, 0.96]	1.00 [0.99, 1.00]	0.93 [0.88, 0.99]
std technology	σ_a	IG (0.15, 1)	1.64 [1.41, 1.90]	0.67 [0.58, 0.77]	0.74 [0.64, 0.86]	0.35 [0.30, 0.40]	0.45 [0.39, 0.51]
AR domestic price markup	ρ_h/ρ_p^*	B (0.6, 0.2)	0.15 [0.04, 0.30]	0.44 [0.11, 0.92]	0.21 [0.05, 0.58]	0.95 [0.92, 0.98]	0.90 [0.79, 0.97]
std domestic price markup	σ_h/σ_p^*	IG (0.15, 1)	0.79 [0.66, 0.94]	0.45 [0.32, 0.62]	0.59 [0.45, 0.77]	0.25 [0.17, 0.34]	0.07 [0.05, 0.11]
AR import price markup	ρ_{im}	B (0.6, 0.2)	0.92 [0.85, 0.96]	0.91 [0.86, 0.94]	0.92 [0.87, 0.95]	0.95 [0.93, 0.97]	[,]
std import price markup	σ_{im}	IG (0.15, 1)	3.25 [1.74, 5.25]	3.24 [1.84, 5.04]	2.12 [1.23, 3.52]	1.06 [0.66, 1.57]	[,]
MP resp. to interest rate	ρ^*	B (0.75, 0.1)	[,]	[,]	[,]	[,]	0.90 [0.87, 0.93]
MP resp. to inflation	ψ_π^*	N (1.5, 0.25)	[,]	[,]	[,]	[,]	1.85 [1.55, 2.20]
MP resp. to output gap	ψ^*	N (0.13, 0.05)	[,]	[,]	[,]	[,]	0.05 [0.02, 0.09]
std monetary policy	σ_{mp}^*	IG (0.15, 1)	[,]	[,]	[,]	[,]	0.09 [0.08, 0.11]
Marginal Likelihood			-1588.2	-825.0	-1078.0	-958.03	-180.70

3.4.2 Business Cycles.

I now turn to the drivers of business cycles over the whole sample; Table (3.3) displays the FEVD ten quarters and years ahead. Four observations about unemployment fluctuations emerge. First, in accordance with the U.S. evidence of Galí et al. (2012b), the exogenous shifts in labor market competitiveness largely account for *long-run* unemployment cycles: they explain 80–97% and 65% of those cycles in the periphery and the Euro Area, respectively. Second, the drivers of *short-run* unemployment cycles differ across countries, and depend on the comovement (correlation) between the latent[7] wage series and unemployment. To shed further light on that link, I plot that correlation against the short- and long-run share of unemployment fluctuations explained by wage markup shocks in Fig.(3.1). The correlation is lower (in absolute terms) in Greece and Italy than in the Euro Area, Spain, and Portugal, and reflects the underlying correlation in the data (see Appx.). The figure shows that, in the long run, wage markup shocks account for unemployment fluctuations regardless the underlying wage–unemployment comovement; in contrast, in the short run, in economies with large wage–unemployment comovement, wage markup shocks are attenuated and account for a moderate share of unemployment fluctuations. Thus, in Greece and Italy, that are characterized by a low correlation between wages and unemployment, as well as by a moderate volatility of wage markup shocks, shifts in labor market competitiveness play the dominant role in the short-run unemployment cycles by explaining 72% and 88% of them, respectively. Conversely, in the Euro Area, Spain, and Portugal, that are characterized by a high correlation between wages and unemployment, as well as by a small volatility of wage markup shocks, the shifts in labor market competitiveness are attenuated. In particular, the combination of demand and supply side shocks is about equal to the contribution of wage markup shocks in Portugal (25% + 20% vs 42%) and Spain (18% + 17% vs 49%), and even exceeds it in the Euro Area (50% + 26% vs 24%).

[7] These series constitute the component of the wage data that leads to the highest possible likelihood.

Third, the periphery differs from the Euro Area in terms of the *short-run* importance of the effect of labor market innovations (the combination of wage markup and labor disutility shocks): that effect is larger in the periphery than in the Euro Area (54-90% vs 25%) where demand side shocks play the dominant role (50%). Fourth, unemployment cycles in the periphery are mainly ignited by domestic rather than euro-area disturbances that explain less than 2% of those cycles.

A few remarks are in order. Despite the persistence and volatility of labor disutility shocks, those shocks exert a small influence on unemployment, in the range of 1-14%, that is aligned with the 11% impact of those shocks on the Swedish unemployment found in Christiano et al. (2011). Technology shocks too exert little influence since they spur a pro-cyclical unemployment response on impact [Galí et al., 2012b]. The influence of domestic and import price markup shocks is small.

To what extent, though, are the innovations in labor market competitiveness diffused to output? Table (3.3) suggests that those innovations influence output cycles less than unemployment cycles. They account for 6-20% and 28-38% of short- and long-run output cycles, respectively. In fact, their *short-run* impact is smaller in the economies with a high correlation between wages and unemployment. Demand side disturbances are the main driver of short-run output cycles (43-66%), but their effect fades out over time by about half (19-33%). The Italian economy is an exception to the above, since wage markup shocks are the main driver of output at any frequency (70/82%). The transmission of euro-area shocks to output, capturing the connectedness between the periphery and the whole Euro Area, is small and comparable to the share (less than 5%) of output fluctuations explained by foreign shocks in Justiniano and Preston (2010).

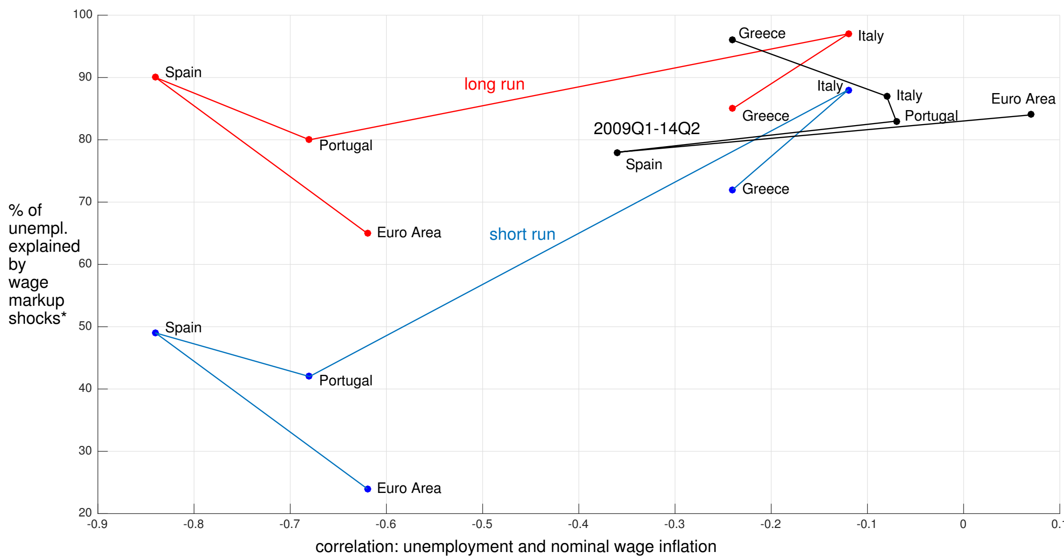
The decomposition of wage and price inflation reveals differences across countries, but not between the short and long run. In terms of wage inflation, labor market shocks account for a larger share of it in the periphery than in the Euro Area (53-85% vs 13%). In contrast, both demand side and supply side disturbances have a more pronounced influence in the Euro Area than in the periphery. In terms of price inflation, supply side shocks are its main determinant in all the economies (31-67%), while labor market shocks exert a more pronounced influence in the periphery than in the Euro Area (22-53% vs 7%) where demand shocks are sizable (26%).

Table 3.3: Business Cycles

	Unemployment					**Output**				
shock	**GR**	**IT**	**PT**	**SP**	**EA**	**GR**	**IT**	**PT**	**SP**	**EA**
demand side	17/10	4/1	25/8	18/4	50/22	65/26	14/5	55/24	43/19	66/33
demand	13/7	2/1	18/6	10/2	31/14	41/15	3/1	31/12	14/4	32/16
spending	4/2	2/1	6/2	9/2	19/8	24/11	12/4	24/13	29/15	34/17
supply side	8/4	5/1	20/7	17/3	26/12	12/21	9/3	23/12	39/29	27/34
technology	7/4	3/1	13/4	8/2	20/9	5/19	8/2	19/11	2/11	11/16
price markup	0/0	0/0	0/0	1/0	5/2	4/2	1/0	2/1	34/16	16/18
import markup	1/0	1/0	7/2	8/2	/	2/1	1/0	2/1	3/1	/
labor market	74/86	90/97	54/84	62/93	25/66	22/52	74/91	16/59	7/46	7/33
wage markup	72/85	88/97	42/80	49/90	24/65	20/38	70/82	11/36	6/37	6/28
labor disutility	2/1	3/1	12/4	14/3	1/0	2/14	4/9	4/23	1/10	1/4
euro-area	0/0	1/0	2/1	2/0	100/100	2/1	2/1	7/4	11/5	100/100
	Nominal Wage Inflation					**Price Inflation**				
shock	**GR**	**IT**	**PT**	**SP**	**EA**	**GR**	**IT**	**PT**	**SP**	**EA**
demand side	17/18	6/6	18/20	9/9	57/57	7/8	3/3	6/7	5/5	26/26
demand	12/13	1/2	10/12	2/3	43/42	3/4	1/1	3/4	1/1	21/20
spending	5/5	4/4	8/8	7/7	15/15	4/4	3/3	3/3	4/4	6/6
supply side	8/8	6/6	21/21	21/21	30/30	64/60	31/31	57/57	49/49	66/67
technology	6/6	3/3	8/8	11/11	18/19	6/6	5/5	9/9	10/10	17/17
price markup	0/0	0/0	1/1	1/1	11/12	21/19	6/6	10/10	14/14	50/50
import markup	2/2	3/3	12/12	9/9	/	37/35	20/20	38/38	25/25	/
labor market	74/74	85/84	55/53	67/66	13/13	22/25	53/53	23/22	39/38	7/7
wage markup	71/71	78/78	33/31	52/51	12/12	19/22	49/49	13/13	30/29	7/7
labor disutility	3/3	7/6	22/21	15/15	1/1	3/4	4/4	9/9	9/8	0/0
euro-area	1/1	3/4	6/7	3/4	100/100	7/7	12/13	14/14	8/8	100/100

Notes: FEVD at the posterior mean 10/40 quarters ahead. EA: Euro Area, GR: Greece, IT: Italy, PT: Portugal, SP: Spain. Demand shocks in the EA include the impact of monetary policy shocks (1/0 for both unempl. & output).

Figure 3.1: The Wage–Unemployment Comovement And Wage Markup Shocks



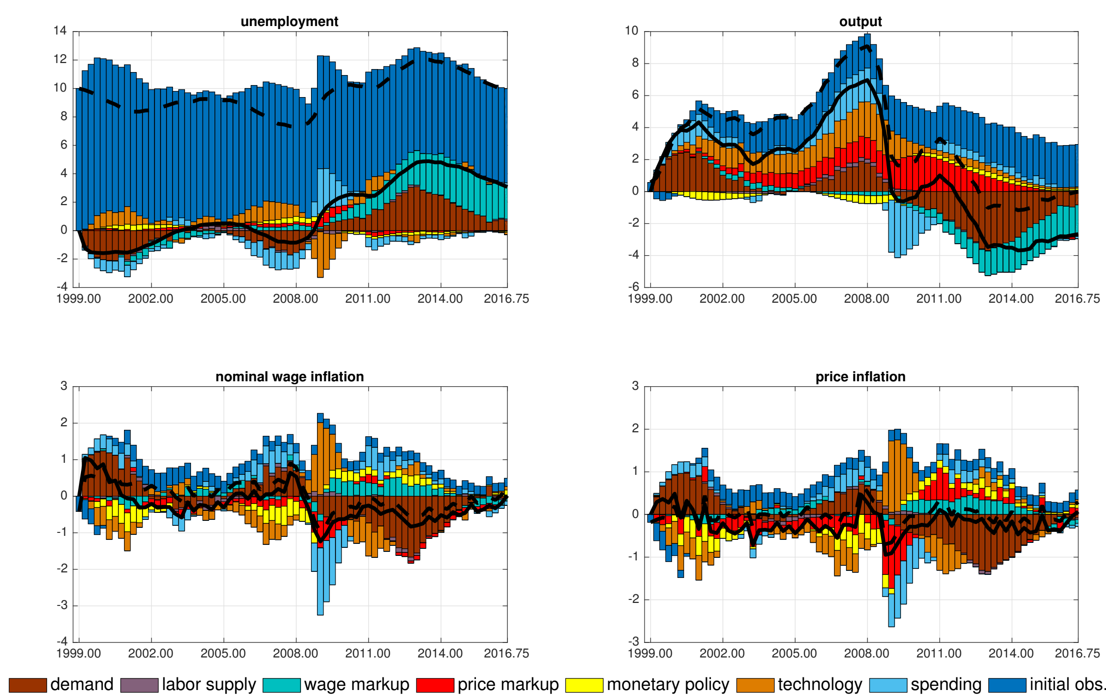
Notes: The figure depicts the connection between the unemployment–wage-inflation correlation and the share of unemployment cycles explained by wage markup shocks. "short-run" and "long-run" pertain to the FEVD 10 and 40 quarters ahead. *"2009Q1-14Q2" is derived from the historical decomposition and displays the share of unemployment cycles explained by the sum of the shares explained by wage markup shocks and by the initial obs.

3.4.3 Unemployment and the Great Recession.

What were the forces – the mix of demand, supply, and labor market disturbances – that led to an unemployment spike during the Great Recession? To address this question, Fig.(3.2) displays the contribution of each disturbance to the historical evolution of unemployment in the Euro Area. Three findings stand out. First, unemployment fluctuations during the Great Recession are largely attributed to two factors: an exogenous contraction in demand, and an adversarial shift in wage markups. The other disturbances exert a small influence. Second, unemployment exhibits two humps during 2008-11 and 2011-16. In fact, those dates correspond to the onset of the recession and the sovereign debt crisis. Third, comparing the Great Recession and the pre-2008 period in terms of the factors shaping unemployment reveals that the influence of wage markup shocks is small in the pre-2008 period where demand side fluctuations are the main determinant, and emerges only during the recession[8].

The above three findings carry over to the decomposition of the output evolution. More specifically, the two output troughs are driven by adversarial demand side and wage markup shocks. The latter shocks obtain a pronounced role only during the Great Recession. Although the exogenous shifts in the euro-area labor market competitiveness worsen unemployment and output, they slow down the fall in wages and prices brought by the demand side contraction. It is worth mentioning once more that the effect of wage markup shocks appears during the Great Recession, whereas in the pre-recession period demand side shocks mainly drive wage and price inflation.

Figure 3.2: Business Cycles in the Great Recession – Euro Area



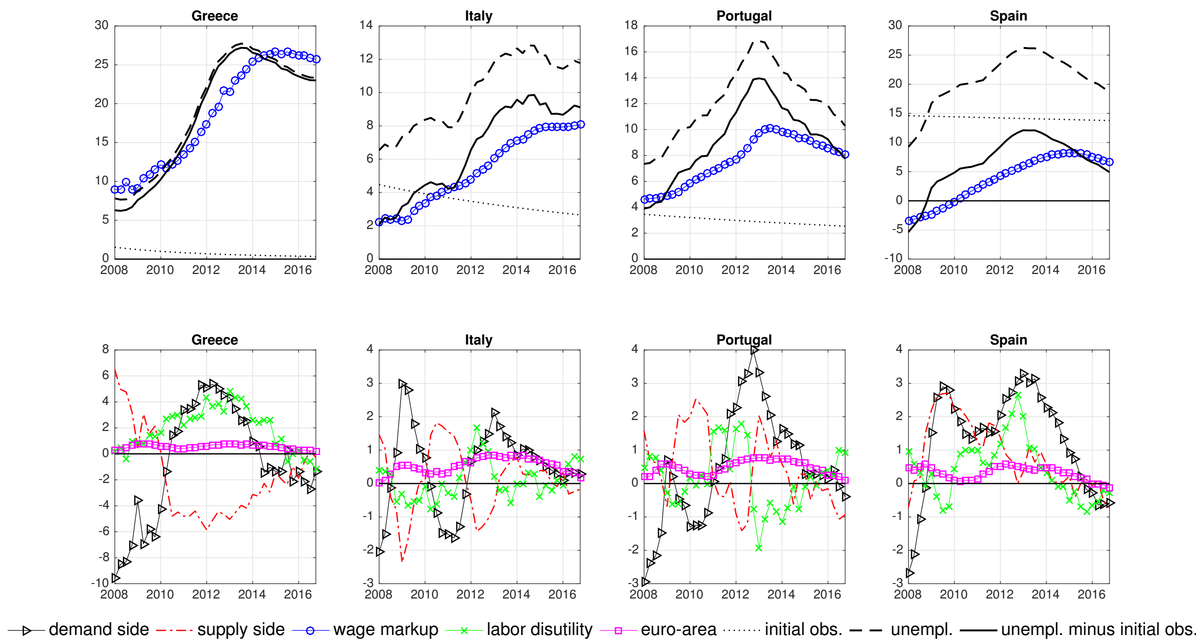
Notes: The figure displays the posterior mean contribution of each innovation to the evolution of four series. Dotted line: actual series. Solid line: actual series minus its part that is explained by the effect of the initial observation.

[8]It is not clear whether this is the case in the southern economies; see the Appendix. In those economies, contrary to the Euro Area, the impact of the initial observation fades out over time. Thus, the increase in the impact of wage markup shocks in the early part of the sample may indicate either a replacement of the impact of the initial observation as more data points become available, or a genuine increase in their influence.

The evolution of unemployment in the southern periphery during the Great Recession is displayed in the first row of panels in Fig.(3.3). The figure reveals that adversarial shifts in the labor market competitiveness contribute to the unemployment spike to a larger extent than they do in the Euro Area. In fact, they are the main determinant of unemployment. Two unemployment humps are seen in Italy and Spain but are not as distinguishable as they are in the Euro Area. They do not appear in Greece and Portugal, because in those economies the Great Recession had a more prolonged effect than it had in the Euro Area. The second row of panels in Fig.(3.3) pins down the contribution of the other disturbances. The two phases of the recession are now visible. During the second phase, 2011-14, an exogenous contraction in the demand side (a combination of demand and spending shocks), as well as an abrupt decrease in labor disutility that expanded the labor force, raise unemployment for a prolonged period in all the economies. During the first phase, 2008-11, unemployment rises due to different forces across countries, likely reflecting asynchronous business cycles: due to negative demand side shocks in Spain and Italy, and due to supply side shocks (the combination of domestic and import price markup shocks and technology shocks) in Greece and Portugal. Euro-area shocks have a persistently adversarial, albeit small, contribution.

Fig.(3.1) shows that the large influence of wage markup shocks in both the Euro Area and the southern economies during that tumultuous period is associated with a sizable decrease in the comovement between wage inflation and unemployment. In both the Euro Area and the periphery, the comovement between wage inflation and unemployment drastically weakens. This weakening suggests a *disconnect* that possibly mirrors downward wage rigidities and an adjustment of the extensive margin of labor supply instead of wages to the underlying economic conditions.

Figure 3.3: Unemployment in the Great Recession – Southern Periphery



Notes: The figure displays the posterior mean contribution of each innovation to the unemployment rate.

3.4.4 The Origins Of Subdued Wage Growth.

A phenomenon observed in advanced economies during the recovery period from the Great Recession is the subdued nominal wage growth [Hee Hong et al., 2018; Bell and Blanchflower, 2018; European Commission, 2017; Ciccarelli and Osbat, 2017]. The present paper documents that phenomenon in the Euro Area and the southern economies. In Table (3.4), I shed light on the cumulative (real) wage growth compared to (real) output growth across three periods; I emphasize *real* wage growth in order to broaden the understanding of wage and inflation cycles *jointly*. During 1999Q2–2007Q4, wages grow more than output in all the economies but in Greece, where although wage growth is comparable to that in the other economies, it is lower than the growth rate of output. During 2008Q1–2014Q2, wages fell by less than output in all economies but in Spain where both wages and output fell by a large amount. During the recovery period, identified as the 2014Q3–2016Q4 window that is characterized by a positive detrended real output growth in the Euro Area, the evidence

Table 3.4: Sluggish Wage Growth, 2014Q3–2016Q4

	Greece		Italy		Portugal		Spain		Euro Area	
	dy_t	dw_t	dy_t	dw_t	dy_t	dw_t	dy_t	dw_t	dy_t	dw_t
1999Q2-2007Q4	26.6	14.5	9.6	11.1	8.6	13.0	16.9	32.1	8.4	9.9
2008Q1-2014Q2	-28.2	-11.2	-11.2	-9.3	-12.3	-10.3	-20.4	-23.4	-10.1	-7.7
2014Q3-2016Q4	0.3	-4.1	1.1	-0.6	2.5	-1.2	3.2	-3.2	1.2	-0.7

Notes: The table displays the cumulative *real* growth rates of (smoothed) output and wages.

shows a subdued wage growth: the cumulative growth rate of wage is smaller than that of output. In fact, that rate is negative and, on average, larger in the southern economies than in the Euro Area.

In Table (3.5), I pin down the structural forces behind the positive 2014Q3–2016Q4 real output–wage differential. Despite the fact that the table paints a picture of a certain degree of country heterogeneity, shifts in labor market competitiveness play a catalytic world in all economies except for Italy. They do so by having the largest impact in absolute terms. In Greece and Portugal where the impact of demand side and supply side shocks almost cancels each other out instead of being aligned to the same direction as in Spain and the Euro Area, the effect of wage markup shocks determines the output-wage differential. Thus, the evidence suggests a sizable weakening in workers' market power as a catalytic factor in the subdued wage growth, that is is aligned with explanations found in the aforementioned papers, i.e. a weakened workers' bargaining power, labor market reforms and compositional effects in labor force that increase competition among workers.

Shifts in labor disutility trigger changes in the labor force, may incorporate the effect of factors such as immigration, and have a heterogeneous impact across countries: they favor output over wage growth in Italy and Portugal; wage over output growth in Greece and Spain; and have no impact in the Euro Area. Euro-area shocks can potentially capture the impact of global factors towards competition: they favor output over wage growth in all the southern economies, but in Greece. Price markup shocks, possibly capturing the impact of a prolonged low realized and expected inflation, favor output over wage growth in the Euro

Table 3.5: The Determinants Of The Sluggish Wage Growth, 2014Q3–2016Q4

	$dy_t - dw_t$				
	GR	**IT**	**PT**	**SP**	**EA**
2014Q3-2016Q4	4.3	1.7	3.8	6.4	1.9
demand side	-6.4	0.2	0.9	2.2	0.0
demand	-7.9	-0.2	0.5	0.9	0.2
spending	1.5	0.5	0.4	1.4	-0.2
supply side	6.7	0.4	-1.0	2.4	0.7
technology	6.9	0.1	-1.6	-0.1	0.0
price markup	-1.3	-0.0	-0.1	0.9	0.7
import markup	1.2	0.4	0.7	1.6	0.0
labor market	4.7	-0.6	3.0	1.6	1.0
wage markup	11.0	-1.4	2.2	2.5	0.9
labor disutility	-6.2	0.8	0.7	-0.8	0.1
euro-area	-0.8	1.3	0.8	0.5	
initial point	0.1	0.3	0.1	-0.3	0.1

Notes: Cumulative impact of each shock on the 20014Q3–2016Q4 cumulative real output–wage differential.

Area, but have a small impact (compared to the magnitude of the overall growth differential) in the periphery[9].

3.5 Robustness Analysis

3.5.1 Unemployment Gaps.

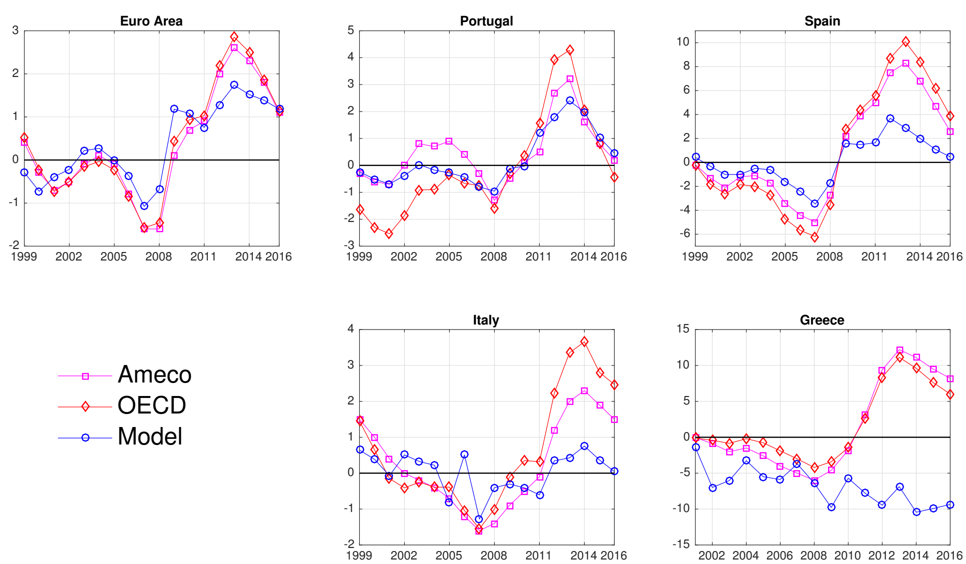
Modeling unemployment à la Gali (2011) provides a definition of natural unemployment as a function of wage markup shocks. To assess the robustness of the model's empirical performance, I investigate the evolution of the model-implied unemployment gap, defined as the deviation of unemployment from its natural counterpart, that gives inklings on the resource utilization. I average that gap over quarters to an annual frequency and compare it to the estimates of both the Organisation for Economic Co-operation and Development

[9] Other explanations involve productivity and part-time employment. Since the data are detrended, the former explanation cannot be examined in the present paper. The latter explanation does not map to a single disturbance.

(OECD) and the European Commission (Ameco) that are derived from reduced-form models. Those models [Staiger et al., 1997; Watson, 2014] use several indicators with few cross-equation restrictions, whereas the model-implied gaps are based on the theoretical structure and the set of observables.

Fig.(3.4) shows that the model-consistent gaps are remarkably well aligned with the empirical estimates in the Euro Area and Portugal. In Spain and Italy, the alignment is qualitatively good, but there are some quantitate differences in the magnitude of the 2011-14 spike. In Greece, the model-implied gap is aligned to the empirical estimates up to 2008, but becomes at odds with those estimates after that period. Interestingly, the three economies in which the gap performs well (Euro Area, Portugal, Spain) are those with the highest correlation between unemployment and wages showed in Fig.(3.1). Despite the case of Greece, all gaps suggest a lengthy resource underutilization since the onset of the Great Recession, as well as an economic "over-heating" in the pre-2008 period.

Figure 3.4: Unemployment Gaps – Model And Empirical Estimates



Notes: "Model": posterior mean of the model-consistent gap. *Sources:* OECD and European Commission (Ameco).

3.5.2 Prior.

Crucial it is to understand whether the large influence of wage markup shocks is an artifact of a dogmatic prior specification? I tackle this question by computing the FEVD at the prior mean (see Appx.). The prior implies a starkly low influence of wage markup shocks on unemployment in the periphery (17%) and the Euro Area (13%), and a sizable influence of demand side shocks. The same implication holds for output. Thus, the prior is non-dogmatic, and it is the data that favor a set of parameters associated with a large influence of wage markup shocks.

3.5.3 The Shadow Rate, Time Variation, And Unemployment Forecasts.

I examine the sensitivity of the paper's results across three dimensions in the Euro Area. Table (3.6) displays the benchmark FEVD along with that stemming from the three modifications. In the interest of space, the posterior is relegated to the Appendix, whereas some pivotal estimates are discussed below.

First, during the Great Recession, monetary policy was not limited only to interest rate changes. Instead, it included unconventional measures. To take into account their impact, I repeat the estimation for the Euro Area by replacing the money market rate with the shadow rate of Wu and Xia (2017) after 2007. The latter delinks from the former to a sizable extent only after 2014. The only change detected in the posterior estimates pertains to a small increase in the policy coefficients and the std of monetary policy innovations. The marginal log-likelihood deteriorates by 23 points. The FEVD under the inclusion of the shadow rate is similar to the benchmark one.

Second, is the influence of wage markup shocks derived entirely from the joint properties of unemployment and wages? I address this question by adding the euro-area medium-term (two-year-ahead) private sector unemployment forecasts in the set of observables. Embedded in those forecasts is the slowly-evolving part of unemployment. No additional structural shock is added since the series are loaded with measurement error. The forecasts are linked to the state via:

$$uf_{t,t+h}^{obs} = \left[\Phi_1(\Theta)^{h+1}\xi_{t-1} + \Phi_2(\Theta)^h\epsilon_t\right]_{[u^*,:]} \tag{3.33}$$

where the left-hand-side term denotes the observed h-quarter-ahead forecast, and the right-hand-side term yields the model-consistent forecast. The inclusion of those forecasts is new since usually inflation forecasts are considered in structural models [Del Negro and Eusepi, 2011]; Kim and Pruitt (2017) consider such forecasts in a reduced-form model. Changes of a small magnitude in the posterior mean of several parameters are detected. The change that plays the most important role pertains to a sizable decrease in parameters associated with the demand side: the habit decreases from 0.96 to 0.87, and the persistence of demand shocks drops from 0.38 to 0.19. Those changes attenuate the importance of demand side shocks for both unemployment (50/22 vs 33/13) and output (66/33 vs 26/6). In terms of unemployment, wage markup shocks now exert a larger influence compared to that in the benchmark case (50/80 vs 25/66). In terms of output, the role of supply side shocks (57/75) increases. Thus, forecasts may be influential in explaining unemployment since they entail a slowly-evolving part that favors the low-volatility persistent wage markup shocks.

Third, how would the results have looked like if a structural break in the parameters associated with the wage Phillips curve (3.16) were taken into account? A break could potentially mirror the effect of structural reforms that took place during that period, or it could indicate an effect of the Great Recession on the deep parameters. I tackle this question by allowing for a change in $\{\gamma_w^*, \theta_w^*, \rho_w^*, \sigma_w^*\}$ between the 1999Q1–2008Q4 and 2009Q1–2016Q4 periods. The

Table 3.6: Euro Area Business Cycles – Robustness Checks

	Benchmark		**Shadow**		**Forecasts**		**pre-08**		**post-08**	
shock	u_t^*	y_t^*	u_t^*	y_t^*	u_t^*	y_t^*	u_t^*	y_t^*	u_t^*	y_t^*
demand side	50/22	66/33	52/25	73/37	33/13	26/6	25/13	45/23	31/9	48/17
demand	30/14	31/16	32/16	37/18	8/3	6/1	11/6	14/7	14/4	15/5
spending	19/8	34/17	19/9	35/18	22/9	18/4	13/7	29/15	17/5	31/11
mon. policy	1/0	1/0	1/0	1/1	3/1	3/1	1/0	2/1	1/0	2/1
supply side	26/12	27/34	27/13	21/34	17/7	57/75	16/8	29/29	19/6	29/21
price markup	5/2	16/18	6/3	13/19	2/1	16/5	1/1	15/12	2/1	15/9
technology	20/9	11/16	21/10	8/15	15/6	40/70	14/7	14/17	18/5	14/12
labor market	25/66	7/33	21/62	6/30	50/80	17/19	59/79	26/48	49/86	24/62
wage markup	24/65	6/28	20/62	5/26	48/79	14/15	58/79	25/43	48/86	22/58
labor disutility	1/0	1/4	1/0	1/4	2/1	2/4	1/0	1/5	1/0	1/3

Notes: Forecast error variance decomposition at the parameters' posterior mean 10/40 quarters ahead.

posterior means of $\{\gamma_w^*, \theta_w^*, \rho_w^*, \sigma_w^*\}$ are $\{0.32, 0.52, 0.953, 0.10\}$ and $\{0.27, 0.53, 0.997, 0.06\}$ in those two periods. Thus, wage stickiness and indexation, as well as the volatility of wage markup shocks, in both periods are higher than the benchmark estimates. The persistence of the wage markup shock exhibits small differences. The variation in the estimates is rather small after taking into account that those parameters are tightly related. In addition, the last two columns of Table (3.6) reveal no sizable differences in terms of the FEVD between the two windows, and an increase in the importance of wage markup shocks compared to the benchmark FEVD. Thus, the findings suggest no break and that a flexible parameter structure may favor the exogenous shifts in worker's market power. The short time windows, though, preclude providing a definitive answer.

3.6 Concluding Remarks

The present paper examined unemployment and wages in the Euro Area through the lens of a structural model and the use of several wage series. It showed that exogenous shifts in labor market competitiveness determine long-run unemployment fluctuations. Nevertheless, the short-run impact of those shocks depends on the joint properties of unemployment and wages. In the Euro Area, Portugal, and Spain, where the unemployment strongly comoves with wages, the short-run impact of the above shocks is moderate. In contrast, in Greece and Italy, where unemployment weakly comoves with wages, the short-run impact of the above shocks is large. The weakening of the comovement during the Great Recession leads to wage markups shaping the unemployment spike of that period. Finally, the paper showed that the nature of wage markup shocks changed during the output recovery: a weakening in the workers' market power led to subdued wage growth.

The above findings point towards three avenues for future work. First, the joint properties of unemployment and wages nest the influence of downward wage rigidities. Thus, empirical work in non-linear frameworks may shed light on the nature of those rigidities. Second, the present paper briefly illustrated the usefulness of unemployment forecasts. In future work, it would be important to draw insights from frameworks where those forecasts are linked to endogenous unemployment expectations. Third, although the model did not include feedback effects from the financial sector to the labor market, the study of those effects along with nominal rigidities, as in Christiano et al. (2011), in the case of the Euro Area is required.

Chapter 4

Wages During Recoveries in Euro-Area Economies. A Structural View

4.1 Introduction

Although unemployment is declining, even to pre-recession levels in some cases, and employment steeply increases, wages exhibit a sluggish evolution in several economies. The puzzling phenomenon of subdued wage growth is documented in the U.S. [Hee Hong et al., 2018, Abdih and Danninger, 2018], the UK [Bell and Blanchflower, 2018], and to some extent in the Euro Area [ECB, 2018; European Commission, 2017; Ciccarelli and Osbat, 2017] and in the southern economies [Charalampidis, 2018].

Fig.(4.1) gives a flavor of the puzzling wage development by comparing developments in a variety of wage indicators[1], the change in the unemployment rate, and the change in

[1] compensation per employee, wages & salaries per employee, hourly compensation, private hourly earnings

employment after the sovereign debt crisis to their analogues during the recoveries in the pre-2013 period in Germany, France, Italy, and Spain. The figure demonstrates that a large decline in unemployment and a sizable pick up in employment in all the economies in the post-2013 period are not accompanied by strong wage growth. For instance, in France and Italy, the post-2013 wage growth remains lower than it was in the previous recoveries.

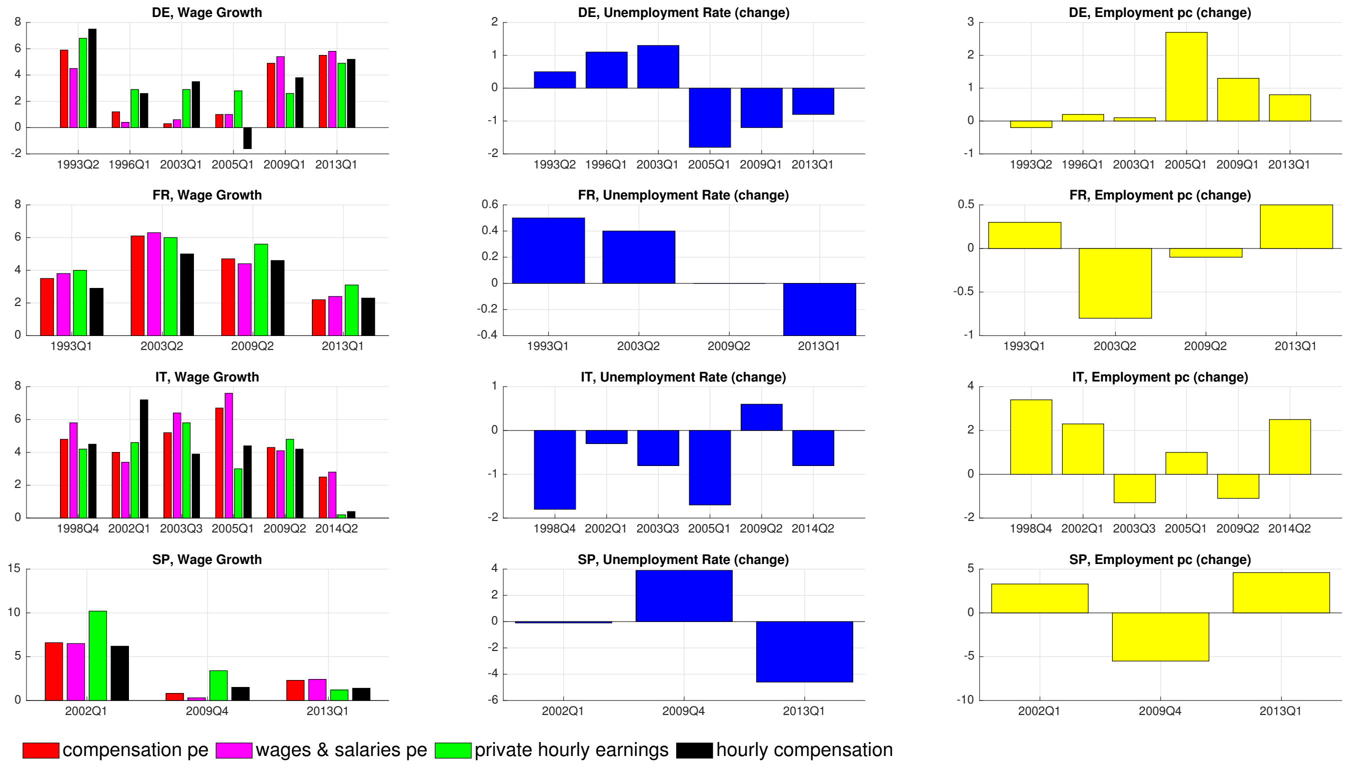
Several explanations for the puzzling phenomenon of subdued wage growth have been proposed. The declining labor productivity and labor's share of income, and to some extent advances in automation, the decline in unionization, and trade globalization, have been found in empirical studies for the U.S. economy [Abdih and Danninger, 2018]. Du Caju, Rycx, and Tojerow (2011), too, find international trade influential for wage dispersion in Belgium. A flattening of the Phillips curve [Leduc and Wilson, 2017] and a problematic measurement of the economic slackness [Hee Hong et al., 2018; Bell and Blanchflower, 2018; Smith, 2014] have been proposed in other empirical analyses. Other authors resort to arguments about a non-linear Phillips curve [Donayre and Panovska, 2016; Kumar and Orrenius, 2016] implying that wage growth is going to pick up once unemployment hits a low level. Structural evidence for the southern euro-area periphery points to a weakening in workers' market power [Charalampidis, 2018] which is compatible with the idea of monopsonies in labor markets [Krugman, 2018]. Bulligan, Guglielminetti, and Viviano (2017) highlight the importance of the intensive margin of labor utilization in the determination of wage growth. Finally, Faberman and Justiniano (2015) find a strong relationship between job switching and nominal wage inflation.

Despite the various explanations above, there still are unresolved issues in the existing literature. We split them in two categories; the first involves the identification of the phenomenon of subdued wage growth itself, and the second involves the identification of the determinants of the phenomenon. As for the first category, not all papers use the same wage measure, the same period of analysis, or the same set of economies. In addition, sometimes even the notion of subdued wage growth is not clear: is wage growth subdued compared to its past experience, compared to what is currently observed in other economies, or compared to what is expected given the slack in the labor market? As for the second category, almost the entire existing literature – with the exception of Charalampidis (2018) – employs reduced form studies blurring causality issues and impeding a general equilibrium approach that would quantify the relative importance of all the driving factors of wage growth.

The present paper contributes in the literature by addressing the above issues. To that end, it focuses on the behavior of wages during output recoveries, and compares the post-2013 wage evolution with the wage evolution during the recoveries from previous troughs. In doing so, it delves into the drivers of wages during those episodes through the lens of a structural workhorse model, namely Galí, Smets, and Wouters (2012a)[2] model. This approach is applied, in turn, on the big four European economies. It is worth mentioning that with the exception of Charalampidis (2018), no other paper employs a structural approach to the determinants of wage growth.

[2]These authors introduce unemployment following the approach of Gali (2011) in the framework developed in Smets and Wouters (2007) and Christiano, Eichenbaum, and Evans (2005).

Figure 4.1: Wages in Recoveries



Notes: Authors' computations. Cumulative change (eight-quarter-ahead after trough) for the pre-2013 troughs. Cumulative change (average eight-quarter-ahead quarterly rolling) for the recovery after the trough of the sovereign debt crisis. Troughs are shown in the horizontal axis – in Spain's panels, the 2002Q1 sizable drop in output is added. *Mnemonics:* Nominal Wage Growth Rate: Compensation per Employee; Wages and Salaries per Employee; Hourly Private Earnings (after 1995; hourly earnings in manufacturing for earlier periods); Hourly Compensation. Unemployment: Unemployment Rate. Employment: (log of) Employment per capita. *Data Sources:* OECD, SDW.

The model is estimated with state-of-the-art Bayesian techniques on a set of observables that includes multiple wage measures to overcome restrictions stemming from the use of a single wage series. The present paper, thus, builds on the strand of the literature that considers a factor approach to DSGE models, as in Boivin and Giannoni (2006), as well as multiple wage indicators in order to strengthen the identification of wage markup shocks. More specifically, in addition to the two wage indicators used in Galí et al. (2012a), Justiniano et al. (2013), and Lindé et al. (2016), the present paper uses up to three more series, as in Charalampidis (2018), in order to deepen our understanding of wage fluctuations.

4.1.1 Results.

The paper finds a *cyclical real wage recovery* in Germany and Spain (the average cumulative eight-quarter-ahead rates are 0.4% and 0.3%, respectively[3]) after the trough of the sovereign debt crisis, but a *cyclical (real) wage-less output recovery* in France and Italy (-1% and -0.6%, respectively).

The main determinant of real wage growth in Germany and Spain is sizable shifts in the pricing power of firms and, in particular, a contraction in price markup shocks that leads to an economic stimulus, rising real wages, and rather small gyrations in price inflation. This effect dominates a productivity slowdown exerting downward pressure to the real wage. In France, the effect of the weakened market power of firms does not exceed that from the productivity slowdown resulting in negative cyclical real wage growth. In Italy, as it is the case in Spain, more factors are at play. In fact, in Italy, the effect of price markup shocks, reinforced by a pick up in demand side shocks, does not suffice to overcome the real wage repression stemming from a weakening in workers' market power over wages, mirrored in negative wage markup shocks, and an increase in labor force participation. In contrast, in Spain, the real wage increases coming from price markup and demand side shocks dominate

[3]A pro-cyclical real wage in Spain is also found in Font, Izquierdo, and Puente (2015).

the downward pressures coming from the weakening in workers' marker power.

Differences in wage developments are observed across recoveries over time. In fact, real wage growth in Germany, France, and Italy during the period after the sovereign debt crisis trough is statistically different from the wage growth during the recoveries over the 1990s-2013 period. The post-2013 weakening in the pricing power of German firms is statistically different from the pricing power observed during past recoveries. A similar result holds for Italy. In both Germany[4] and France, the productivity slowdown is statistically different from the strong productivity growth observed during the pre-2013 recoveries. In Spain, the post-2013 sizable weakening in workers' market power, possibly capturing some of the structural reforms that took place during that period, is statically different from the past power of workers' in raising wages above its equilibrium level during output recoveries.

The above picture is compatible with the evidence for the drivers of unemployment and nominal wage inflation in the post-2013 period. In Germany and France, economies where price markup and productivity shocks are the main influence of the real wage, wage markup shocks mainly account for unemployment. In contrast, in Italy and Spain, economies where all shocks influence the real wage, demand side shocks are highly influential for unemployment. As for nominal wage inflation, the case of Spain demonstrates the need of jointly examining price and wage inflation. More specifically, cyclical nominal wage inflation is the highest in Germany whereas in the other economies it is not only below that of Germany, but it is also below its past level and negative. Only when price inflation is taken into account in the case of Spain, the Spanish cyclical real wage growth appears positive and above that of France and Italy. A difference in the decomposition between nominal and real wages is that the entire set of innovations determine nominal wage inflation in all the economies of the sample.

[4]Interestingly, in Germany, although wage markup shocks have never exerted sizable influence on the real wage, their influence changes sign after 2003, from boosting wages to negatively affecting them while pushing unemployment downwards. This sign change likely reflects the implementation of the various waves of labor market reforms (Hartz reforms) after 2003.

Despite the statistically different behavior of wages during recoveries over time, we find no evidence of a change in the wage evolution during recessions leading to troughs. Furthermore, the volatility of the real wage and of its determinants during recoveries suggests no differences over time. Overall, price markup shocks are more volatile than demand side shocks during recoveries, while wage markup shocks have always been volatile in Spain.

Although the above analysis puts emphasis on structural innovations, we also investigate the role of the structural characteristics of the sample economies in influencing the transmission of innovations. More specifically, we assess the structural differences between the German labor market and the labor markets of the other economies. We find that the structural differences among the German, French, and Italian labor markets are not enough to generate a counterfactual real wage growth that would be higher than the realized one. Nonetheless, if the Spanish labor market were more similar to the German one – if, in particular, it had a higher inverse Frisch elasticity than the observed one – then the Spanish real wage growth would be higher during the recovery from the sovereign debt crisis.

Section 2 outlines the structural model. Section 3 briefly presents the estimation and identification strategy. Section 4 displays the results. Section 5 concludes. A detailed Appendix includes the full model, the complete estimation approach, and additional results.

4.2 Model

Wage fluctuations are examined through the lens of a medium-scale DSGE model and, in particular, the Galí, Smets, and Wouters (2012b) model that has also been used in Galí, Smets, and Wouters (2012a), Lindé, Smets, and Wouters (2016), Lindé, Maih, and Wouters (2017), and has been extended in an open economy framework in Charalampidis (2018).

This paragraph sketches the model, while the log-linearized solution[5] is relegated to the Appendix – the next paragraph reports the stochastic sources of fluctuations included in the model. Capital, produced by units of the final good, is channeled to a continuum of monopolistically competitive firms. The firms combine capital and labor to produce intermediate goods, and choose prices in a staggered fashion. Households invest in one-period risk-less nominal bonds[6], consume the final good, and supply labor. Perfect risk sharing holds. Each household is a large family and consists of a continuum of members situated in the unit square – the members have heterogeneous labor types and labor disutility. The differentiated labor is uniformly distributed, indivisible and supplied along the extensive margin, and priced in a staggered fashion by monopolistically competitive unions.

The model features eight disturbances categorized in three groups: demand side, supply side, and labor market shocks. Demand side shocks include the risk premium shock altering the inter-temporal price of consumption, the investment shock altering the conversion of investment to capital, the government spending shock affecting the allocation of economy wide resources, and a shock affecting the interest rate paid on bonds. Supply side shocks include a technology shock affecting labor productivity, and a price markup shock stemming from the degree of substitutability between goods and mirroring shifts in the degree of competition in goods markets. Labor market shocks involve a labor disutility shock causing variations in labor supply and capturing factors such as immigration and the women's entrance in the labor force, and a wage markup shock reflecting shifts in the degree of workers' market power over wages and, thus, the degree of competition in labor markets [Justiniano et al., 2011,

[5] Given the linear solution, the case of downward nominal wage rigidities (DNWR) cannot be examined and remains outside the scope of the paper. Recent studies using high-quality administrative data find no DNWR before and during the Great Recession in some euro-area economies [Verdugo, 2016] and Ireland [Doris et al., 2015] (Kurmann and McEntarfer (2017) and Elsby et al. (2016) find similar evidence for the U.S.A.), and challenge previous survey-based studies [Fabiani et al., 2010; Babecký et al., 2010].

[6] The determination of the country-specific interest rate is stylized and in response to domestic developments in inflation, as well as in the level and the growth rate of the output gap. This is a sufficient approach for our purpose which is the study of wage fluctuations. An alternative option would entail a multi-country framework and a common monetary policy; doing so, though, would make us lose focus by increasing the model complication without adding any substantial gain from additional observables; in fact, Charalampidis (2018) shows that open economy shocks have negligible influence on labor market variables.

Galí et al., 2012b].

4.3 Estimation

The DSGE model is estimated with Bayesian methods, starting in 1991Q2 for Germany and France, and in 1995Q2 for Italy and Spain, and stoping in 2017Q4. Briefly discussed below are the data, the measurement equations, and the state space approach – a detailed discussion is relegated to the Appendix.

4.3.1 Data And A Factor Approach To Wages.

Twelve quarterly series are obtained from ECB, Eurostat, and OECD; a detailed description appears in the Appendix. The series for nominal GDP, private final consumption, and investment are divided by aggregate population and the GDP price deflator. The quarterly log-difference of the latter corresponds to the model's inflation rate. In addition, the three-month interbank interest rate, the unemployment rate, and (the log of) employment per capita enter the observation vector.

Five wage measures are used. First, compensation per employee is the most widely used wage measure. Second, to exclude the influence of social benefits from compensation, wages and salaries per employee are included. Third, to incorporate information on remuneration in the non-public sector (and, thus, attenuating the impact of public sector wage freezes[7]), hourly earnings in the private sector[8] are used. Fourth, to further incorporate wages in the

[7]The findings of Holm-Hadulla et al. (2010) suggest a pro-cyclical bias in public wages. Radowski and Bonin (2008) find wage freezes in the private sector too and, in particular, in services and manufacturing in Germany.

[8]The index is available from the mid-90s; it is bridged to hourly earnings in the manufacture for the countries where the estimation starts earlier than the mid-90s.

private sector, an index for negotiated wages is included[9]. Fifth, to take into account the fluctuations in hours (since, as pointed out by Galí et al. (2012a), the production function is written in terms of labor hours), we include compensation per hour in the observation vector. All wage measures are plotted in the Appendix. They are loaded through a factor specification (the factor for compensation per employee is normalized to one) as in Galí et al. (2012a), Justiniano et al. (2013), Lindé et al. (2016), and Charalampidis (2018), and all wage series include a disperse measurement error.

4.3.2 Priors.

The priors are conventional and reported in Table (D.1). The loading factors are sampled from a disperse Normal distribution around 1 (0.5 std). The prior for the standard deviation of the measurement errors associated with the wage measures is as disperse as that for the standard deviation of the structural shocks. To ease the exploration of the posterior surface, we set a high prior mean for the autoregressive coefficient of the labor disutility shock (0.8) – Galí et al. (2012a), in fact, fix it at 0.999. Including in the sample the volatile behavior of the series during the Great Recession is going to influence the volatility of shocks. This inclusion along with a relative moderate sample length renders useful to reduce the standard deviation of a couple of parameters so that they are kept within ranges aligned with economic theory. For example, the standard deviation of the capital share and of wage stickiness are a tad lower than what is usually postulated in the literature.

4.3.3 State Space.

As for the Bayesian estimation, the treatment of the state space proceeds as in Charalampidis (2018) who operationalizes the state approach of Chan and Jeliazkov (2009) in a DSGE

[9]No such index is available for Spain

context. That approach achieves computational gains and does not require filtering recursions. The Random Walk Metropolis-Hastings algorithm is used to simulate draws from the non-tractable posterior.

4.4 Findings

The presentation of findings begins with real wage growth before moving to nominal wage inflation and unemployment. After that, I examine, in turn, the drivers of wages during the downturns before the troughs, the volatility of shocks during recoveries, and the the role of structural differences in the labor markets of the sample economies in influencing wage growth.

4.4.1 The Determinants of Cyclical Wage Growth during Recoveries.

Real Wage Growth.

Table (4.1) collects the decomposition of real wage growth to trend and cycle, as well as the structural decomposition of the cyclical component. According to these figures, sizable and statistically significant differences in the speed of real wage recoveries across countries and time are observed. In particular, real wage growth in Germany and Spain is about the same, and faster in the period following the sovereign debt crisis than it was on average during the recoveries since the 1990s and up to 2013. In contrast, real wage growth in France and Italy is slower in the former period than it is in the latter. In fact, real wage growth in Italy is negligible. Furthermore, those differences in wage evolution across time are statistically significant in Germany, France, and Italy, but not in Spain.

The above differences are shaped by the cyclical component of real wage growth. More specifically, the evidence of the present paper suggests *a cyclical real wage recovery* in Germany and Spain (the average cumulative eight-quarter-ahead rates are 0.4% and 0.3%, respectively[10]) after the trough of the sovereign debt crisis, and *a cyclical (real) wage-less output recovery* in France and Italy (-1% and -0.6%, respectively).

Delving into the determinants of the cyclical component reveals both similarities and differences across the economies of the sample. A productivity slowdown putting downward pressures to wages in the post-2013 period is observed in all the economies – more so in Germany and France than in Italy and Spain. Moreover, in the post-2013 period, Germany and Spain – the two economies with sizable real wage growth – are characterized by sizable negative price markup shocks elevating the real wage. These shocks imply shifts in the pricing power of firms and a weakening in the pass-through of production costs tp inflation during that period.

In Germany, both cyclical components are ultimately determined by the two supply shocks, namely the competing influence of productivity and price markup shocks, while demand side and labor market shocks have a negligible influence. In the post-2013 period, the upward wage pressures stemming from the price markup shocks exceed the negative effect of the productivity slowdown resulting in a positive real wage growth. In contrast, in the pre-2013 the opposite picture is observed: positive price markup shocks, exerting downward pressure in the real wage, cannot match the positive wage effect stemming from an acceleration in productivity.

The underlying forces of real wage growth in France are similar to those in Germany. The absence of strong negative price markup shocks in the post-2013 period is the only difference compared to the German case. That absence, in fact, explains why the post-2013 real wage growth is not stronger than it was in the pre-2013 period. The absence of an influential

[10] A pro-cyclical real wage in Spain is also found in Font, Izquierdo, and Puente (2015).

role for those shocks in France in the post-2013 period, is validated by the absence of a statistically significant difference between the effect of price markup shocks between the two time windows. In Germany and France, therefore, the size and direction of price markup shocks are highly influential for real wage growth.

Table 4.1: Real Wage Inflation in Recoveries: A Structural Decomposition

	Germany			**France**			**Italy**			**Spain**		
	pre	post	diff	pre	post	diff	pre	post	diff	pre	post	diff
extracted	1.2	2.6	1.4*	2.2	1.0	-1.2**	1.7	-0.1	-1.7**	1.1	2.9	1.8
trend growth	2.2	2.2	0.0	2.1	2.1	0.0	0.5	0.5	0.0	2.5	2.5	0.0
cycle	-1.0	0.4	1.5*	-0.0	-1.0	-1.0	0.8	-0.6	-1.4	-1.8	0.3	2.0
initial obs.	0.0	0.0	-0.0	0.2	-0.0	-0.2	0.4	-0.0	-0.4	0.4	0.1	-0.3
supply	-0.7	0.5	1.2	0.1	-1.1	-1.2**	-0.0	0.3	0.3	-0.6	1.3	1.9
productivity	0.7	-0.8	-1.5*	1.0	-0.7	-1.7**	-1.3	0.0	1.3	-0.3	-0.4	-0.0
price mkp	-1.4	1.3	2.7**	-0.9	-0.3	0.5	1.3	0.3	-1.0*	-0.3	1.6	1.9
demand	-0.2	-0.1	0.1	-0.1	0.1	0.2	1.1	0.5	-0.5	-1.0	1.6	2.6
risk premium	-0.1	0.1	0.2	-0.1	0.0	0.1	0.3	1.3	1.0***	-0.9	1.3	2.3
investment	0.1	-0.1	-0.2**	-0.0	0.1	0.1	0.1	-0.4	-0.5**	0.3	-0.2	-0.5
spending	0.0	-0.1	-0.1***	-0.0	-0.0	0.0	-0.2	-0.2	0.0	-0.2	-0.0	0.1
int. rate	-0.2	0.0	0.3	0.1	-0.0	-0.1	0.8	-0.2	-1.0	-0.3	0.5	0.8
labor	-0.1	-0.0	0.1	-0.1	-0.1	0.0	-0.3	-1.4	-1.2	-0.1	-2.5	-2.5*
wage mkp	-0.1	-0.1	0.1	-0.1	-0.1	-0.0	-0.5	-0.9	-0.4	0.3	-2.7	-3.0**
labor disutility	-0.0	0.1	0.1	-0.0	0.0	0.1	0.2	-0.5	-0.7	-0.4	0.1	0.5

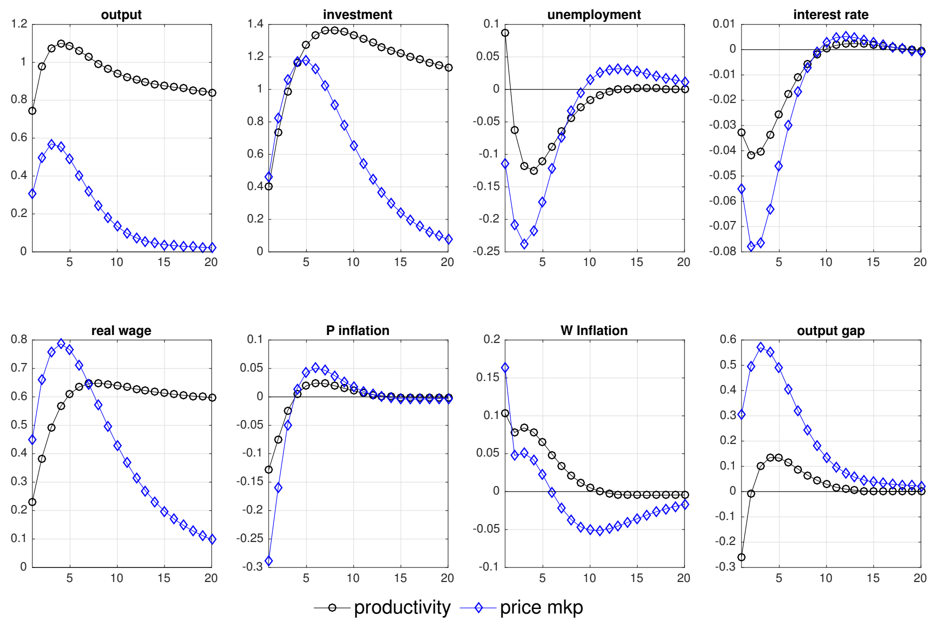
Notes: "Pre": average eight-quarter-ahead cumulative change after a trough during the pre-2013 recoveries. "Post": average eight-quarter-ahead quarterly-rolling cumulative change after the sovereign debt crisis trough and up to the end of the sample. "diff": difference between the pre and post figures. Asterisks (***,** ,*) indicate rejection of the null hypothesis that the cumulative changes during the pre-2013 recoveries come from a normal distribution with mean equal to the post-2013 average change and unknown variance at the (1%, 5%, 10%) significance level (one-sample t-test). *Data Sources:* See text; Authors' computations.

What do positive and markup shocks imply in terms of real wage growth though? Exogenous changes in price markup shocks mirror shifts in the competitiveness of goods markets, and result in a misalignment of prices and production costs: positive/negative price markups raise/decrease price inflation independently of the evolution of costs. Fig.(4.2) reports the impulse response functions to price markup and productivity shocks[11]. In response to a negative price markup shock, inflation decreases and the real wage rises. Decreasing prices lower the interest rate paid on bonds, and trigger an economic stimulus: output, the output

[11] The parameters are set at the posterior mean of Germany.

gap, investment, and nominal wage inflation are boosted while unemployment falls.

Figure 4.2: Price Markups, Productivity, and the Real Wage



Notes: Authors' computations. Impulse Response Functions to a negative price markup shock and a positive productivity shock, evaluated at the posterior parameter mean of Germany.

Before moving to the analysis of Italy and Spain, it is worth delving into the role of wage markup shocks in the case of Germany where the implementation of the various waves of the Hartz labor market reforms started in 2003. According to the evidence of Table (4.1) no statistically significant or sizable difference is observed between the pre- and post-2013 effect of wage markup shocks in Germany. Nevertheless, delving into the effect of wage markup shocks after each trough of the past reveals a richer picture. According to the findings of Table (4.2), the influence of wage markup shocks on real wages, unemployment, and nominal wages changes before and after 2003. For real wages and unemployment, in particular, that influence changes sign. During the pre-2003 recoveries, the real wage increases above what was justified by the labor market slack. In contrast, during the post-2003 recoveries, a weakening in workers' market power over wages leads to a real wage contraction and a steep decline in unemployment. As for nominal wages, they are boosted by wage markup innovations during the pre-2003 recoveries more than they are during the post-2003 recoveries.

Labor supply innovations do not reveal a clear pattern of time variation.

Table 4.2: Workers' Market Power and Adjustment in the German Labor Market

		93:2	96:1	03:1	05:1	09:1	13:1
Δw_t^r	cycle	-0.6	-1.0	-2.6	-2.2	1.2	0.4
	labor	-0.2	-0.1	0.2	-0.7	0.0	-0.0
	wage mkp	-0.1	0.0	0.3	-0.7	-0.1	-0.1
	labor disutility	-0.1	-0.1	-0.1	0.0	0.1	0.1
ΔU_t	cycle	0.7	1.1	1.3	-1.8	-1.2	-0.8
	labor	0.2	0.3	1.2	-1.0	-0.8	-0.5
	wage mkp	0.1	0.3	1.1	-1.0	-0.4	-0.5
	labor disutility	0.1	0.1	0.0	-0.0	-0.4	0.0
π_t^w	cycle	-1.3	-5.1	-4.6	-4.3	-0.6	0.1
	labor	1.2	1.7	2.9	0.9	1.0	-0.2
	wage mkp	1.3	1.9	3.1	0.9	1.0	-0.1
	labor disutility	-0.2	-0.2	-0.2	-0.0	0.0	-0.1

Notes: Eight-quarter-ahead cumulative change after a trough. *Data Sources:* See text; Authors' computations. Δw_t^r: real wage growth; ΔU_t: change in the unemployment rate; π_t^w: nominal wage inflation.

Turning to the determinants of the cyclical part of real wage inflation in Italy and Spain, we observe that all types of innovations are influential. During the post-2013 period, both countries exhibit similarities in the sense that, in both economies, price markup shocks shape the overall effect of supply side shocks, and that both supply and demand side shocks boost real wage growth whereas labor market shocks, driven by a weakening in workers' market power exert downward pressures to real wages. In both economies, the pick-up of demand side shocks is determined by the risk premium shock – a result that is compatible with the rising role of that shock in the U.S. economy found by Galí, Smets, and Wouters (2012a). Nevertheless, the -0.6% post-2013 cyclical real wage change in Italy falls below the 0.3% wage change observed in Spain due to fact that in the latter country the combination of demand and supply side shocks exceeds the effect of labor market shocks whereas in the former country it does not. That difference is heavily influence by the sizable price markup shocks in Spain.

Italy and Spain demonstrate additional differences between their respective pre- and post-2013 recoveries. More specifically, in Italy risk premium and investment shocks exhibit a statistically significant difference across time, implying an increase in the sensitivity of the real wage to demand conditions. In contrast, in Spain, sizable wage markup shocks suggest a weakening of workers' market power and bridge the declining unemployment with the observed weak wage growth. It is worthwhile to mention that labor supply shocks in Italy during the post-2013 period exert downward wage pressures. This effect likely implies an increase in the Italian labor force participation. The origins of the latter could be a combination of immigration, a decrease in the number of undocumented employees, and an increase in the participation of workers in the market.

Nominal Wage Growth.

Considering nominal wage growth in Table (4.3) reveals a picture compatible with that observed for real wage growth. In nominal terms, wage growth during the recovery from the Great Recession is weaker in France and Italy than it is in Germany and Spain. Nevertheless, the cyclical component of nominal wage inflation is negative in the post-2013 period in all the economies but in Germany. This observation for the case of Spain in the post-2013 period highlights the importance of jointly studying wages and inflation: despite the negative cyclical nominal wage growth(-4.1%), cyclical real wage growth is positive (0.3%).

The decomposition of the cyclical part of nominal wage inflation reveal that the entire set of innovations influences nominal wages contrary to real wages where only subset of disturbances matters in some economies. In Germany, no influence of supply side shocks on nominal wage inflation is found. Instead, the positive cyclical nominal wage growth in Germany is driven by a demand stimulus that overcomes a small negative effect coming from labor market shocks. In fact, both effects are statistically different from the negative effect of demand side shocks and the positive effect coming from the market power of workers during the pre-2013 recoveries.

France and Germany are not as similar in terms of nominal wages as they are in term of the real wage. In France, sizable supply side shocks, accompanied by demand side shocks and in particular risk premium innovations, exert downward pressures on nominal wages. In Italy, sizable downward pressures on nominal wages coming from the supply side and the labor market dominate the positive, albeit small, effect of rising demand. The cyclical nominal wage contraction in Spain is driven by demand and labor market shocks.

Table 4.3: Nominal Wage Inflation in Recoveries: A Structural Decomposition

	Germany			**France**			**Italy**			**Spain**		
	pre	post	diff	pre	post	diff	pre	post	diff	pre	post	diff
extracted	3.2	5.9	2.7**	4.7	2.3	-2.4*	5.0	1.5	-3.5***	5.1	3.7	-1.3
trend growth	5.5	5.5	0.0	4.9	4.9	0.0	4.8	4.8	0.0	6.9	6.9	0.0
cycle	-3.2	0.1	3.3**	-0.9	-2.7	-1.8	-0.7	-3.6	-2.9**	-3.9	-4.1	-0.2
initial obs.	0.8	0.2	-0.6*	0.7	0.1	-0.6	0.9	0.3	-0.6	2.1	0.9	-1.1
supply	-0.2	-0.2	0.0	-0.0	-1.0	-1.0**	-0.0	-2.3	-2.3**	0.4	0.1	-0.3
productivity	-0.0	-0.7	-0.7	0.3	-0.7	-1.0	-2.1	0.1	2.2**	-2.3	-1.0	1.3
price mkp	-0.2	0.6	0.8	-0.3	-0.3	-0.0	2.1	-2.4	-4.5***	2.7	1.0	-1.6
demand	-4.5	0.5	5.0***	-1.2	-1.7	-0.5	1.1	0.7	-0.4	-1.5	-0.4	1.2
risk premium	-4.0	-2.2	1.9**	-1.1	-3.0	-1.9**	0.4	1.3	0.9***	-2.9	0.1	3.0
investment	-0.1	-1.0	-0.9*	-0.4	0.3	0.8*	0.1	-0.2	-0.2	-0.3	-0.5	-0.2
spending	0.1	0.5	0.5***	0.0	0.1	0.1	-0.2	-0.2	0.0	-0.1	0.2	0.3*
int. rate	-0.5	3.2	3.6*	0.3	0.8	0.5	0.9	-0.2	-1.1	1.7	-0.2	-1.9
labor	1.5	-0.2	-1.7***	0.3	0.0	-0.3*	-1.8	-2.0	-0.2	-2.8	-3.8	-1.0
wage mkp	1.6	-0.1	-1.7**	0.4	0.2	-0.2	-2.0	-1.5	0.5	-2.8	-4.0	-1.2
labor disutility	-0.1	-0.1	-0.0	-0.1	-0.1	-0.0	0.2	-0.5	-0.7*	0.0	0.2	0.2

Notes: "Pre": average eight-quarter-ahead cumulative change after a trough during the pre-2013 recoveries. "Post": average eight-quarter-ahead quarterly-rolling cumulative change after the sovereign debt crisis trough and up to the end of the sample. "diff": difference between the pre and post figures. Asterisks (***,** ,*) indicate rejection of the null hypothesis that the cumulative changes during the pre-2013 recoveries come from a normal distribution with mean equal to the post-2013 average change and unknown variance at the (1%, 5%, 10%) significance level (one-sample t-test). *Data Sources:* See text; Authors' computations.

Unemployment.

It is important to investigate how the above findings about the shocks' influence are reflected on the unemployment fluctuations. Table (4.4) reports the decomposition for unemployment. The table reveals that in all economies but in Italy, a weakening in workers' market power is the main determinant of the post-2013 unemployment decline. In Italy, and in Spain to a some extent, a sizable influence of the post-2013 demand pick up on the unemployment decline is found.

Table 4.4: The Unemployment Rate in Recoveries: A Structural Decomposition

	Germany			France			Italy			Spain		
	pre	post	diff	pre	post	diff	pre	post	diff	pre	post	diff
cycle	0.0	-0.8	-0.8	0.4	-0.4	-0.7*	-0.8	-0.8	0.0	1.9	-4.6	-6.5
initial obs.	-0.0	0.0	0.0	-0.1	0.0	0.1	-0.0	0.0	0.0	0.0	0.0	-0.0
supply	0.3	-0.2	-0.6***	0.2	-0.0	-0.2	1.6	0.2	-1.4*	-0.1	-0.2	-0.1
technology	-0.1	-0.1	-0.0	-0.3	-0.0	0.2	1.5	0.1	-1.4**	-0.3	0.0	0.3
price mkp	0.4	-0.1	-0.5***	0.4	0.0	-0.4*	0.1	0.1	-0.0	0.1	-0.2	-0.4
demand	-0.3	-0.1	0.2	-0.3	-0.1	0.2	-1.4	-1.1	0.3	0.2	-1.1	-1.3
risk prem.	-0.3	-0.1	0.2**	0.1	-0.1	-0.2	-1.5	-1.2	0.3	-0.4	-0.7	-0.3
investment	-0.5	-0.0	0.5	-0.3	-0.0	0.3	-0.5	0.3	0.9*	-0.2	0.2	0.4
spending	-0.2	0.1	0.3	0.1	0.0	-0.1	0.4	0.0	-0.4	-0.2	-0.0	0.2
int. rate	0.8	0.0	-0.7***	-0.2	0.0	0.2	0.3	-0.3	-0.5	1.0	-0.5	-1.6
labor	-0.0	-0.5	-0.5	0.5	-0.3	-0.8***	-1.0	0.2	1.2	1.8	-3.2	-5.1
wage mkp	0.0	-0.5	-0.5	0.4	-0.2	-0.6**	-0.4	-0.4	-0.0	1.3	-3.4	-4.8
supply	-0.0	0.0	0.1	0.1	-0.0	-0.2*	-0.7	0.5	1.2	0.5	0.2	-0.3

Notes: "Pre": average eight-quarter-ahead cumulative change after a trough during the pre-2013 recoveries. "Post": average eight-quarter-ahead quarterly-rolling cumulative change after the sovereign debt crisis trough and up to the end of the sample. "diff": difference between the pre and post figures. Asterisks (***,** ,*) indicate rejection of the null hypothesis that the cumulative changes during the pre-2013 recoveries come from a normal distribution with mean equal to the post-2013 average change and unknown variance at the (1%, 5%, 10%) significance level (one-sample t-test). *Data Sources:* See text; Authors' computations.

4.4.2 The Determinants of Cyclical Wage Growth during Recessions.

The present paper has uncovered a statistically different wage behavior between the output recoveries in the pre-2013 period and the post-2013 experience. That difference has been traced out to its origins. Nevertheless, the above analysis does not shed light on whether the wage developments in the pre- and post-2013 periods differ during recessionary episodes that end up in an economic trough.

This section tackles this issue by pinning down the determinants of the wage evolution during recessions that led to a trough in the pre- and post-2013 period. Table (4.5) computes wage growth during the recessionary episodes and decomposes it in its driving forces – in the interest of space, only the decomposition to the three categories of shocks is shown; detailed results are available upon request.

According to the evidence of Table (4.5), three results stand out. First, the evidence does not suggest statistically significant differences across time in the wage behavior during economic downturns that lead to a recession. This observation contradicts the statistically different wage behavior uncovered during the recoveries. Second, rather surprisingly, in Germany, wage growth is positive during the eight quarters preceding the sovereign debt crisis trough, whereas the opposite holds in all other economies. This result entirely stems from the effect of supply side shocks. Given the positive effect of those shocks on the real wage during the recovery, this result implies that the positive effect of supply side shocks, and in particular of the negative price markup shocks, on the German real wage has started well before the trough and continued after that, and it was not affected by the economic downturn. Third, demand side shocks are prevalent in the southern economies during the recession of the sovereign debt crisis, and imply a steep decline in the real wage.

4.4.3 The Determinants of Wage Volatility during Recoveries.

The above analysis has examined the first moments of the stochastic properties of wages and of their determinants. Thus, it has not been informative about the volatility of the influence of its shock on wage growth. Hence, we now turn to the volatility of wages and of their determinants during recoveries – we consider the pre-2009 recoveries, and the recoveries from the Great Recession and the sovereign debt crisis separately to examine whether those two periods exhibit similar or different characteristics.

Table 4.5: Real Wage Growth, Recoveries vs Recessions

	Germany			**France**			**Italy**			**Spain**		
	pre	post	diff	pre	post	diff	pre	post	diff	pre	post	diff
recession												
cycle	-0.3	1.0	1.4	0.4	-0.5	-0.9	-0.8	0.0	0.7	2.5	-5.2	-7.7
supply	-0.4	1.0	1.4	0.3	-0.7	-1.1	-0.3	0.2	0.5	0.1	-0.7	-0.8
demand	-0.1	0.0	0.1	-0.3	0.1	0.3**	0.2	-2.1	-2.3**	-0.8	-3.8	-2.9
labor	0.1	0.0	-0.1	0.3	0.2	-0.1	-0.7	1.9	2.6**	3.3	-0.7	-4.0
recovery												
cycle	-1.0	0.4	1.5*	0.0	-1.0	-1.0	0.8	-0.6	-1.4	-1.8	0.3	2.0
supply	-0.7	0.5	1.2	0.1	-1.1	-1.2**	0.0	0.3	0.3	-0.6	1.3	1.9
demand	-0.2	-0.1	0.1	-0.1	0.1	0.2	1.1	0.5	-0.5	-1.0	1.6	2.6
labor	-0.1	0.0	0.1	-0.1	-0.1	0.0	-0.3	-1.4	-1.2	-0.1	-2.5	-2.5*

Notes: "Pre": average eight-quarter cumulative change before a trough during the pre-2013 recoveries. "Post": average eight-quarter cumulative change before the sovereign debt crisis trough. "diff": difference between the pre and post figures. Asterisks (***,** ,*) indicate rejection of the null hypothesis that the cumulative changes during the pre-2013 recoveries come from a normal distribution with mean equal to the post-2013 average change and unknown variance at the (1%, 5%, 10%) significance level (one-sample t-test). *Data Sources:* See text; Authors' computations.

Table (4.6) reveals sizable time differences neither in wage volatility nor in the volatility of the drivers of real wage growth. Price markup shocks are one of the most volatile shocks contradicting the low volatility of demand side shocks. Wage markup shocks too exhibit low volatility, with Spain being an exception where these shocks have been volatile across time.

Table 4.6: Wage Volatility In Recoveries

	Germany			**France**			**Italy**			**Spain**		
	pre	GR	SD	pre	GR	SD	pre	GR	SD	pre	GR	SD
cycle	0.3	0.5	0.2	0.2	0.3	0.2	0.6	0.3	0.2	0.4	0.5	0.5
productivity	0.1	0.7	0.1	0.1	0.2	0.1	0.1	0.2	0.0	0.0	0.0	0.0
price mkp	0.3	0.4	0.2	0.1	0.3	0.2	0.6	0.3	0.2	0.2	0.2	0.4
risk premium	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.1
investment	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
spending	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.1
int. rate	0.0	0.2	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.2	0.1
wage mkp	0.2	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.3	0.4	0.4
labor disutility	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.1

Notes: "Pre": average eight-quarter volatility after a trough during the pre-2009 recoveries. "GR": average eight-quarter volatility after the trough of the Great Recession. "SD": average eight-quarter volatility after the trough of the sovereign debt crisis. *Data Sources:* See text; Authors' computations.

4.4.4 Wages and the Role of Structures during Recoveries.

The present study has so far investigated the stochastic properties of the disturbances across time, but has remained silent about structural differences across the economies that may influence the transmission of shocks and, in turn, wage growth. To that end, we now look at the role of structural differences in the labor markets of the sample economies. Table (4.7) presents a subset of the posterior parameter estimates that includes only those that are directly associated with the labor market. The table reveals some differences across the four economies – the differences are rather sizable in terms of the inverse Frisch elasticity and the volatility of wage and labor disutility shocks. Both Germany and France suggest high inverse Frisch elasticity estimates compared to the estimates for Italy and Spain. The volatility of wage markup shocks is the highest in Germany, whereas the volatility of exogenous shifts in the labor force is the largest in Spain.

Table 4.7: Parameter Estimates associated with the Labor Market

		Posterior Mean [5-95%]			
		Germany	**France**	**Italy**	**Spain**
wage mkp	υ_w	0.33 [0.26, 0.40]	0.43 [0.32, 0.54]	0.27 [0.18, 0.38]	0.33 [0.23, 0.47]
inv. Frisch	χ	5.73 [4.69, 6.95]	3.99 [3.11, 4.90]	2.18 [1.46, 3.00]	1.37 [1.00, 1.89]
wage Calvo	ζ_w	0.42 [0.31, 0.56]	0.48 [0.40, 0.55]	0.54 [0.45, 0.63]	0.40 [0.31, 0.51]
wage index.	ι_w	0.33 [0.15, 0.53]	0.23 [0.11, 0.37]	0.14 [0.07, 0.22]	0.40 [0.18, 0.65]
wealth effect	ν	0.04 [0.00, 0.14]	0.04 [0.00, 0.10]	0.01 [0.00, 0.02]	0.00 [0.00, 0.01]
AR wage mkp	ρ_w	0.86 [0.68, 0.95]	0.91 [0.85, 0.96]	0.93 [0.86, 0.97]	0.85 [0.76, 0.91]
std wage mkp	σ_w	8.83 [4.62, 18.46]	2.28 [1.57, 3.27]	1.58 [0.74, 3.10]	4.60 [2.73, 7.53]
AR labor dis.	ρ_χ	1.00 [0.99, 1.00]	0.99 [0.97, 1.00]	0.94 [0.89, 0.97]	0.92 [0.90, 0.95]
std labor dis.	σ_χ	1.62 [1.31, 1.99]	0.79 [0.61, 1.00]	1.74 [1.22, 2.38]	2.49 [1.78, 3.44]

Notes: The table reports a subset of the posterior distribution of all the parameters estimates of the model. The complete set is relegated to the Appendix. *Data Sources:* See text; Authors' computations.

To understand the influence of the above structural differences on wage growth, we conduct the following experiment. We ask, how would the post-2013 real wage growth have looked like, if the labor markets of all the economies had been similar to the German labor market ? To answer this question, the posterior mean estimates of the parameters associated with the German labor market are substituted in the model for each of the economies of the sample –

the latter model is then simulated on the set of extracted innovations for the period after the sovereign debt crisis trough. The eight-quarter-ahead quarterly rolling cumulative change in the real wage is then computed and displayed in Table (4.8).

The evidence of the table suggests no sizable differences when all the parameters associated with the labor market are similar to those in Germany. Thus, in the sample economies, the structural differences in the labor market are not sufficient to generate sizable differences in terms of the wage evolution. An exception is the case of Spain, where the simulated cyclical real wage growth is higher than its observed counterpart. The entire effect in that case comes from replacing the low Spanish inverse Frisch elasticity (1.4) with the much higher German one (5.7): the higher that elasticity, the higher the response of wages to labor market aggregates. Hence, the steep unemployment decline in Spain would translate to strong wage growth for a high inverse Frisch elasticity.

Table 4.8: Post-2013 Real Wage Growth, The Role of Structural Differences

	actual	**simulated**	**diff.**
Germany	0.4	0.4	-0.1
France	-1.0	-1.1	-0.1
Italy	-0.6	-0.8	-0.2
Spain	0.4	2.7	2.3

Notes: The table reports the simulated real wage growth in each economy when the posterior mean of the parameters associated with the labor market in Germany replaces the same parameters of each economy, and simulation takes place in the time period after the sovereign debt crisis trough.

4.5 Concluding Remarks

The present paper contributes in the literature that studies the driving factors of wage growth after the Great Recession in two ways. First, it provides a structural interpretation of the driving factors of wage growth and, thereby, quantifies the relative importance of a variety of factors. Second, it emphasizes the wage evolution during output recoveries since the 1990s to today. In doing so, it sheds light on an unexplored aspect of business cycle fluctuations.

The present paper documents the phenomenon of a cyclical real wage recovery in Germany and Spain, and of a cyclical wage-less output recovery in France and Italy during the period after the sovereign debt crisis. In terms of the underlying forces of those phenomena, this paper finds a weakening in the pass-through of production costs to inflation, as well as a productivity slowdown, in all the economies of the sample to some extent. Those phenomena are prevalent in Germany and France and influential in Italy and Spain. In the last two economies, however, both a pick up in demand and a weakening in workers' market power are highly influential on wage growth as well.

This study provided a versatile platform to further build upon it. Further explorations to be undertaken involve digging deeper on the role of structural differences in the labor markets of the sample economies, understanding better the post-2013 wage experience compared to previous recoveries in terms of changes in the structural features of the sample economies, and connecting the results of the post-2013 period to the structural reforms that took place in those economies.

Appendix A

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

A.1 Model

A.1.1 Nonlinear.

This section collects the nonlinear non-stationary equilibrium equations.

Households.

The first order equilibrium conditions for μ family read as follows:

$$\Xi_t^{\mu} = 1/\left[C_t^{\mu} - \eta C_{t-1}^{\mu}\right] \tag{A.1}$$

$$\Xi_t^{\mu} = E_t \beta^{\mu} \Xi_{t+1}^{\mu} e^{\upsilon_t^b} R_t / \Pi_{t+1} + \Lambda_t^{\mu} \tag{A.2}$$

$$\begin{aligned} \Xi_t^{\mu} Q_t \left[1 + S'_{\omega}\left(\frac{\Omega_t^{\mu}}{\Omega_{t-1}^{\mu}}\right)\right] &= \beta^{\mu} E_t \Xi_{t+1}^{\mu} Q_{t+1} \left[1 - S_{\omega}\left(\frac{\Omega_{t+1}^{\mu}}{\Omega_t^{\mu}}\right) + \frac{\Omega_{t+1}^{\mu}}{\Omega_t^{\mu}} S'_{\omega}\left(\frac{\Omega_{t+1}^{\mu}}{\Omega_t^{\mu}}\right)\right] \\ &+ \frac{\phi^{\mu} \upsilon_t^{\omega}}{\Omega_t^{\mu}} + \Xi_t^{\mu} V_t + \Lambda_t^{\mu} m_t E_t \left(\frac{Q_{t+1}\Pi_{t+1}}{e^{\upsilon_t^b} R_t}\right) \end{aligned} \tag{A.3}$$

$\{\Xi_t^{\mu}, \Lambda_t^{\mu}\}$ are the multipliers associated with the budget constraints. (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:

$$W_t^{i,h,r}(j) = \theta(L_t^i(j))^{\chi}/\Xi_t^i = \theta(L_t(j))^{\chi}/\Xi_t^{\mu} \tag{A.4}$$

The first order equilibrium conditions for τ family read as follows:

$$\Xi_t^{\tau} = 1/\left[C_t^{\tau} - \eta C_{t-1}^{\tau}\right] \tag{A.5}$$

$$\Xi_t^{\tau} = E_t \beta^{\tau} \Xi_{t+1}^{\tau} e^{\upsilon_t^b} R_t / \Pi_{t+1} \tag{A.6}$$

$$\begin{aligned} \Xi_t^{\tau} Q_t \left[1 + S'_{\omega}\left(\frac{\Omega_t^{\tau}}{\Omega_{t-1}^{\tau}}\right)\right] &= \beta^{\tau} E_t \Xi_{t+1}^{\tau} Q_{t+1} \left[1 - S_{\omega}\left(\frac{\Omega_{t+1}^{\tau}}{\Omega_t^{\tau}}\right) + \frac{\Omega_{t+1}^{\tau}}{\Omega_t^{\tau}} S'_{\omega}\left(\frac{\Omega_{t+1}^{\tau}}{\Omega_t^{\tau}}\right)\right] \\ &+ \frac{\phi^{\tau} \upsilon_t^{\omega}}{\Omega_t^{\tau}} + \Xi_t^{\tau} V_t \end{aligned} \tag{A.7}$$

where $\{\Xi_t^{\tau}\}$ 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:

$$W_t^{i,h,r}(j) = \theta(L_t^i(j))^\chi/\Xi_t^i = \theta(L_t(j))^\chi/\Xi_t^\tau \tag{A.8}$$

Capital Production.

The optimization problem of the capital producing firm (1.8) pins down the equilibrium rental rate of capital:

$$R_t^{k,r} \equiv R_t^k/P_t = a'(u_t) \tag{A.9}$$

The price of capital, Q_t^k, is determined by

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

Investment dynamics are pinned down by

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

Intermediate Good Firms.

Maximization of (2.6) yields the optimal price for an optimizing firm as the weighted average of current and future marginal costs:

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

Taking into account the infrequent price adjustment and that all optimizing firms choose the same price P_t°, the evolution of the aggregate price index (2.2) is described by

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

Labor Unions.

Maximization of (2.12) yields the optimal wage, W_t°, chosen by all re-optimizing unions:

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

The aggregate wage is given by:

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

A.1.2 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. $c_t^j = C_t^j / Z_t$, $b_t^j = B_t^j / (P_t Z_t)$ 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 $\lambda_t^\mu = \Lambda_t^\mu Z_t$. 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: $\omega_t^j \equiv \Omega_t^j/1$.

Households.

The first order conditions (A.1-A.3) for the middle class become:

$$\xi_t^\mu = 1/\left[c_t^\mu - \eta c_{t-1}^\mu/(e^\gamma)\right] \tag{A.16}$$

$$\xi_t^\mu = E_t \beta^\mu \xi_{t+1}^\mu \frac{1}{e^\gamma} \frac{e^{\upsilon_t^b} R_t}{\Pi_{t+1}} + \lambda_t^\mu \tag{A.17}$$

$$\begin{aligned} \xi_t^\mu q_t \left[1 + S_\omega'\left(\frac{\omega_t^\mu}{\omega_{t-1}^\mu}\right)\right] = \beta^\mu E_t \xi_{t+1}^\mu q_{t+1} \left[1 - S_\omega\left(\frac{\omega_{t+1}^\mu}{\omega_t^\mu}\right) + \frac{\omega_{t+1}^\mu}{\omega_t^\mu} S_\omega'\left(\frac{\omega_{t+1}^\mu}{\omega_t^\mu}\right)\right] + \\ + \frac{\phi^\mu \upsilon_t^\omega}{\omega_t^\mu} + \xi_t^\mu \upsilon_t + \lambda_t^\mu e^\gamma m_t E_t \left(\frac{q_{t+1}\Pi_{t+1}}{e^{\upsilon_t^b} R_t}\right) \end{aligned} \tag{A.18}$$

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

$$\xi_t^\tau = 1/\left[c_t^\tau - \eta c_{t-1}^\tau/(e^\gamma)\right] \tag{A.19}$$

$$\xi_t^\tau = E_t \beta^\tau \xi_{t+1}^\tau \frac{1}{e^\gamma} \frac{e^{\upsilon_t^b} R_t}{\Pi_{t+1}} \tag{A.20}$$

$$\begin{aligned} \xi_t^\tau q_t \left[1 + S_\omega'\left(\frac{\omega_t^\tau}{\omega_{t-1}^\tau}\right)\right] = \beta^\tau E_t \xi_{t+1}^\tau q_{t+1} \left[1 - S_\omega\left(\frac{\omega_{t+1}^\tau}{\omega_t^\tau}\right) + \frac{\omega_{t+1}^\tau}{\omega_t^\tau} S_\omega'\left(\frac{\omega_{t+1}^\tau}{\omega_t^\tau}\right)\right] + \\ + \frac{\phi^\tau \upsilon_t^\omega}{\omega_t^\tau} + \xi_t^\tau \upsilon_t \end{aligned} \tag{A.21}$$

The budget constraints (2.14) and (1.7) for the bottom become:

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

and

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

Capital Producers.

The effective capital and the rental rate read as

$$k_t = u_t \bar{k}_{t-1}\frac{1}{e^{\gamma}} \quad and \quad R_t^{k,r} = a'(u_t) \tag{A.24}$$

Period-t (real) dividends (1.8) are given by

$$div_t \equiv R_t^{k,r}k_t - a(u_t)\bar{k}_{t-1}\frac{1}{e^{\gamma}} - i_t - \Phi_k \tag{A.25}$$

The law of capital accumulation (2.9) becomes:

$$\bar{k}_t = (1-\delta)\bar{k}_{t-1}\frac{1}{e^{\gamma}} + \upsilon_t^i \left(1 - S\left(\frac{i_t}{i_{t-1}}e^{\gamma}\right)\right) i_t \tag{A.26}$$

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

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

Investment dynamics are governed by

$$1 = q_t^k \upsilon_t^i \left[1 - S\left(\frac{i_t}{i_{t-1}}e^{\gamma}\right) - \frac{i_t}{i_{t-1}}e^{\gamma} S'\left(\frac{i_t}{i_{t-1}}e^{\gamma}\right)\right] + E_t \frac{\xi_{t+1}^{avg}}{\xi_t^{avg} e^{\gamma}} q_{t+1}^k \upsilon_{t+1}^i \left(\frac{i_{t+1}}{i_t}e^{\gamma}\right)^2 S'\left(\frac{i_{t+1}}{i_t}e^{\gamma}\right) \tag{A.28}$$

Average Stochastic Discount Factor.

The stationary factor reads as

$$\xi_{t+s}^{avg}/\xi_t^{avg} \equiv (\beta^{\tau})^s [n^{\tau}\xi_{t+s}^{\tau} + n^{\mu}\xi_{t+s}^{\mu}]/[n^{\tau}\xi_t^{\tau} + n^{\mu}\xi_t^{\mu}] \tag{A.29}$$

Intermediate Good.

The production function (2.3) reads as:

$$y_t(i) = e^{\widehat{z}_t} k_t^{\alpha}(i) L_t(i)^{1-\alpha} - \Phi_y \tag{A.30}$$

The capital-labor ratio reads as

$$k_t(i)/L_t(i) = [\alpha/(1-\alpha)](W_t/P_t Z_t)/(R_t^k/P_t) = [\alpha/(1-\alpha)](w_t^r/R_t^{k,r}) \tag{A.31}$$

and the (real) marginal cost (2.5) as:

$$mc_t^r \equiv MC_t/P_t = (\alpha)^{-\alpha}(1-\alpha)^{-(1-\alpha)}(w_t^r)^{(1-\alpha)}(R_t^{k,r})^{\alpha} e^{-\widehat{z}_t} \tag{A.32}$$

Aggregate (real) profits in the intermediate good sector are:

$$\pi_t^{int} \equiv \Pi_t^{int}/Z_t = y_t - w_t^r L_t - R_t^{k,r} k_t \tag{A.33}$$

The optimal price for optimizing firms (A.12) is determined by

$$E_t \sum_{s=0}^{+\infty} (\zeta_p)^s \left[\xi_{t+s}^{avg}/\xi_t^{avg}\right] (X_{t,s}^p/P_{t+s})^{-\lambda_{p,t+s}} y_{t+s} \frac{1}{\upsilon_{t+s}^p} \left[\frac{P_t^{\circ,r} X_{t,s}^p}{\prod_{l=1}^s \Pi_{t+l}} - (1+\upsilon_{t+s}^p) mc_{t+s}^r\right] = 0 \tag{A.34}$$

where $P_t^{\circ,r} \equiv P_t^\circ/P_t$ and the time-varying price markup is redefined as $(1+\upsilon_t^p) \equiv \lambda_t^p/(\lambda_t^p - 1)$, that is, $\lambda_t^p = 1 + 1/\upsilon_t^p$. The evolution of the aggregate price index (A.13) is described by

$$1 = (1-\zeta_p)(P_t^{\circ,r})^{1-\lambda_t^p} + \zeta_p \left(\Pi_{t-1}^{\iota_p} \Pi^{1-\iota_p}/\Pi_t\right)^{1-\lambda_t^p} \tag{A.35}$$

Labor Demand.

Labor demand for type "j" workers and the aggregate wage (2.11) are given by:

$$L_t(j) = \left(\frac{w_t(j)}{w_t}\right)^{-\lambda_t^w} L_t \quad and \quad w_t = \left(\int w_t(j)^{1-\lambda_t^w} dj\right)^{1/(1-\lambda_t^w)} \tag{A.36}$$

The labor disutility (1.14) expressed in terms of the final good is given by

$$w_t^h(j) = W_t^h(j)/Z_t = \theta(L_t(j))^\chi [n^\mu/\xi_t^\mu + n^\tau/\xi_t^\tau] \tag{A.37}$$

The first order condition determining the (real) optimal wage (A.14) $w_t^\circ = w_t^\circ(j)$ is given by

$$E_t \sum_{s=0}^{+\infty} (\zeta_w)^s \left[\xi_{t+s}^{avg}/\xi_t^{avg}\right] \frac{1}{\upsilon_{t+s}^w} \left[\frac{w_t^{\circ,r} X_{t,s}^w}{e^{\sum_{l=1}^s(\gamma)} \prod_{l=1}^s \Pi_{t+l}} - (1+\upsilon_{t+s}^w) w_{t+s}^h(j)\right] L_{t+s}(j) = 0 \tag{A.38}$$

The gross time-varying wage markup is redefined as $(1+\upsilon_t^w) \equiv \lambda_t^w/(\lambda_t^w - 1)$. The (real) aggregate wage reads as:

$$w_t^r = \left[(1-\zeta_w)(w_t^{\circ,r})^{1-\lambda_{w,t}} + \zeta_w \left(e^\gamma \Pi_{t-1}^{\iota_w} \Pi^{1-\iota_w} w_{t-1}^r/[e^\gamma \Pi_t]\right)^{1-\lambda_{w,t}}\right]^{1/(1-\lambda_{w,t})} \tag{A.39}$$

Policy.

The following equation describes the policy rule (2.16) in the stationary model

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_r} \left[\left(\frac{\Pi_t}{\Pi}\right)^{\psi_\pi} \left(\frac{y_t}{y_t^f}\right)^{\psi_y} \left(\frac{y_t/y_{t-1}}{y_t^f/y_{t-1}^f}\right)^{\psi_{\Delta y}}\right]^{1-\rho_r} e^{\upsilon_{mp,t}} \tag{A.40}$$

Aggregation.

Aggregate consumption is the weighted sum of type-specific consumption profiles: $c_t = n^\tau c_t^\tau + n^\mu c_t^\mu$. 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 $n^\tau b_t^\tau = n^\mu b_t^\mu$, and in the equity market: $n^\tau \omega_t^\tau + n^\mu \omega_t^\mu = \omega_t \equiv 1$, where the sum of all equity shares is normalized to unity. Aggregate output is given by $Y_t = e^{\hat{z}_t} k_t^\alpha L_t^{1-\alpha} - \Phi_y$. Aggregate profits in the intermediate good sector are $\{\pi_t^{int} \equiv y_t - w_t^r L_t - R_t^{k,r} k_t\}$. The period-t dividends of the fund managing capital production are given by $\{div_t \equiv R_t^{k,r} k_t - a(u_t)\bar{k}_{t-1}/e^\gamma - i_t - \Phi_k\}$. Thus, economy wide profits are: $\upsilon_t = \pi_t^{int} + div_t$. The resource constraint (2.17) becomes:

$$y_t = c_t + i_t + g_t + ac_t + \Phi_k \tag{A.41}$$

$$ac_t = a(u_t)\bar{k}_{t-1}e^{-\gamma} + q_t\left[n^{\mu}\omega_{t-1}^{\mu}S_{\omega}\left(\omega_t^{\mu}/\omega_{t-1}^{\mu}\right) + n^{\tau}\omega_{t-1}^{\tau}S_{\omega}\left(\omega_t^{\tau}/\omega_{t-1}^{\tau}\right)\right] \tag{A.42}$$

A.1.3 Steady State

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 υ_p and υ_w are estimated in this paper. The real marginal cost is given by eq.(A.34): $mc^r = 1/(1+\upsilon_p)$, with eq.(A.35) implying $P^{\circ,r} = P^{\circ}/P = 1$. 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): $k = \bar{k}/e^{\gamma}$. The latter combined with the capital accumulation equation (A.26) yields the investment-to-output 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: $w^r = [mc^r(\alpha)^{\alpha}(1-\alpha)^{(1-\alpha)}(R^{k,r})^{-\alpha}]^{1/(1-\alpha)}$. 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: $\Pi_t^f = y - w^r L - R^{k,r}k = [(w^r L)/(1-\alpha)][(1/mc^r) - 1] - \Phi_y$. 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: $\xi_{+1}^{avg}/\xi^{avg} = \beta^{\tau}$ 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):

$$R = \Pi e^{\gamma}/\beta^{\tau} \tag{A.43}$$

It coincides with the risk-free rate in the representative agent model given that the discount factor of the top (β^{τ}) 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: $w^{r} = w^{\circ,r} = (1+\upsilon_{w})w^{h}$. Plugging the expressions for the multipliers in the labor disutility (A.37) implies $w^{h} = \theta L^{\chi}[n^{\mu}/\xi^{\mu} + n^{\tau}/\xi^{\tau}] = \theta L^{\chi}[1-\eta/e^{\gamma}][n^{\mu}c^{\mu} + n^{\tau}c^{\tau}] = \theta L^{\chi}[1-\eta/e^{\gamma}]c$. 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.

Family-specific variables.

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

$$\lambda^{\mu} = (\beta^{\tau} - \beta^{\mu})\xi^{\mu}/\beta^{\tau} \tag{A.44}$$

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:

$$\omega^{\tau} q = \left[\frac{\phi^{\tau}(1-\eta/e^{\gamma})}{1-\beta^{\tau}}\right] c^{\tau} \quad \text{and} \quad \omega^{\mu} q = \left[\frac{\phi^{\mu}(1-\eta/e^{\gamma})}{1-\beta^{\mu}-(\beta^{\tau}-\beta^{\mu})m}\right] c^{\mu} \tag{A.45}$$

The last two equations suggest that the top-to-middle-clss 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 (ϕ^{τ}/ϕ^{μ}); ii) the consumption ratio c^{τ}/c^{μ}; and iii) the difference in the magnitudes between β^{τ} and β^{μ}. 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:

$$b^{\mu} = m\Pi e^{\gamma}\omega^{\mu} q \tag{A.46}$$

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

$$c^{\mu} + b^{\mu}\left[\frac{1}{\Pi e^{\gamma}} - \frac{1}{R}\right] = sw^{r} L/n^{\mu} - g \tag{A.47}$$

Plugging (A.45) in (A.46), and the result in (A.47) yields a solution for the consumption of the middle class (c^{μ}) as a function of aggregate variables already pinned down and of parameters. Then, the consumption of the top (c^{τ}) 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 λ^{μ} from (A.44). Given the equity levels, the intra-household debt (b^μ) 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.1.4 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 $\widehat{x}_t \equiv ln(x_t/x)$. Additionally, $\widehat{r}_t^{k,r} \equiv ln(R_t^{k,r}/R^{k,r})$, $\widehat{\pi}_t \equiv ln(\Pi_t/\Pi)$, and $\widehat{r}_t \equiv ln(R_t/R)$. Since the intermediate good (π_t^{int}) and aggregate (v_t) profits, as well as the dividends (div_t), have a zero steady state value, I define their log-linearized analogues as a ratio to final output, i.e. $\widehat{v}_t = v_t/y = \widehat{\pi}_t^{int} + \widehat{div}_t = \pi_t^{int}/y + div_t/y$.

Households.

The first order conditions for the middle class (A.16-A.18) yield

$$-(1-\eta/e^\gamma)\widehat{\xi}_t^\mu = \widehat{c}_t^\mu - (\eta/e^\gamma)\widehat{c}_{t-1}^\mu \tag{A.48}$$

$$\widehat{\xi}_t^\mu = \left(\frac{\beta^\mu R}{\Pi e^\gamma}\right) E_t\left(\widehat{\xi}_{t+1}^\mu + \widehat{\upsilon}_t^b + \widehat{r}_t - \widehat{\pi}_{t+1}\right) + \left(1 - \frac{\beta^\mu R}{\Pi e^\gamma}\right)\widehat{\lambda}_t^\mu \tag{A.49}$$

$$\begin{aligned}\widehat{\omega}_t^\mu \left[1 + \beta^\mu + \frac{\phi^\mu}{\omega^\mu q \xi^\mu S_\omega''}\right] + \left(\frac{1}{S_\omega''}\right)(\widehat{\xi}_t^\mu + \widehat{q}_t) &= \widehat{\omega}_{t-1}^\mu + \beta^\mu E_t\widehat{\omega}_{t+1}^\mu + (\beta^\mu/S_\omega'')E_t\widehat{\xi}_{t+1}^\mu + \\ &+ \left[\frac{\beta^\mu}{S_\omega''} + \frac{\lambda^\mu}{\xi^\mu}\frac{e^\gamma m\Pi}{S_\omega'' R}\right] E_t\widehat{q}_{t+1} + \left(\frac{\phi^\mu}{\omega^\mu q\xi^\mu S_\omega''}\right)\widehat{\upsilon}_t^\omega + \left(\frac{y}{S_\omega'' q}\right)\widehat{v}_t \\ &+ \left[\frac{\lambda^\mu}{\xi^\mu}\frac{e^\gamma m\Pi}{S_\omega'' R}\right] E_t\left(\widehat{\lambda}_t^\mu + \widehat{m}_t + \widehat{\pi}_{t+1} - \widehat{r}_t - \widehat{\upsilon}_t^b\right)\end{aligned} \tag{A.50}$$

where $\widehat{\upsilon}_t^b \equiv ln(\upsilon_t^b)$ and $\widehat{\upsilon}_t^\omega \equiv ln(\upsilon_t^\omega)$.

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

$$-(1-\eta/e^{\gamma})\widehat{\xi}_t^{\tau} = \widehat{c}_t^{\tau} - (\eta/e^{\gamma})\widehat{c}_{t-1}^{\tau} \tag{A.51}$$

$$\widehat{\xi}_t^{\tau} = E_t\left(\widehat{\xi}_{t+1}^{\tau} + \widehat{\upsilon}_t^{b} + \widehat{r}_t - \widehat{\pi}_{t+1}\right) \tag{A.52}$$

$$\begin{aligned}\widehat{\omega}_t^{\tau}\left[1+\beta^{\tau}+\frac{\phi^{\tau}}{\omega^{\tau}q\xi^{\tau}S''_{\omega}}\right] + \left(\frac{1}{S''_{\omega}}\right)(\widehat{\xi}_t^{\tau}+\widehat{q}_t) &= \widehat{\omega}_{t-1}^{\tau} + \beta^{\tau}E_t\widehat{\omega}_{t+1}^{\tau} + (\beta^{\tau}/S''_{\omega})E_t\widehat{\xi}_{t+1}^{\tau} + \\ &+ \left[\frac{\beta^{\tau}}{S''_{\omega}}\right]E_t\widehat{q}_{t+1} + \left(\frac{\phi^{\tau}}{\omega^{\tau}q\xi^{\tau}S''_{\omega}}\right)\widehat{\upsilon}_t^{\omega} + \left(\frac{y}{S''_{\omega}q}\right)\widehat{\upsilon}_t\end{aligned} \tag{A.53}$$

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

$$\widehat{b}_t^{\mu} = \widehat{m}_t + E_t\widehat{q}_{t+1} + \widehat{\omega}_t^{\mu} + E_t\widehat{\pi}_{t+1} \tag{A.54}$$

$$\begin{aligned}c^{\mu}\widehat{c}_t^{\mu} - (b^{\mu}/R)(\widehat{b}_t^{\mu} - \widehat{r}_t - \widehat{\upsilon}_t^{b}) + (\omega^{\mu}q)(\widehat{\omega}_t^{\mu} - \widehat{\omega}_{t-1}^{\mu}) &= (sw^{r}L/n^{\mu})(\widehat{w}_t^{r} + \widehat{L}_t) + (sw^{r}L/n^{\mu})\widehat{s}_t \\ &- (b^{\mu}/[\Pi e^{\gamma}])(\widehat{b}_{t-1}^{\mu} - \widehat{\pi}_t) + (\omega^{\mu}y)\widehat{\upsilon}_t - g\widehat{g}_t\end{aligned} \tag{A.55}$$

where (A.55) uses the government budget constraint: $t = t^{\mu} = t^{\tau} = g$ and $\widehat{t}_t = \widehat{t}_t^{\mu} = \widehat{t}_t^{\tau} = \widehat{g}_t$. The deviation of the income share from its steady state value is defined as: $\widehat{s}_t \equiv ln(s_t/s)$.

Capital Production.

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

$$\widehat{k}_t = \widehat{u}_t + \widehat{\bar{k}}_{t-1} \quad and \quad \widehat{r}_t^{k,r} = [\psi/(1-\psi)]\widehat{u}_t \tag{A.56}$$

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

$$\widehat{div}_t \equiv (R^{k,r}k/y)\left[\widehat{r}^{k,r}_t + \widehat{k}_t - \widehat{u}_t - \left(\frac{e^{\gamma}-1+\delta}{e^{\gamma}/\beta^{\tau}-1+\delta}\right)\widehat{i}_t\right] \tag{A.57}$$

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

$$\widehat{\bar{k}}_t = [(1-\delta)/e^{\gamma}](\widehat{\bar{k}}_{t-1}) + [1-(1-\delta)/e^{\gamma}](\widehat{\upsilon}^i_t + \widehat{i}_t) \tag{A.58}$$

where $\widehat{\upsilon}^i_t \equiv ln(\upsilon^i_t)$. The dynamics of the price of capital (A.27) are pinned down by:

$$\widehat{q}^k_t = E_t\left(\widehat{\xi}^{avg}_{t+1} - \widehat{\xi}^{avg}_t\right) + \left(\frac{R^{k,r}}{R^{k,r}+1-\delta}\right)E_t\widehat{r}^{r,k}_{t+1} + \left(\frac{1-\delta}{R^{k,r}+1-\delta}\right)E_t\widehat{q}^k_{t+1} \tag{A.59}$$

Investment dynamics (A.28) are governed by

$$\widehat{i}_t = \left(\frac{1}{1+\beta^{\tau}}\right)(\widehat{i}_{t-1}) + \left(\frac{\beta^{\tau}}{1+\beta^{\tau}}\right)(E_t\widehat{i}_{t+1}) + \left[\left(\frac{1}{1+\beta^{\tau}}\right)\left(\frac{1}{e^{2\gamma}S''}\right)\right](\widehat{q}^k_t + \widehat{\upsilon}^i_t) \tag{A.60}$$

Discounting.

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

$$\widehat{\xi}^{avg}_{t+1} - \widehat{\xi}^{avg}_t = \left(\frac{n^{\tau}\xi^{\tau}}{n^{\tau}\xi^{\tau}+n^{\mu}\xi^{\mu}}\right)(\widehat{\xi}^{\tau}_{t+1} - \widehat{\xi}^{\tau}_t) + \left(\frac{n^{\mu}\xi^{\mu}}{n^{\tau}\xi^{\tau}+n^{\mu}\xi^{\mu}}\right)(\widehat{\xi}^{\mu}_{t+1} - \widehat{\xi}^{\mu}_t) \tag{A.61}$$

Intermediate Good.

Log-linearizing the aggregate production function yields

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

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

$$\widehat{k}_t = \widehat{w}_t^r - \widehat{r}_t^{k,r} + \widehat{L}_t \tag{A.63}$$

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

$$\widehat{mc}_t^r = (1-\alpha)\widehat{w}_t^r + \alpha\widehat{r}_t^{k,r} - \widehat{z}_t \tag{A.64}$$

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

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

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

$$\widehat{\pi}_t = \left(\frac{\beta^\tau}{1+\iota_p\beta^\tau}\right)E_t\widehat{\pi}_{t+1} + \left(\frac{1}{1+\iota_p\beta^\tau}\right)\widehat{\pi}_{t-1} \tag{A.66}$$

$$+ \left[\frac{(1-\zeta_p)(1-\zeta_p\beta^\tau)}{\zeta_p(1+\iota_p\beta^\tau)}\right]\left(\widehat{mc}_t^r + \left(\frac{\upsilon_p}{1+\upsilon_p}\right)\widehat{\upsilon}_t^p\right) \tag{A.67}$$

Labor Demand.

Linearizing the labor demand and the wage aggregator in (A.36), the labor disutility (1.14), and the aggregate wage dynamics (A.39) and, then, plugging all those equations in the linearized condition for the optimal wage (A.38) yields:

$$\begin{aligned}&\widehat{w}_t^r - \widehat{w}_{t-1}^r + \widehat{\pi}_t - \iota_w \widehat{\pi}_{t-1} = \beta^\tau \left[E_t \widehat{w}_{t+1}^r - \widehat{w}_t^r + E_t \widehat{\pi}_{t+1} - \iota_w \widehat{\pi}_t\right] + \\ &+ \left[\frac{(1-\zeta_w)(1-\zeta_w\beta^\tau)}{\zeta_w(1+\chi\epsilon_w)}\right] \left(\chi \widehat{L}_t - \left(\frac{(n^\mu \xi^\tau)\widehat{\xi}_t^\mu + (n^\tau \xi^\mu)\widehat{\xi}_t^\tau}{n^\mu \xi^\tau + n^\tau \xi^\mu}\right) - \widehat{w}_t^r + \left(\frac{\upsilon_w}{1+\upsilon_w}\right)\widehat{\upsilon}_t^w\right)\end{aligned} \tag{A.68}$$

The latter is similar to the analogous condition of the representative agent model (A.85) with the difference been detected in the average discount factor of the right-hand-side expression.

Policy.

The linearized policy rule is derived from (A.40):

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r)\left[\psi_\pi \widehat{\pi}_t + \psi_y(\widehat{y}_t - \widehat{y}_t^f) + \psi_{\Delta y}\Delta(\widehat{y}_t - \widehat{y}_t^f)\right] + \epsilon_t^{mp} \tag{A.69}$$

where Δ stands for the first-difference operator.

Aggregation & Market Clearing.

Equity and bonds market clearing imply:

$$(n^\tau \omega^\tau)\widehat{\omega}_t^\tau + (n^\mu \omega^\mu)\widehat{\omega}_t^\mu = 0 \tag{A.70}$$

$$\widehat{b}_t^\tau = \widehat{b}_t^\mu \tag{A.71}$$

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

$$\widehat{c}_t = [n^\mu c^\mu / c]\widehat{c}_t^\mu + [n^\tau c^\tau / c]\widehat{c}_t^\tau \tag{A.72}$$

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

$$(c/y)\widehat{c}_t + (i/y)\widehat{i}_t + (g/y)\widehat{g}_t + (R^{k,r}k/y)\widehat{u}_t = \widehat{y}_t \tag{A.73}$$

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

$$\widehat{v}_t = \widehat{\pi}_t^{int} + \widehat{div}_t \tag{A.74}$$

Equilibrium Definition.

The eight equations (D.19)–(A.53), (A.54), and (A.55) of the household side determine a solution for eight variables: $\{\widehat{\xi}_t^\mu, \widehat{\xi}_t^\tau, \widehat{\lambda}_t^\mu, \widehat{c}_t^\mu, \widehat{c}_t^\tau, \widehat{b}_t^\mu, \widehat{\omega}_t^\mu, \widehat{\omega}_t^\tau\}$. The bond holdings of the top $\{\widehat{b}_t^\tau\}$ are, then, pinned down by the bonds market clearing condition (A.71). The price of equity $\{\widehat{q}_t\}$ is pinned down by the equity market clearing condition (A.70). Aggregate consumption $\{\widehat{c}_t\}$ is given by (A.72). The six equations (D.5)–(D.8) in the capital production side determine a solution for the following six variables: $\{\widehat{\bar{k}}_t, \widehat{k}_t, \widehat{r}_t^{k,r}, \widehat{q}_t^k, \widehat{i}_t, \widehat{div}_t\}$. Equation

(A.61) yields the average discount factor $\{\widehat{\xi}_t^{avg}\}$. The five equations (A.62)–(D.9) pin down the following five variables: $\{\widehat{y}_t, \widehat{L}_t, \widehat{\pi}_t^{int}, \widehat{\pi}_t, \widehat{mc}_t^r\}$. Equation (D.10) determines the real wage $\{\widehat{w}_t^r\}$. The nominal interest rate $\{\widehat{r}_t\}$ is found by (D.17). A solution for the utilization rate $\{\widehat{u}_t\}$ stems from the resource constraint (D.18). Aggregate profits $\{\widehat{v}_t\}$ are given by (A.74).

Dimensionality Reduction.

To reduce the state dimensionality, $\{\xi_t^{\tau}, \xi_t^{\mu}, \widehat{\xi}_t^{avg}\}$ are substituted out of the system using equations (D.19, A.51, A.61). Similarly, the bonds and equity market clearing conditions (A.71, A.70) are used to eliminate $\{\widehat{b}_t^{\mu}\}$ and $\{\widehat{\omega}_t^{\mu}\}$. $\{\widehat{k}_t\}$ is eliminated using (A.24). $\{\widehat{mc}_t^r\}$ is substituted out using (A.64). $\{\widehat{\pi}_t^{int}, \widehat{div}_t, \widehat{v}_t\}$ are eliminated using (A.65, A.57, A.74).

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 A.2 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 ($\widehat{s}_t$) 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 ($\widehat{v}_t^{\omega}$) are scaled to enter with a unitary coefficient in (A.53) and with a properly adjusted coefficient in (D.20). The shock to the debt limit ($\widehat{m}_t$) is not scaled.

Table A.1: Shock Processes

Demand Side		
1. Risk Premium	$\widehat{\upsilon}_t^b = \rho_b \widehat{\upsilon}_{t-1}^b + \epsilon_t^b$	$\epsilon_t^b \sim N(0, \sigma_b^2)$
2. Investment Adjustment Cost	$\widehat{\upsilon}_t^i = \rho_i \widehat{\upsilon}_{t-1}^i + \epsilon_t^i$	$\epsilon_t^i \sim N(0, \sigma_i^2)$
3. Government Spending	$\widehat{g}_t = \rho_g \widehat{g}_{t-1} + \epsilon_t^g + \rho_{gz} \epsilon_t^z$	$\epsilon_t^g \sim N(0, \sigma_g^2)$
4. Monetary Policy Innovation		$\epsilon_t^{mp} \sim N(0, \sigma_{mp}^2)$
Supply Side		
5. Technology	$\widehat{z}_t = \rho_z \widehat{z}_{t-1} + \epsilon_t^z$	$\epsilon_t^z \sim N(0, \sigma_z^2)$
6. Price Markup	$\widehat{\upsilon}_t^p = \rho_p \widehat{\upsilon}_{t-1}^p + \epsilon_t^p$	$\epsilon_t^p \sim N(0, \sigma_p^2)$
7. Wage Markup	$\widehat{\upsilon}_t^w = \rho_w \widehat{\upsilon}_{t-1}^w + \epsilon_t^w$	$\epsilon_t^w \sim N(0, \sigma_w^2)$
Distributional		
8. Income Shock	$\widehat{s}_t = \rho_s \widehat{s}_{t-1} + \epsilon_t^s$	$\epsilon_t^s \sim N(0, \sigma_s^2)$
9. Wealth Shock	$\widehat{\upsilon}_t^\omega = \rho_\omega \widehat{\upsilon}_{t-1}^\omega + \epsilon_t^\omega$	$\epsilon_t^\omega \sim N(0, \sigma_\omega^2)$
10. Credit Shock	$\widehat{m}_t = \rho_m \widehat{m}_{t-1} + \epsilon_t^m$	$\epsilon_t^m \sim N(0, \sigma_m^2)$

A.2 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 complete set of log-linearized equations is reported below.

Inter-Temporal Consumption

$$\widehat{c}_t = \left(\frac{1}{1+\eta/e^{\gamma}}\right)\left[E_t\widehat{c}_{t+1} + (\eta/e^{\gamma})(\widehat{c}_{t-1}) - (1-\eta/e^{\gamma})\left(\widehat{r}_t - E_t\widehat{\pi}_{t+1} - \upsilon_t^b\right)\right] \tag{A.75}$$

Capital Accumulation

$$\widehat{\bar{k}}_t = \left(\frac{1-\delta}{e^{\gamma}}\right)(\widehat{\bar{k}}_{t-1}) + \left(1 - \frac{1-\delta}{e^{\gamma}}\right)\left(\widehat{i}_t + \upsilon_t^i\right) \tag{A.76}$$

Capital Price

$$\widehat{q}_t^k = -\left(\widehat{r}_t - E_t\widehat{\pi}_{t+1} + \upsilon_t^b\right) + \left(\frac{R^{k,r}}{R^{k,r}+1-\delta}\right)E_t\widehat{r}_{t+1}^{k,r} + \left(\frac{1-\delta}{R^{k,r}+1-\delta}\right)E_t\widehat{q}_{t+1}^k \tag{A.77}$$

Investment Dynamics

$$\widehat{i}_t = \left(\frac{\beta}{1+\beta}\right)(E_t\widehat{i}_{t+1}) + \left(\frac{1}{1+\beta}\right)(\widehat{i}_{t-1}) + \left[\left(\frac{1}{1+\beta}\right)\left(\frac{1}{e^{2\gamma}S''}\right)\right]\left(\widehat{q}_t^k + \upsilon_t^i\right) \tag{A.78}$$

Capital Rental Rate

$$\widehat{r}_t^{k,r} = (\psi/(1-\psi))\,\widehat{u}_t \tag{A.79}$$

Effective Capital

$$\widehat{k}_t = \widehat{u}_t + \widehat{\bar{k}}_{t-1} \tag{A.80}$$

Capital Demand

$$\widehat{k}_t = \widehat{w}_t^r - \widehat{r}_t^{k,r} + \widehat{L}_t \tag{A.81}$$

Production Function

$$\widehat{y}_t = (1+\Phi_y/y)\left(\alpha\widehat{k}_t + (1-\alpha)\widehat{L}_t + \widehat{z}_t\right) \tag{A.82}$$

Marginal Cost

$$\widehat{mc}_t^r = (1-\alpha)\widehat{w}_t^r + \alpha\widehat{r}_t^{k,r} - \widehat{z}_t \tag{A.83}$$

Inflation

$$\widehat{\pi}_t = \left(\frac{\beta}{1+\iota_p\beta}\right)E_t\widehat{\pi}_{t+1} + \left(\frac{1}{1+\iota_p\beta}\right)\widehat{\pi}_{t-1} + \left[\frac{(1-\zeta_p)(1-\zeta_p\beta)}{\zeta_p(1+\iota_p\beta)}\right]\left(\widehat{mc}_t^r + \left(\frac{\upsilon_p}{1+\upsilon_p}\right)\widehat{\upsilon}_t^p\right) \tag{A.84}$$

Wage Dynamics

$$\widehat{w}_t^r - \widehat{w}_{t-1}^r + \widehat{\pi}_t - \iota_w \widehat{\pi}_{t-1} = \beta \left[E_t \widehat{w}_{t+1}^r - \widehat{w}_t^r + E_t \widehat{\pi}_{t+1} - \iota_w \widehat{\pi}_t \right] + \\ + \left[\frac{(1-\zeta_w)(1-\zeta_w \beta)}{\zeta_w (1+\chi \epsilon_w)} \right] \left(\chi \widehat{L}_t + \left(\frac{1}{1-\eta/e^\gamma} \right) (\widehat{c}_t - (\eta/e^\gamma)(\widehat{c}_{t-1})) - \widehat{w}_t^r + \left(\frac{\upsilon_w}{1+\upsilon_w} \right) \widehat{\upsilon}_t^w \right) \tag{A.85}$$

Market Clearing

$$(c/y)\widehat{c}_t + (i/y)\widehat{i}_t + (g/y)\widehat{g}_t + \left(R^{k,r} k/y \right) \widehat{u}_t = \widehat{y}_t \tag{A.86}$$

Monetary Policy

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r) \left[\psi_\pi \widehat{\pi}_t + \psi_y (\widehat{y}_t - \widehat{y}_t^f) + \psi_{\Delta y} \Delta (\widehat{y}_t - \widehat{y}_t^f) \right] + \epsilon_t^{mp} \tag{A.87}$$

A.2.1 Shocks.

A few shocks are scaled to enter with a coefficient of one; the risk premium shock is scaled in eq.(A.75) and adjusted accordingly in eq.(A.77); the investment adjustment cost is scaled in eq.(A.78) and adjusted accordingly in eq.(A.76); the price and wage markup shocks are scaled in equations (A.84) and (A.85), respectively; the government spending shock is scaled in eq.(A.86). These adjustments improve the converge of the sampler, introduce correlated priors, and illustrate the impact of the disturbances' prior standard deviation.

A.3 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".

A.4 Observation Equations For Inequality Measures

In this section, I derive the observation equations (1.19) and (1.23) for the top income and wealth shares. The annual top income share (TIS_T) is given by:

$$\frac{\sum_{j=0}^{3} n^{\tau}\left[\frac{(1-s_{t-j})W^{r}_{t-j}L_{t-j}}{n^{\tau}} + \Omega^{\tau}_{t-j}V_{t-j} + \frac{B^{\tau}_{t-j-1}}{P_{t-j-1}\Pi_{t-j}} - \frac{B^{\tau}_{t-j}}{e^{\upsilon^{b}_{t-j}}R_{t-j}P_{t-j}}\right]}{\sum_{j=0}^{3}\left[W^{r}_{t-j}L_{t-j} + V_{t-j}\right]} = \tag{A.88}$$

$$\frac{\sum_{j=0}^{3} n^{\tau}\left[\begin{array}{c}\frac{Z_{t-j}(1-s_{t-j})W^{r}_{t-j}L_{t-j}}{n^{\tau}Z_{t-j}} + Z_{t-j}\Omega^{\tau}_{t-j}\frac{V_{t-j}}{Z_{t-j}} \\ +Z_{t-j}\frac{B^{\tau}_{t-j-1}}{Z_{t-j}P_{t-j-1}\Pi_{t-j}} - Z_{t-j}\frac{B^{\tau}_{t-j}}{e^{\upsilon^{b}_{t-j}}R_{t-j}P_{t-j}Z_{t-j}}\end{array}\right]}{\sum_{j=0}^{3}\left[Z_{t-j}\frac{W^{r}_{t-j}L_{t-j}}{Z_{t-j}} + Z_{t-j}\frac{V_{t-j}}{Z_{t-j}}\right]} = \tag{A.89}$$

$$\frac{\sum_{j=0}^{3} n^{\tau}Z_{t-j}\left[\frac{(1-s_{t-j})w^{r}_{t-j}L_{t-j}}{n^{\tau}} + \omega^{\tau}_{t-j}v_{t-j} + \frac{b^{\tau}_{t-j-1}}{e^{\gamma+\widehat{z}_{t-j}}\Pi_{t-j}} - \frac{b^{\tau}_{t-j}}{e^{\upsilon^{b}_{t-j}}R_{t-j}}\right]}{\sum_{j=0}^{3} Z_{t-j}\left[w^{r}_{t-j}L_{t-j} + v_{t-j}\right]} = \tag{A.90}$$

$$\frac{\sum_{j=0}^{3} n^{\tau}Z_{t-j}\left[\begin{array}{c}\frac{(1-se^{\widehat{s}_{t-j}})w^{r}Le^{\widehat{w}^{r}_{t-j}+\widehat{L}_{t-j}}}{n^{\tau}} + \omega^{\tau}ye^{\widehat{\omega}^{\tau}_{t-j}}\widehat{v}_{t-j} + \frac{b^{\tau}}{e^{\gamma}\Pi}e^{\widehat{b}^{\tau}_{t-j-1}-\widehat{z}_{t-j}-\widehat{\Pi}_{t-j}} \\ -\frac{b^{\tau}}{R}e^{\widehat{b}^{\tau}_{t-j}-\widehat{\upsilon}^{b}_{t-j}-\widehat{r}_{t-j}}\end{array}\right]}{\sum_{j=0}^{3} Z_{t-j}\left[w^{r}Le^{\widehat{w}^{r}_{t-j}+\widehat{L}_{t-j}} + y\widehat{v}_{t-j}\right]} = \tag{A.91}$$

$$= \ldots \text{(first order expansion around the steady state)} \tag{A.92}$$

$$\approx (1-s) + \left(\frac{n^{\tau}b^{\tau}}{e^{\gamma}\Pi w^{r}L} - \frac{n^{\tau}b^{\tau}}{Rw^{r}L}\right) + \tag{A.93}$$

$$+\sum_{j=0}^{3}\nu_j\left[\begin{array}{c}-s\widehat{s}_{t-j} + \left(\frac{n^{\tau}b^{\tau}}{e^{\gamma}\Pi w^{r}L}\right)\left(\widehat{b}^{\tau}_{t-j-1} - \widehat{\pi}_{t-j} - \widehat{w}^{r}_{t-j} - \widehat{L}_{t-j}\right) + \\ -\left(\frac{n^{\tau}b^{\tau}}{Rw^{r}L}\right)\left(\widehat{b}^{\tau}_{t-j} - \widehat{r}_{t-j} - \widehat{\upsilon}^{b}_{t-j} - \widehat{w}^{r}_{t-j} - \widehat{L}_{t-j}\right) + \\ +\widehat{v}_{t-j}\left(\frac{y}{w^{r}L}\right)\left(n^{\tau}\omega^{\tau} - (1-s) - \left(\frac{n^{\tau}b^{\tau}}{e^{\gamma}\Pi w^{r}L}\right)\right)\end{array}\right] \tag{A.94}$$

$$
= \overline{tis} + \sum_{j=0}^{3} \nu_j \begin{bmatrix} -s\widehat{s}_{t-j} - \overline{tis}_b \left(\widehat{w}^r_{t-j} + \widehat{L}_{t-j} \right) \\ + \left(\frac{n^\tau b^\tau}{e^\gamma \Pi w^r L} \right) \left(\widehat{b}^\tau_{t-j-1} - \widehat{\pi}_{t-j} \right) \\ + \left(\frac{n^\tau b^\tau}{R w^r L} \right) \left(\widehat{b}^\tau_{t-j} - \widehat{r}_{t-j} - \widehat{v}^b_{t-j} \right) \\ + \widehat{v}_{t-j} \left(\frac{y}{w^r L} \right) \left(n^\tau \omega^\tau - \overline{tis} \right) \end{bmatrix} \tag{A.95}
$$

where the weights are given by: $\nu_j \equiv e^{(3-j)\gamma}/[e^{3\gamma} + e^{2\gamma} + e^{1\gamma} + 1]$, and $\overline{tis} \equiv (1-s) + \left(\frac{n^\tau b^\tau}{e^\gamma \Pi w^r L} - \frac{n^\tau b^\tau}{R w^r L} \right) = (1-s) + \overline{tis}_b$, and $\overline{tis}_b \equiv \left(\frac{n^\tau b^\tau (R - e^\gamma \Pi)}{e^\gamma \Pi R w^r L} \right)$.

The annual wealth share (1.23) 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 ($n^\tau \Omega^\tau_t + n^\mu \Omega^\mu_t = 1$):

$$\frac{\sum_{j=0}^{3} n^{\tau}\left[Q_{t-j}\Omega_{t-j}^{\tau}+\frac{B_{t-j}^{\tau}}{e^{v_{t-j}^{b}}R_{t-j}P_{t-j}}\right]}{\sum_{j=0}^{3}\left[Q_{t-j}\right]}= \tag{A.96}$$

$$\frac{\sum_{j=0}^{3} n^{\tau}Z_{t-j}\left[\frac{Q_{t-j}}{Z_{t-j}}\Omega_{t-j}^{\tau}+\frac{B_{t-j}^{\tau}/Z_{t-j}}{e^{v_{t-j}^{b}}R_{t-j}P_{t-j}}\right]}{\sum_{j=0}^{3} Z_{t-j}\left[\frac{Q_{t-j}}{Z_{t-j}}\right]}= \tag{A.97}$$

$$\frac{\sum_{j=0}^{3} n^{\tau}Z_{t-j}\left[q_{t-j}\omega_{t-j}^{\tau}+\frac{b_{t-j}^{\tau}}{e^{v_{t-j}^{b}}R_{t-j}}\right]}{\sum_{j=0}^{3} Z_{t-j}\left[q_{t-j}\right]}= \tag{A.98}$$

$$\frac{\sum_{j=0}^{3} n^{\tau}Z_{t-j}\left[q\omega^{\tau}e^{\widehat{q}_{t-j}\widehat{\omega}_{t-j}^{\tau}}+(b^{\tau}/R)e^{\widehat{b}_{t-j}^{\tau}-\widehat{v}_{t-j}^{b}-\widehat{r}_{t-j}}\right]}{\sum_{j=0}^{3} Z_{t-j}\left[qe^{\widehat{q}_{t-j}}\right]}= \tag{A.99}$$

$$= \ldots \text{(first order expansion around the steady state)} \tag{A.100}$$

$$\approx \left(n^{\tau}\omega^{\tau}+\frac{n^{\tau}b^{\tau}}{Rq}\right)+\sum_{j=0}^{3}\nu_j\left[(n^{\tau}\omega^{\tau})\widehat{\omega}_{t-j}^{\tau}+\left(\frac{n^{\tau}b^{\tau}}{Rq}\right)\left(\widehat{b}_{t-j}^{\tau}-\widehat{r}_{t-j}-\widehat{v}_{t-j}^{b}-\widehat{q}_{t-j}\right)\right] \tag{A.101}$$

$$= \overline{tws}+\sum_{j=0}^{3}\nu_j\left[(n^{\tau}\omega^{\tau})\widehat{\omega}_{t-j}^{\tau}+\overline{tws}_b\left(\widehat{b}_{t-j}^{\tau}-\widehat{r}_{t-j}-\widehat{v}_{t-j}^{b}-\widehat{q}_{t-j}\right)\right] \tag{A.102}$$

where $\overline{tws} \equiv \left(n^{\tau}\omega^{\tau}+\frac{n^{\tau}b^{\tau}}{Rq}\right) = n^{\tau}\omega^{\tau}+\overline{tws}_b$, and $\overline{tws}_b \equiv \left(\frac{n^{\tau}b^{\tau}}{Rq}\right)$.

A.5 Data Overview

In Tables (A.2) and (A.3), 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 (A.2) 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 (A.3), 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 A.2: Descriptive Statistics, First Moments

Growth (real)	1954-2009	1954-1983	1984-2009
Top Income Decile	0.40	-0.01	0.86
Top Wealth Decile	0.16	-0.24	0.62
Output	1.8	1.8	1.7
Consumption	2.0	2.1	1.9
Inflation	3.4	4.4	2.4
Home Mortgages	4.7	3.9	5.5
Consumer Credit	3.2	3.0	3.5

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.

Figure (A.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.(A.2) plots the evolution of the top income and wealth deciles and of the (log-) real per

Table A.3: Descriptive Statistics, Correlations

	Y	C	π	HM	CC
1954-2009					
TIS	-0.07	-0.01	-0.33	0.02	-0.07
TWS	0.49	0.46	-0.16	0.34	0.32
1954-1983					
TIS	-0.01	0.09	-0.27	0.21	0.08
TWS	0.43	0.46	-0.19	0.37	0.43
1984-2009					
TIS	-0.22	-0.24	-0.21	-0.56	-0.47
TWS	0.68	0.56	0.37	0.23	0.19

Notes: Annual Frequency. Real per capita growth rates. Correlations. Top 10% income and wealth shares. *Data sources:* FRED. World Inequality Database.

capita household debt in terms of home mortgages and consumer credit. After the early 1980s, all the series exhibit an upward trend.

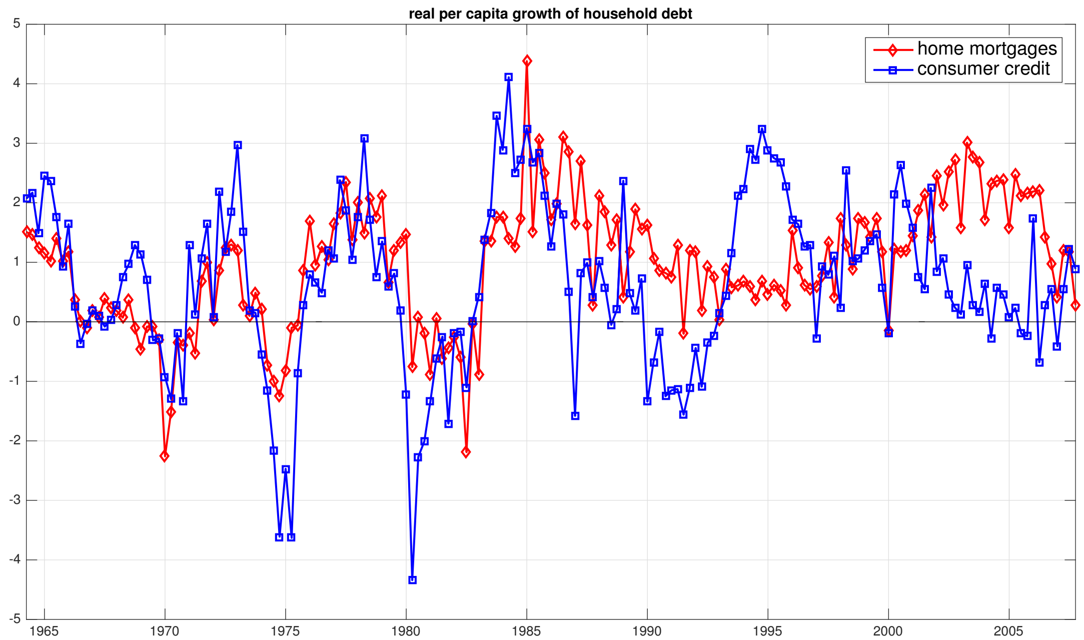
Fig.(A.3) reports the actual evolution of the top income and wealth deciles along with their cyclical components and the associated measurement errors of the observation equations. The cyclical top income decile is more volatile than the cyclical top wealth share. Furthermore, the cyclical component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

A.6 Additional Results

A.6.1 Measurement Errors.

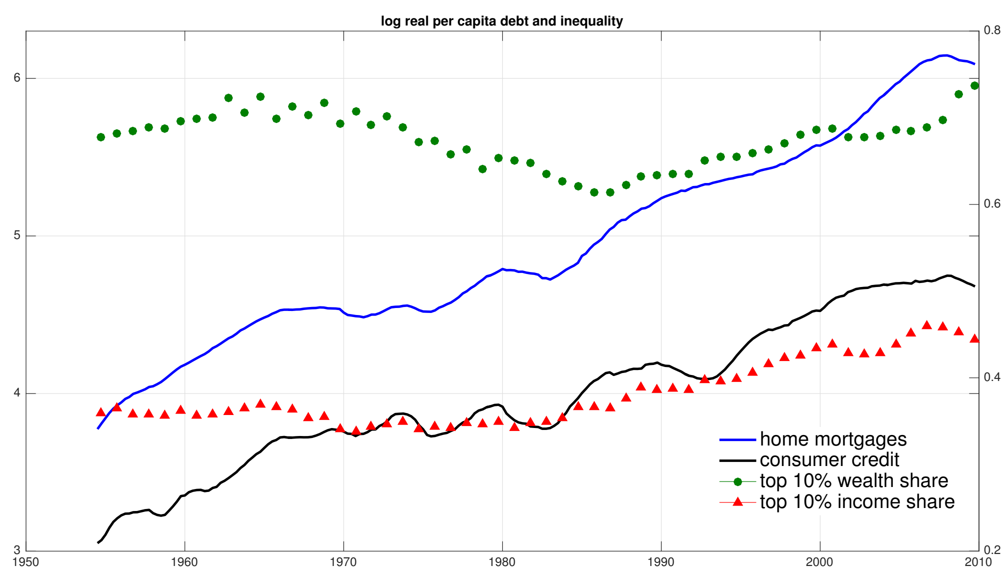
Tables (D.2) and (A.5) display the posterior standard deviation (std) of the measurement errors (m.e.) for the variables that are matched to a single observable. Their priors are tight and imply negligible measurement errors in order to preserve comparability with traditional estimated DSGE models that do not include measurement errors for those observables.

Figure A.1: Outstanding Household Debt



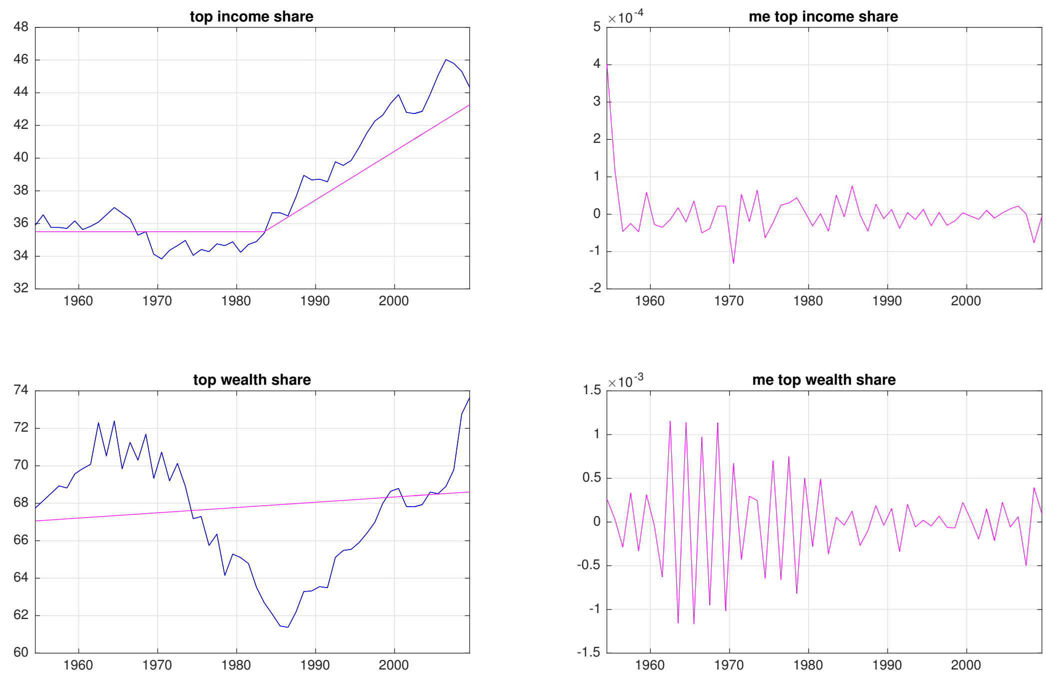
Notes: Real per capita household debt growth in the form of home mortgages and consumer credit. *Source:* FRED.

Figure A.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 A.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.

Table A.4: Posterior Distribution – Common Measurement Errors

	Prior	**Posterior** Mean [5-95%]	
		Rep. Agent	D. Imbalances
μ_w	IG(0.01,0.001)	0.0101[0.0085,0.0118]	0.0101[0.0085,0.0119]
μ_y	IG(0.01,0.001)	0.0100[0.0085,0.0116]	0.0101[0.0086,0.0120]
μ_c	IG(0.01,0.001)	0.0100[0.0085,0.0117]	0.0100[0.0085,0.0119]
μ_i	IG(0.01,0.001)	0.0100[0.0085,0.0117]	0.0100[0.0085,0.0119]
μ_π	IG(0.01,0.001)	0.0100[0.0085,0.0117]	0.0101[0.0086,0.0118]
μ_r	IG(0.01,0.001)	0.0100[0.0085,0.0116]	0.0100[0.0086,0.0118]
μ_l	IG(0.01,0.001)	0.0100[0.0085,0.0118]	0.0099[0.0085,0.0116]

Notes: Author's computations. "Rep. Agent" refers to the Smets and Wouters (2007) model estimated over the 1954Q3-2009Q4 period.

A.6.2 Prior.

Table (A.6) 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

Table A.5: Posterior Distribution – Distributional Measurement Errors

		Prior	Posterior
			Mean [5-95%]
std m.e. income inequality	μ_{tis}	IG(0.01, 0.001)	0.01002 [0.00846, 0.01185]
std m.e. wealth inequality	μ_{tws}	IG(0.01, 0.001)	0.01004 [0.00852, 0.01183]

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

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.

Table A.6: Business Cycles – The Role of the Prior

	variable							
shock	$\widehat{y}_t$	$\widehat{i}_t$	$\widehat{w}_t^r$	$\widehat{\pi}_t$	$\widehat{r}_t$	$\widehat{b}_t^\tau$	$\widehat{tis}_t$	$\widehat{tws}_t$
income	0/0	1/1	0/0	0/0	0/1	1/1	66/66	1/2
wealth	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
credit	0/0	0/0	0/0	0/0	0/0	1/0	0/0	0/0
distributional	0/0	1/1	0/0	0/0	0/1	2/2	67/67	1/2
technology	15/15	2/3	2/2	1/1	1/1	2/3	1/1	3/3
price markup	9/9	8/7	75/63	31/31	10/10	4/4	6/6	4/4
wage markup	9/10	14/15	14/13	9/9	4/4	5/9	1/1	1/2
supply side	34/34	24/25	91/78	42/42	15/15	11/16	7/7	8/9
risk premium	56/54	41/40	7/11	49/49	74/73	73/53	24/24	84/82
investment	5/6	30/30	1/9	3/3	4/5	9/25	1/1	1/2
govt spending	1/1	1/1	0/0	0/0	0/0	0/1	0/0	0/0
policy	4/4	4/4	1/1	6/6	6/6	5/4	2/2	5/5
demand side	66/66	76/74	9/21	58/58	85/84	87/83	26/26	90/89

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

A.6.3 Representative Agent Model.

Table (A.7) shows the FEVD in the representative agent model. Figures (A.4, A.5, A.6) display a comparison of the IRFs of aggregate variables in response to aggregate shocks between the present model and the representative agent model. Fig.(A.7) compares the output gaps in the present model and the representative agent model.

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.(A.5). 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.(A.7) 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 the interaction of distributional imbalances with nominal price and wage rigidities.

A.6.4 Quantifying the Effect of Imbalances on Inflation.

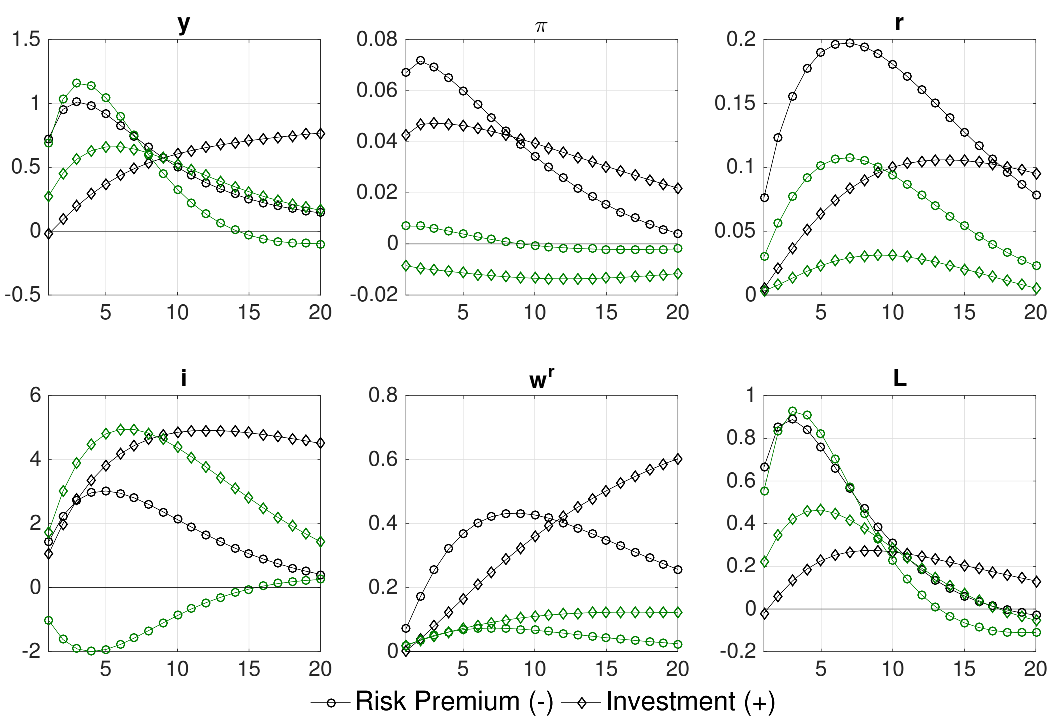
Figures (A.8) and (A.9) display a graphical depiction of the influence of endogenous and exogenous distributional imbalances on aggregate demand and inflation described in detail in the paper. The figures corroborate that the distributional shocks as well as the channels of MPC differentials and imperfect insurance have a more profound influence on aggregate demand than on inflation.

Table A.7: Business Cycles – Representative Agent Model

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

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

Figure A.4: Demand Side Innovations: A Comparison Across Models



Notes: Impulse Response Functions (posterior mean). Black: benchmark model with Distributional Imbalances. Green: Representative Agent model.

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.(A.9) 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.

A.6.5 Marginal Propensity to Consume and Wealth Preferences.

Fig.(A.10) plots the difference in the MPC between the benchmark model with $\phi^{\tau} \neq \phi^{\mu}$ and an alternative model featuring $\phi^{\tau} = \phi^{\mu}$. 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.

A.6.6 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.(A.11) and (A.12) cope with that question. Fig.(A.11) 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 A.5: Policy Innovations: A Comparison Across Models

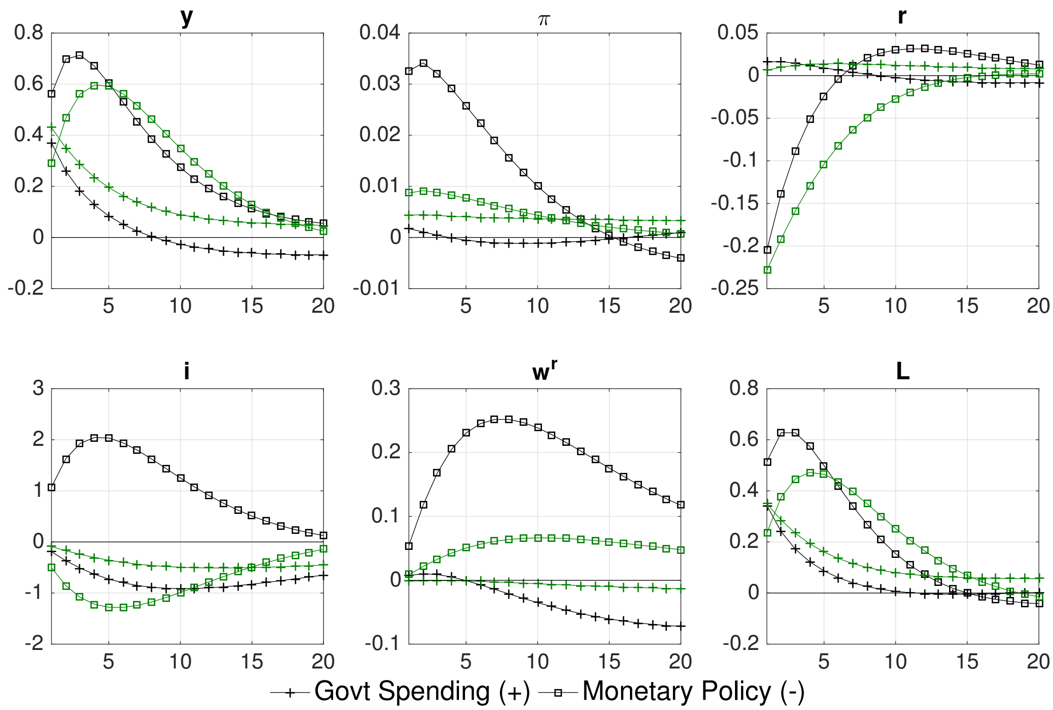
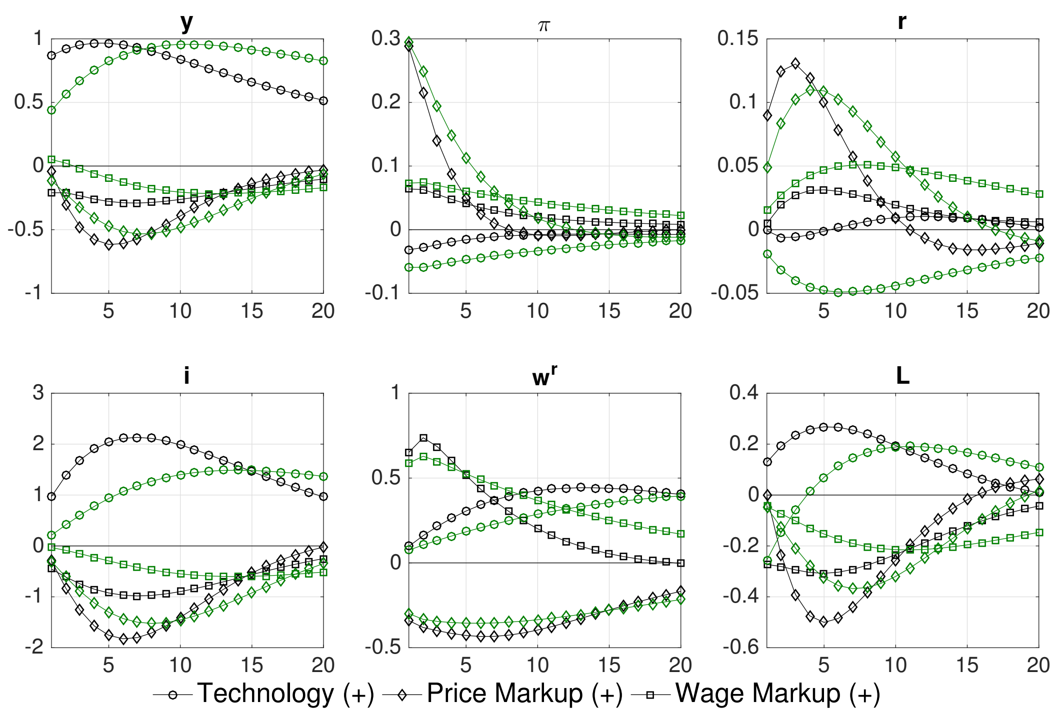
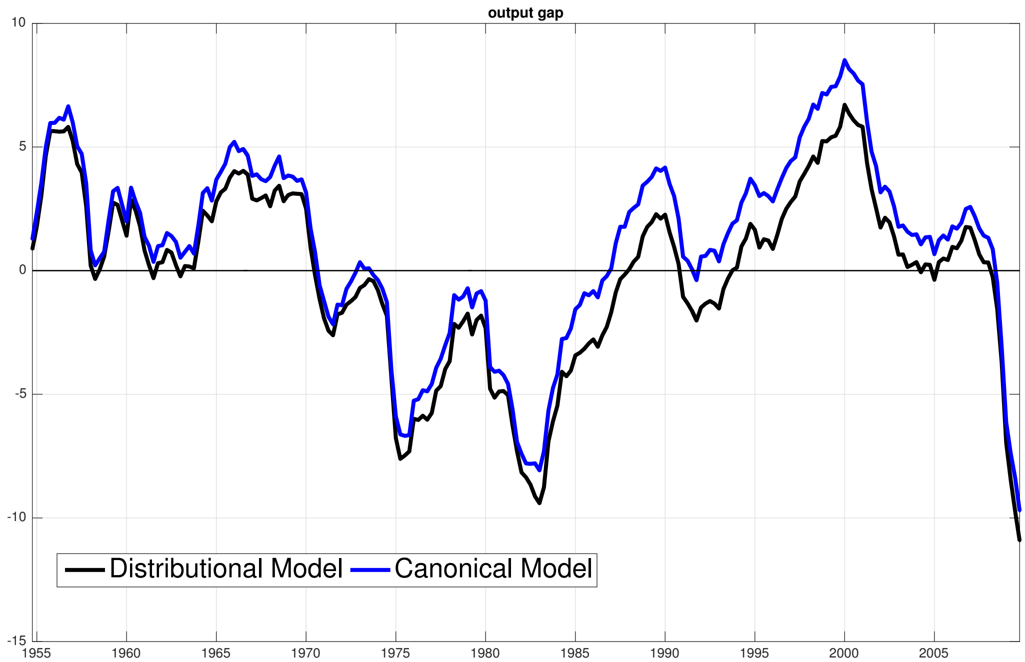


Figure A.6: Supply Side Innovations: A Comparison Across Models



Notes: Impulse Response Functions (posterior mean). Black: benchmark model with Distributional Imbalances. Green: Representative Agent model.

Figure A.7: U.S. Output Gap Fluctuations



Notes: Author's computations. Output Gap. Black: benchmark model with Distributional Imbalances. Blue: Representative Agent model.

Figure A.8: Quantifying the Effect of Imbalances on Aggregate Demand

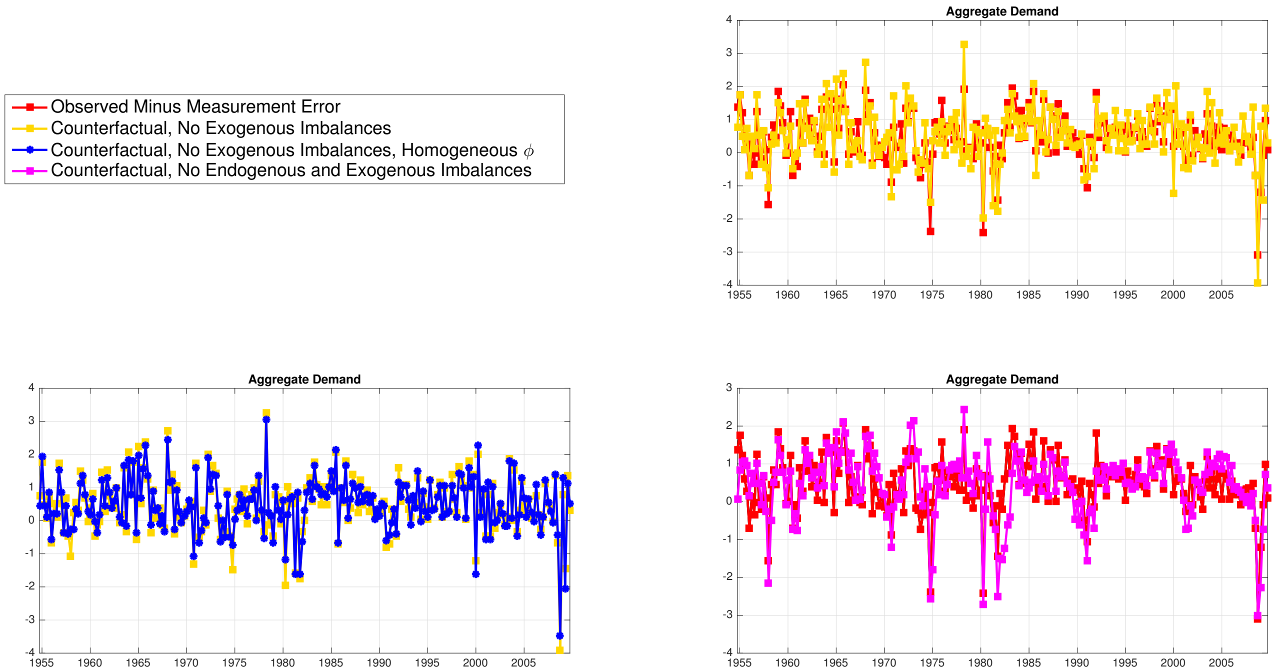
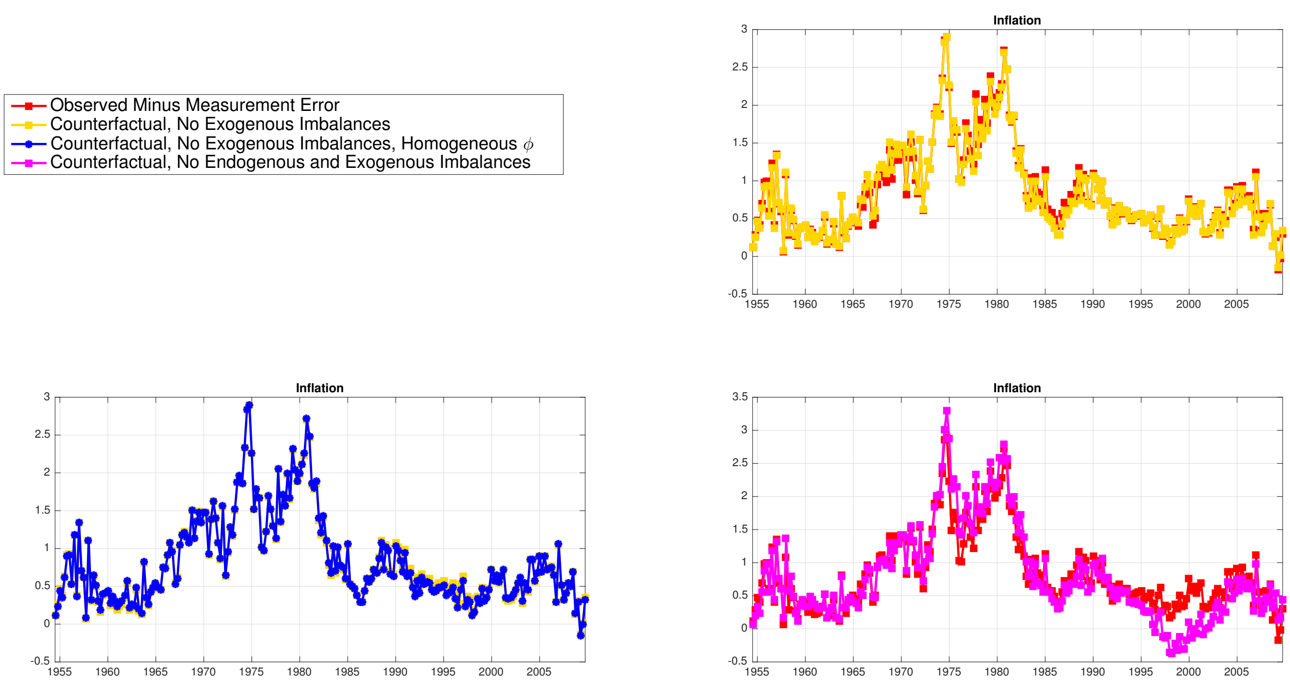
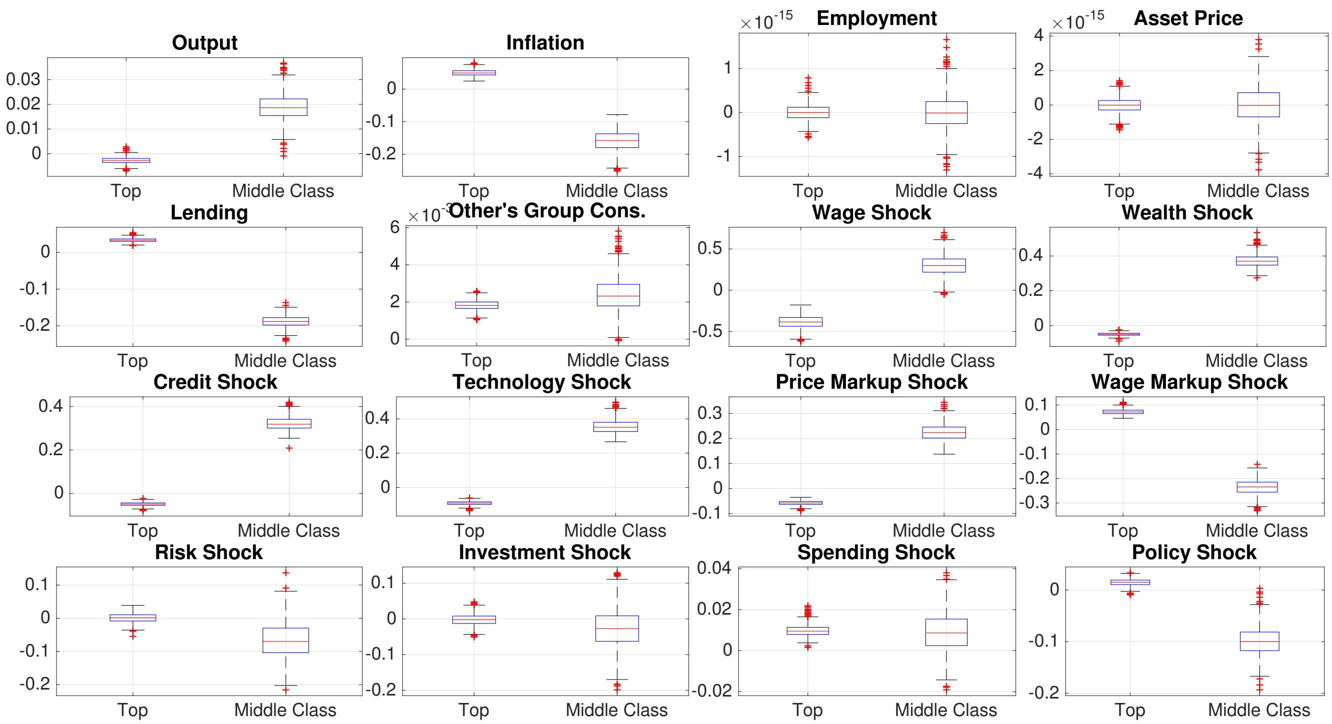


Figure A.9: Quantifying the Effect of Imbalances on Inflation



Notes: Author's computations. All figures in %.

Figure A.10: 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 $\phi^{\tau} = \phi^{\mu}$.

Figure A.11: Cyclical Swings in the Top 10% Income Share, 1954–2009

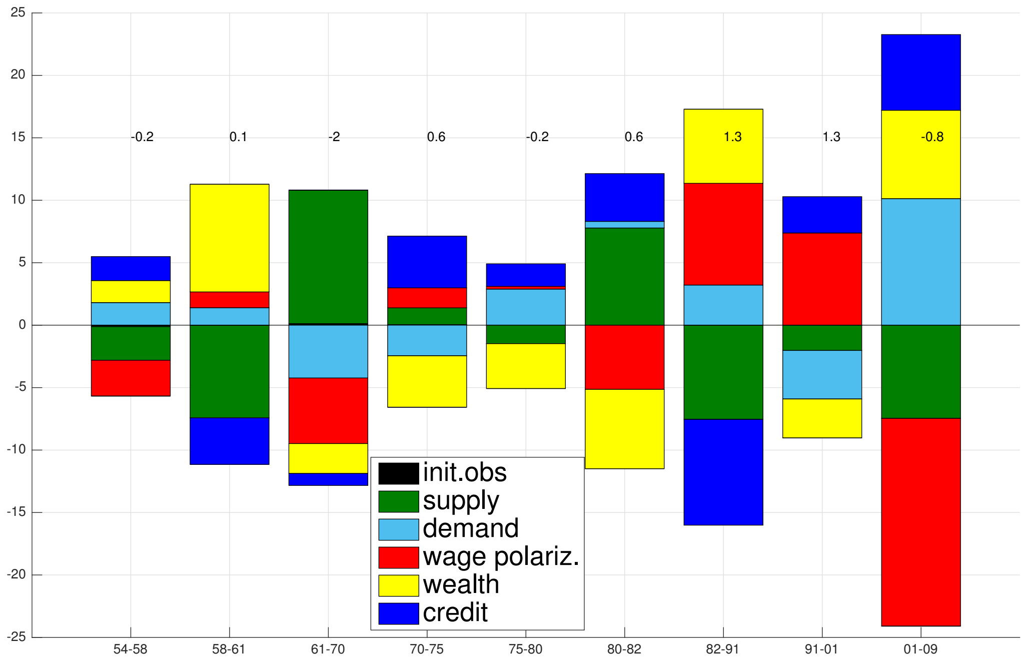
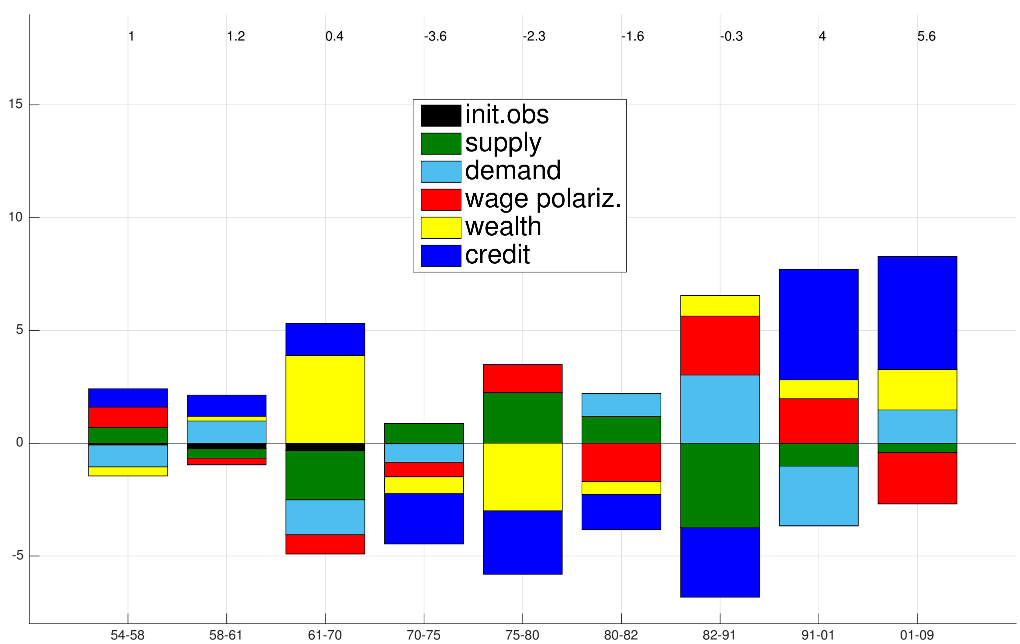


Figure A.12: Cyclical Swings in the Top 10% Wealth Share, 1954–2009



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 %.

Appendix B

The U.S. Labor Income Share and Automation Shocks

B.1 Model Equilibrium

The equilibrium conditions, log-linearized around the balanced growth steady state path, are collected here. Small letters denote non-stationary variables (expressed in capital letters) normalized with the composite technology. The log-deviation of a generic stationary variable (x_t) from its steady state (x) is denoted as $\widehat{x}_t \equiv ln(x_t/x)$.

Aggregate Production Function[1]

$$\widehat{y}_t = (1 + \Phi_y/y)[\alpha\widehat{k}_t + (1-\alpha)\widehat{L}_t + \alpha ln(k/L)\widehat{\alpha}_t] \tag{B.1}$$

Capital-To-Labor Ratio

[1] $log(k/L) > 0$, since in the steady state $w^r/r^{k,r} > (1-\alpha)/\alpha$ and $k/L = \alpha w^r/[(1-\alpha)r^{k,r}]$ from eq.(2.4).

$$\widehat{k}_t = \widehat{w}_t^r - \widehat{r}_t^{k,r} + \widehat{L}_t + [1/(1-\alpha)]\widehat{\alpha}_t \tag{B.2}$$

Marginal Cost

$$\widehat{mc}_t^r = (1-\alpha)\widehat{w}_t^r + \alpha\widehat{r}_t^{k,r} - \alpha ln\,(k/L)\,\widehat{\alpha}_t \tag{B.3}$$

Rental Rate of Capital

$$\widehat{r}_t^{k,r} = [\psi/(1-\psi)]\widehat{u}_t \tag{B.4}$$

Effective Capital

$$\widehat{k}_t = \widehat{u}_t + \widehat{\bar{k}}_{t-1} - \widehat{z}_t - [1/(1-\alpha)]\widehat{\upsilon}_t^{\omega} \tag{B.5}$$

Capital Accumulation

$$\widehat{\bar{k}}_t = k_1(\widehat{\bar{k}}_{t-1} - \widehat{z}_t - [1/(1-\alpha)]\widehat{\upsilon}_t^{\omega}) + (1-k_1)(\widehat{\upsilon}_t^i + \widehat{\tilde{i}}_t) \tag{B.6}$$

where $k_1 = (1-\delta)/e^{\gamma+\gamma_\omega}$.

Price of Capital

$$\widehat{q}_t^k = E_t\left(\widehat{\xi}_{t+1} - \widehat{\xi}_t - \widehat{z}_{t+1} - [1/(1-\alpha)]\widehat{\upsilon}_{t+1}^{\omega}\right) + q_1 E_t \widehat{r}_{t+1}^{r,k} + (1-q_1)\, E_t \widehat{q}_{t+1}^k \tag{B.7}$$

where $q_1 = \left(r^{k,r}/[r^{k,r} + 1 - \delta]\right)$.

Investment

$$\widehat{\widehat{i}}_t = i_1(\widehat{\widehat{i}}_{t-1} - \widehat{z}_t - \frac{1}{1-\alpha}\widehat{\upsilon}_t^{\omega}) + (1-i_1)\,(E_t\widehat{\widehat{i}}_{t+1} + E_t\widehat{z}_{t+1} + \frac{1}{1-\alpha}\widehat{\upsilon}_{t+1}^{\omega}) + i_2(\widehat{q}_t^k + \widehat{\upsilon}_t^i) \tag{B.8}$$

where $i_1 = 1/[1+\beta]$ and $i_2 = i_1/\left[e^{2(\gamma+\gamma_\omega)}S''\right]$.

Relative Investment Price

$$\Delta(\widehat{p^I/p})_t = -\widehat{\upsilon}_t^{\omega} \tag{B.9}$$

Price Inflation

$$\widehat{\pi}_t = (\pi_1\beta)E_t\widehat{\pi}_{t+1} + (\pi_1\iota_p)\widehat{\pi}_{t-1} + \kappa_p\left(\widehat{mc}_t^r + (\upsilon_p/[1+\upsilon_p])\,\widehat{\upsilon}_t^p\right) \tag{B.10}$$

where $\kappa_p = (1-\zeta_p)(1-\zeta_p\beta)/\left[\zeta_p(1+\iota_p\beta)\right]$ and $\pi_1 = 1/[1+\iota_p\beta]$.

Wage Inflation

$$\widehat{w}_t^r - \widehat{w}_{t-1}^r + \widehat{\pi}_t + \widehat{z}_t + [\alpha/(1-\alpha)]\widehat{\upsilon}_t^\omega - \iota_w \widehat{\pi}_{t-1} - \iota_w \widehat{z}_{t-1} - \iota_w[\alpha/(1-\alpha)]\widehat{\upsilon}_{t-1}^\omega =$$

$$\beta \left[E_t \widehat{w}_{t+1}^r - \widehat{w}_t^r + E_t \widehat{\pi}_{t+1} + E_t \widehat{z}_{t+1} + [\alpha/(1-\alpha)] E_t \widehat{\upsilon}_{t+1}^\omega - \iota_w \widehat{\pi}_t - \iota_w \widehat{z}_t - \iota_w [\alpha/(1-\alpha)] \widehat{\upsilon}_t^\omega \right]$$

$$+ \kappa_w \left(\chi \widehat{L}_t - \widehat{\xi}_t - \widehat{w}_t^r + (\upsilon_w/[1+\upsilon_w])\, \widehat{\upsilon}_t^w \right) \tag{B.11}$$

where $\kappa_w = (1-\zeta_w)(1-\zeta_w\beta)/\left[\zeta_w(1+\chi\epsilon_w)\right]$.

Monetary Policy[2]

$$r_t^o = \max\{0, r + \widehat{r}_t\} \tag{B.12}$$

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r) \left[\psi_\pi \widehat{\pi}_t + \psi_y (\widehat{y}_t - \widehat{y}_t^f) + \psi_{\Delta y} \Delta (\widehat{y}_t - \widehat{y}_t^f) \right] + \epsilon_t^{mp} \tag{B.13}$$

Resource Constraint

$$(c/y)\widehat{c}_t + (i/y)\widehat{\widehat{i}}_t + (g/y)\widehat{g}_t + (r^{k,r}k/y)\widehat{u}_t = \widehat{y}_t \tag{B.14}$$

Lagrange Multiplier

$$-(1-\eta/e^\gamma)\widehat{\xi}_t = \widehat{c}_t - (\eta/e^\gamma)\widehat{c}_{t-1} + (\eta/e^\gamma)\widehat{z}_t + (\eta/e^\gamma)[\alpha/(1-\alpha)]\widehat{\upsilon}_t^\omega \tag{B.15}$$

Inter-Temporal Consumption Dynamics

[2] The steady state net interest rate is given by $r = e^\gamma \Pi/\beta - 1$, where Π stands for gross inflation.

$$\widehat{\xi}_t = E_t\left(\widehat{\xi}_{t+1} - \widehat{z}_{t+1} - [\alpha/(1-\alpha)]\widehat{v}^{\omega}_{t+1} + \widehat{v}^{b}_t + \widehat{r}_t - \widehat{\pi}_{t+1}\right) \tag{B.16}$$

Labor Share

$$\widehat{ls}_t = \widehat{w}^r_t + \widehat{L}_t - \widehat{y}_t \tag{B.17}$$

B.1.1 Equilibrium Definition.

Equations (D.19, D.20) of the household side determine $\{\widehat{\xi}_t, \widehat{c}_t\}$. Equations (D.4)–(D.8) in capital production determine: $\{\widehat{\bar{k}}_t, \widehat{k}_t, \widehat{r}^{k,r}_t, \widehat{q}^k_t, \widehat{\tilde{i}}_t\}$. Equations (D.10) and (D.9) determine the real wage, $\widehat{w}^r_t$, and inflation, $\widehat{\pi}_t$, respectively. Equations (D.1)–(D.3) pin down the following variables: $\{\widehat{y}_t, \widehat{L}_t, \widehat{mc}^r_t\}$. The relative investment price, $(\widehat{p^I/p})_t$, is given in (B.9). The policy rate in normal times and during the zero lower bound is found by (B.12) and (D.17). A solution for the utilization rate $\{\widehat{u}_t\}$ is obtained from the resource constraint (D.18). (D.21) determines the labor income share $(\widehat{ls}_t)$.

The flexible price and wage equilibrium is obtained from the above set of equations (D.1–D.20) for zero price and wage stickiness. Automation shocks appear in that equilibrium.

The stochastic structure of the disturbances is described in the paper. A few shocks are scaled: the risk premium shock is scaled in (D.20) after substituting in (D.19), and adjusted accordingly in (D.7) after substituting in (D.20); the price and wage markup shocks are scaled in equations (D.9) and (D.10), respectively; the government spending shock is scaled in (D.18). These adjustments improve the convergence of the sampler, introduce correlated priors, and illustrate the impact of the disturbances' prior standard deviation.

B.2 Additional Results

B.2.1 Measurement Errors.

Table (D.2) reports the standard deviation of measurement errors for variables with a single observable series. Those are tightly estimated with a low prior mean.

Table B.1: Posterior Distribution – Standard Deviation Of Measurement Errors

		Prior	**Posterior** Mean [5-95%]	
			Without LS	**With LS**
std m.e. compensation	μ_w	IG (0.01, 0.001)	0.0101 [0.0085, 0.0118]	0.0101 [0.0085, 0.0119]
std m.e. output	μ_y	IG (0.01, 0.001)	0.0100 [0.0085, 0.0116]	0.0101 [0.0086, 0.0120]
std m.e. consumption	μ_c	IG (0.01, 0.001)	0.0100 [0.0085, 0.0117]	0.0100 [0.0085, 0.0119]
std m.e. investment	μ_i	IG (0.01, 0.001)	0.0100 [0.0085, 0.0117]	0.0100 [0.0085, 0.0119]
std m.e. inflation	μ_π	IG (0.01, 0.001)	0.0100 [0.0085, 0.0117]	0.0101 [0.0086, 0.0118]
std m.e. interest rate	μ_r	IG (0.01, 0.001)	0.0100 [0.0085, 0.0116]	0.0100 [0.0086, 0.0118]
std m.e. labor hours	μ_l	IG (0.01, 0.001)	0.0100 [0.0085, 0.0118]	0.0099 [0.0085, 0.0116]
Marginal Likelihood			-1484	-1863

Notes: "Without/With LS": without/with multiple labor income share observables.

B.2.2 Prior.

I investigate the robustness of the results to the prior specification. Table (B.2) displays the forecast error variance decomposition at the prior mean, and shows that the influence of automation shocks is much smaller than that obtained at the posterior mean.

B.2.3 Real Wage.

Fig.(B.1) displays the extracted wage from the model with and without the LS series, and overlaps both of them with the data series. The extracted wages demonstrate a substantially different evolution. The wage in the model with the LS is more volatile than the wage in the model without the LS, and on average follows more closely the compensation index than

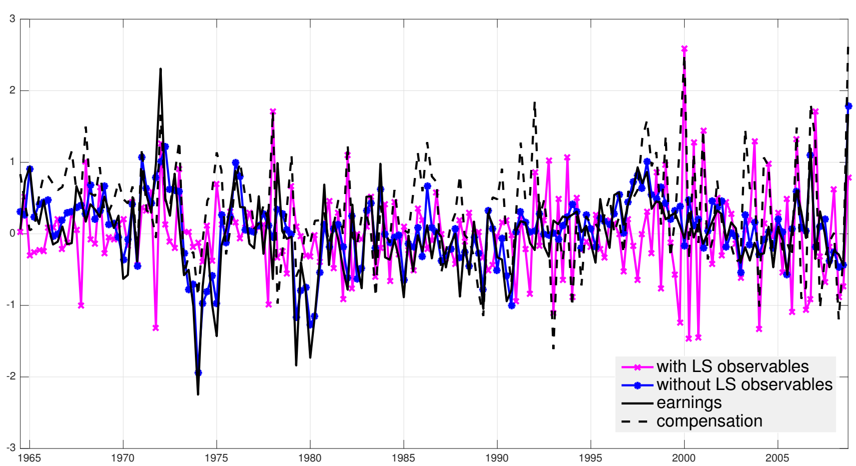
Table B.2: FEVD – With LS – Prior Mean

	variable						
shock	y_t	i_t	π_t	r_t	L_t	w_t^r	ls_t
technology	14/18	12/12	5/6	1/6	36/38	41/42	26/27
price markup	13/11	7/7	54/52	24/21	7/6	24/13	44/43
wage markup	10/10	15/17	14/14	11/10	11/9	5/3	16/15
IST	16/21	41/41	1/3	1/7	3/15	28/40	4/6
supply side	53/59	76/77	74/75	37/45	57/67	98/99	90/90
risk premium	36/31	13/12	17/17	38/33	32/25	1/1	0/0
MEI	1/1	7/7	0/0	0/0	1/1	0/0	0/0
govt spending	3/3	0/0	0/0	0/0	3/2	0/0	0/0
policy	6/5	3/3	7/6	23/21	5/4	0/0	0/0
demand side	46/40	23/23	24/24	62/55	41/32	1/1	0/0
automation	1/1	1/1	1/1	1/1	2/1	0/0	10/10

Notes: Computations at the prior mean 8/80 quarters ahead.

the wage in the model without the LS does.

Figure B.1: Real Wage Growth

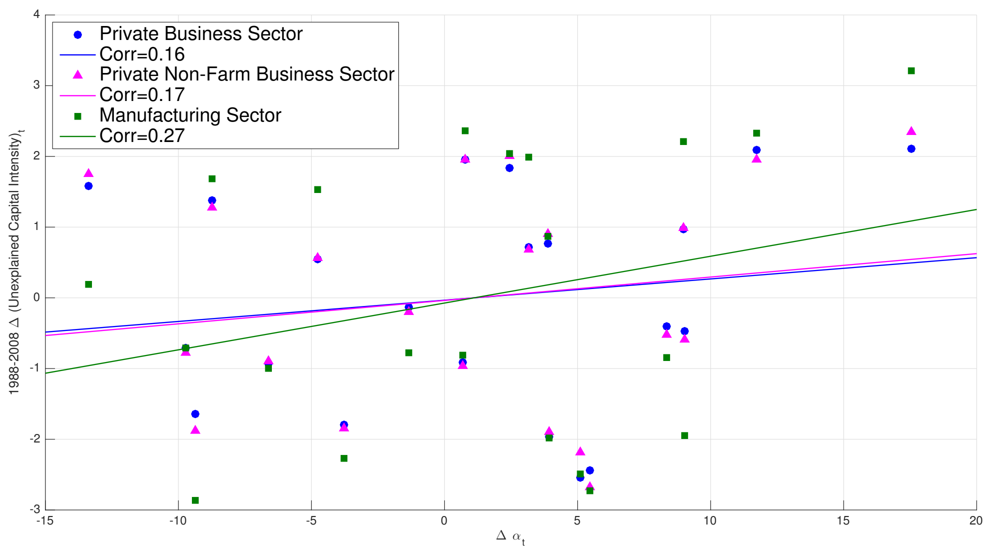


Notes: Observed real wage growth in earnings and compensation index series. Posterior mean of smooth real wage growth in the estimation with/without LS observables.

B.2.4 Capital Intensity.

Fig.(B.2) reports the comovement between automation shocks and the unexplained part of the growth rate of three capital intensity indices for the 1988-2008 period that corresponds to the time period of the estimation of the model. The figure shows a positive comovement. Nevertheless, the comovement is smaller than that obtained when the extracted automation shocks for the 2009-2016 period are included. This result may in fact reflect that during that period automation shocks play a large role in explaining the swings in the labor share according to the historical decomposition shown in the paper.

Figure B.2: Capital Intensity and Automation Shocks, 1988-2008



Notes: Author's computations. *Data Sources:* Bureau of Labor Statistics.

Appendix C

On Unemployment And Wage Cycles: Euro Area, 1999–2016

C.1 Model Overview

I present the model derivation for a small open economy. The euro-area block is obtained for a zero trade share (τ).

Households. A continuum of representative households populates the economy. The household is a large family of individuals who differ in terms of their labor type ("i"), situated in the unit interval, and disutility of work given by j^{χ}, should the household member is employed, and by zero otherwise, where "j" is an index uniformly distributed in the unit interval, and χ governs the curvature of the labor disutility. Thus, household members are situated in the unit square and indexed by $(i, j) \in [0, 1] \times [0, 1]$. Labor is indivisible. Individual period-t preferences are given by

$$u\left(C_t(i,j), j, C_{t-1}, \upsilon_{\chi,t}, \Omega_t, \upsilon_{d,t}, \chi\right) = \left[log\big(C_t(i,j) - \eta C_{t-1}\big) - \ \mathbf{1} e^{\upsilon_{\chi,t}} \Omega_t j^{\chi}\right] e^{\upsilon_{d,t}} \tag{C.1}$$

where **1** is an indicator function that equals to unity when the individual is employed and zero otherwise. The CRRA is set to unity. Ω_t is defined below. $\upsilon_{\chi,t}$ is the AR(1) disutility of work shock. η captures the strength of external habit formation. Perfect consumption insurance ($C_t(i,j) = C_t \ \forall i,j$) and a common discount factor (β) are postulated across household members. Household preferences are the equally weighted average of individual utilities:

$$E_0 \sum_{t=0}^{\infty} \beta^t \int_0^1 \int_0^1 u(\cdot) dj di = E_0 \sum_{t=0}^{\infty} \beta^t \left[log\big(C_t - \eta C_{t-1}\big) - \ e^{\upsilon_{\chi,t}} \Omega_t \int_0^1 \frac{{N_{it}}^{1+\chi}}{(1+\chi)} di \right] e^{\upsilon_{d,t}} \tag{C.2}$$

N_{it} denotes the period-t employment rate among workers of type "i". χ has now the interpretation of a Frisch elasticity along the extensive margin. $\upsilon_{d,t}$ is an AR(1) demand shock. Ω_t is an endogenous shifter that allows the parameterization of the strength of wealth effects on labor supply and helps the model match the cyclical properties of labor force in response to monetary policy shocks. It preserves additive separability in the preferences between consumption and the aggregate disutility of employment across occupations, and reconciles the existence of a balanced growth path with an arbitrarily small wealth effect. The shifter is defined as

$$\Omega_t = Z_t \big(C_t - \eta C_{t-1}\big)^{-1} \qquad \text{where} \qquad Z_t = Z_{t-1}^{1-\omega} \big(C_t - \eta C_{t-1}\big)^{\omega} \tag{C.3}$$

ω governs the strength of the wealth effects of consumption to labor supply. Z_t is a distributed lag of consumption and evolves according to a first-order difference equation.

The household chooses consumption (C_t) at price P_t, and savings across domestic (B_t) and euro-area bonds (D_t). Both bonds are nominal one-period risk-less securities denominated in the same union currency with interest rates i_t and i_t^*, respectively. Nevertheless, trading on the euro-area bond is subject to a debt elastic premium over the risk-less euro-area nominal interest rate that guarantees stationarity in the foreign debt position and constitutes a reduced-form representation of financial intermediation costs. The premium depends on the debt-to-income ratio ($d_t \equiv D_t/\bar{Y}P_t$), and is given by $\Phi\left(D_t/\bar{Y}P_t\ ;\phi\right) = exp\left(-\phi D_t/\bar{Y}P_t\right)$, where ϕ is the debt premium elasticity, and D_t captures the foreign position ($D_t < 0$ denotes debt). The flow budget constraint is given by

$$\begin{aligned} & P_tC_t + B_t + D_t = \\ & = B_{t-1}(1+i_{t-1}) + D_{t-1}(1+i_{t-1}^*)\Phi\left(\cdot\right) + \int_0^1 (1+\iota_w)W_{it}N_{it}di + \Pi_{H,t} + \Pi_{M,t} - T_t \end{aligned} \tag{C.4}$$

T_t stands for taxes/transfers and "ι_w" is a labor subsidy correcting the market power of labor unions at the steady state. The two resulting Euler equations read as:

$$\begin{aligned} & \left(C_t - \eta C_{t-1}\right)^{-1} = \\ & = \beta E_t\left[\left(C_{t+1} - \eta C_t\right)^{-1}\left[(1+i_t^*)/(1+\pi_{t+1})\right]exp(-\phi(D_t/YP_t) + \upsilon_{d,t+1} - \upsilon_{d,t})\right] \end{aligned} \tag{C.5}$$

$$\begin{aligned} & \left(C_t - \eta C_{t-1}\right)^{-1} = \\ & = \beta E_t\left[\left(C_{t+1} - \eta C_t\right)^{-1}\left[(1+i_t)/(1+\pi_{t+1})\right]exp(\upsilon_{d,t+1} - \upsilon_{d,t})\right] \end{aligned} \tag{C.6}$$

Their combination yields the uncovered interest parity (UIP):

$$E_t \left(C_{t+1} - \eta C_t\right)^{-1} e^{\upsilon_{d,t+1} - \upsilon_{d,t}} / (1 + \pi_{t+1}) \left[(1 + i_t^*) e^{-\phi(D_t / Y P_t)} - (1 + i_t) \right] = 0 \tag{C.7}$$

In addition, the household allocates consumption expenditure across domestic ($C_{H,t}$) and imported ($C_{M,t}$) goods, at prices $P_{H,t}$ and $P_{M,t}$, respectively, where the consumption aggregate measure has a Dixit-Stiglitz CES structure:

$$C_t = \left[(1 - \tau)^{\frac{1}{\nu}} C_{H,t}^{\frac{\nu - 1}{\nu}} + \tau^{\frac{1}{\nu}} C_{M,t}^{\frac{\nu - 1}{\nu}} \right]^{\frac{\nu}{\nu - 1}} \tag{C.8}$$

$(1 - \tau) \in [0, 1]$ is the share of domestic goods in the consumption basket. ν is the trade elasticity. Domestic and imported good aggregates, $C_{H,t}$ and $C_{M,t}$, respectively, are defined via the CES aggregators:

$$C_{H,t} = \left(\int_0^1 C_{H,t}(j)^{(\zeta_{h,t} - 1)/\zeta_{h,t}} dj \right)^{\zeta_{h,t}/(\zeta_{h,t} - 1)}, \tag{C.9}$$

$$C_{M,t} = \left(\int_0^1 C_{M,t}(j)^{(\zeta_{m,t} - 1)/\zeta_{m,t}} dj \right)^{\zeta_{m,t}/(\zeta_{m,t} - 1)} \tag{C.10}$$

$\zeta_{h,t}, \zeta_{m,t}$ are the substitution elasticities within domestic and imported goods, respectively. The aggregate price is given by:

$$P_t = \left[(1 - \tau) P_{H,t}^{1 - \nu} + \tau P_{M,t}^{1 - \nu} \right]^{1/(1 - \nu)} \tag{C.11}$$

$P_{H,t}$ and $P_{M,t}$ are the prices required to obtain a unit of the domestic and imported consumption aggregates, respectively, and are defined by

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\zeta_{h,t}} dj \right)^{1/(1-\zeta_{h,t})} \quad and \quad P_{M,t} = \left(\int_0^1 P_{M,t}(j)^{1-\zeta_{m,t}} dj \right)^{1/(1-\zeta_{m,t})} \tag{C.12}$$

Thus, the household chooses a sequence $\{C_t, B_t, D_t, C_{H,t}, C_{M,t}, \{C_{H,t}(j), C_{M,t}(j)\}_{\forall j \in [0,1]}\}_{t=0}^{\infty}$ to maximize the expected present discounted value of inter-temporal utility, while taking as given prices $\{P_{H,t}, P_{M,t}, P_t, i_t, i_t^*\}_{t=0}^{\infty}$, firms' profits $\{\Pi_{H,t}, \Pi_{M,t}\}_{t=0}^{\infty}$, and taxes $\{T_t\}_{t=0}^{\infty}$.

Labor Market. All type"i" workers, for every type $i \in [0,1]$, form a monopolistically competitive coalition, and set wages in a staggered fashion while seeking to maximize the inter-temporal household utility taking into account the labor demand function emanating from a labor aggregator that operates in a perfectly competitive environment. Aggregate labor, used by domestic producers, is given by

$$N_t = \left[\int_0^1 N_{it}^{(\epsilon_{w,t}-1)/\epsilon_{w,t}} di \right]^{\epsilon_{w,t}/(\epsilon_{w,t}-1)} \tag{C.13}$$

$\epsilon_{w,t}$ is the time-varying elasticity of substitution across labor types. Labor demand for type "i" is

$$N_{it} = (W_{it}/W_t)^{-\epsilon_{w,t}} N_t \tag{C.14}$$

and the wage index is $W_t = \left(\int_0^1 W_{it}^{1-\epsilon_{w,t}} di \right)^{1/(1-\epsilon_{w,t})}$. The real average wage is

$$W_t^r = W_t/Pt \tag{C.15}$$

The marginal rate of substitution between labor and consumption for the type "i" workers that are employed reads as $mrs_{it} \equiv e^{\upsilon_{\chi,t}}\Omega_t N_{it}^{\chi}(C_t - \eta C_{t-1})$. The individual (i,j) is willing to participate in the market when the real wage exceeds his/her marginal rate of substitution: $W_{it}/P_t \geq e^{\upsilon_{\chi,t}}\Omega_t j^{\chi}(C_t - \eta C_{t-1})$. The latter condition at the symmetric equilibrium becomes

$$W_{it}/P_t = e^{\upsilon_{\chi,t}}\Omega_t L_{it}^{\chi}(C_t - \eta C_{t-1}) = e^{\upsilon_{\chi,t}} Z_t L_{it}^{\chi} \tag{C.16}$$

where L_{it} denotes the marginal worker who is indifferent between participating in and staying out of the labor market. Hence, L_{it} denotes the mass of workers participating in the market.

Each union resets wages with probability $1-\theta_w$, $\theta_w \in [0,1]$. In the periods in which wages are not reset, they are partially updated according to the price inflation and the wage indexation parameter γ_w. The period-T wage for labor type workers "i" and a wage that was lastly reset in period t at W_{it}°, is given by $W_{iT|t} = W_{it}^{\circ}\left(P_{T-1}/P_{t-1}\right)^{\gamma_w}$. Union's optimization, constrained by the type-specific labor demand, yields the optimal wage (for $1 + \upsilon_{w,t} = \epsilon_{w,t}/(\epsilon_{w,t} - 1)$)

$$E_t \sum_{s=0}^{\infty} \frac{(\beta\theta_w)^s N_{it,t+s}}{C_{t+s} - \eta C_{t+s-1}} \left[\frac{W_{it+s|t}}{P_{t+s}} - \frac{(1+\upsilon_{w,t})}{(1+\iota_w)} e^{\upsilon_{\chi,t+s}}\Omega_{t+s} N_{it,t+s}^{\chi}(C_{t+s} - \eta C_{t+s-1})\right] = 0 \tag{C.17}$$

International Prices. The real exchange rate is given by the cross-country price ratio, $Q_t = P_t^*/P_t$. The terms of trade are given by the ratio of import to export prices, $S_t = P_{F,t}/P_{H,t}$.

Domestic Intermediate Good Firms indexed by $i \in [0,1]$, operate under monopolistic competition. Each firm hires $N_t(i)$ units of labor at the wage W_t, and produces $Y_{H,t}(i)$ according to a linear production function:

$$Y_{H,t}(i) = e^{\upsilon_{a,t}} N_t(i) \tag{C.18}$$

where $\upsilon_{a,t}$ is an AR(1) neutral technology shock. The firm receives a subsidy ι_h over the market wage, that yields a real marginal cost in terms of output, $MC_t = (1-\iota_h)W_t/[P_{H,t} exp(\upsilon_{a,t})]$, that is independent of firm-specific characteristics.

Each firm chooses price $P_t^{\circ}(i)$ in a staggered fashion with θ_h governing the price stickiness, and sells both domestically and abroad at that price since the domestic economy is small relative to the union. The period-t demand schedule faced by a firm is given by

$$Y_{H,t}(i) = C_{H,t}(i) + C^*_{H,t}(i) \quad , \quad \forall i \in [0,1] \;\text{ and }\; \forall t \tag{C.19}$$

where it is postulated that the foreign demand for domestic variety "i", $C^*_{H,t}(i)$, has the same functional form as the domestic demand for that variety, that is,

$$C^*_{H,t}(i) = \left(P^*_{H,t}(i)/P^*_{H,t}\right)^{-\zeta_{h,t}} C^*_{H,t} \tag{C.20}$$

Partial price indexation to one-period lagged inflation for non-optimizing firms, governed by the parameter γ_h, implies that the period-T (nominal) price of firm "i" that has not reset prices since period t is: $P_{H,T|t}(i) = P^{\circ}_{H,t}(i) \left(P_{H,T-1}/P_{H,t-1}\right)^{\gamma_h}$. The associated demand schedule and real profits can then be written as

$$Y_{H,T|t}(i) = \left(P_{H,T|t}(i)/P_{H,T}\right)^{-\zeta_{h,t}} (C_{H,T} + C^*_{H,T}) \tag{C.21}$$

and

$$\Pi_{H,T|t} = Y_{H,T|t}(i) \left[P_{H,T|t}(i)/P_{H,T} - MC_T\right] \tag{C.22}$$

Hence, each firm that is allowed to reset its period-t price, maximizes the present discounted value of future profits, $E_t \sum_{T=t}^{\infty} (\beta\theta_h)^{T-t} \Lambda_{t,T} \Pi_{H,T|t}$, subject to the demand schedule, by choosing a price that is the weighted sum of current and future marginal costs[1]:

$$P^{\circ}_{H,t}(i) = (1 + \upsilon_{h,t}) E_t \sum_{T=t}^{\infty} \left[\frac{(\theta_h\beta)^{T-t} \Lambda_{t,T} Y_{H,T|t}(i)}{E_t \sum_{J=t} (\theta_h\beta)^{J-t} \Lambda_{t,J} Y_{H,J|t}(i) \left(\frac{1}{P_{H,J}} \left(\frac{P_{H,J-1}}{P_{H,t-1}} \right)^{\gamma_h} \right)} \right] MC_T \tag{C.23}$$

Intermediate Good Importers indexed by $j \in [0, 1]$, operate under monopolistic competition. They purchase goods from abroad at the euro-area price (the law of one price holds at the docks) which is subsidized at rate ι_m in order to consider an efficient steady state production. Each importer chooses domestic price $P^{\circ}_{M,t}(j)$ in a staggered fashion governed by the parameter θ_m, in order to maximize the present discounted value of future profits: $E_t \sum_{T=t}^{\infty} (\beta\theta_m)^{T-t} \Lambda_{t,T} \Pi_{M,T|t}$, where period-T profits for an importer who has not reset prices since period t, are given by

[1] $\Lambda_{t,T}$ stands for the ratio of period-T to period-t marginal utility of consumption, and $1+\upsilon_{h,t} = \zeta_{h,t}/(\zeta_{h,t}-1)$.

$$\Pi_{M,T|t} = Y_{M,T|t}(j) \left[P^{\circ}_{M,t}(j) \left(P_{M,T-1}/P_{M,t-1}\right)^{\gamma_m} - (1-\iota_m)P^{*}_{M,T}\right] \tag{C.24}$$

The behavior of an importing firm is constrained by the downward sloping demand $C_{M,t}(j)$. Those who do not reset prices, are able to automatically update prices according to the one-period-lagged imported-good inflation and the parameter γ_m that governs the strength of indexation. Thus, the constraint for a producer who has not reset prices for T periods reads as

$$Y_{M,T|t}(j) \equiv C_{M,T|t}(j) = \left(P^{\circ}_{M,t}(j) \left(P_{M,T-1}/P_{M,t-1}\right)^{\gamma_m} / P_{M,T}\right)^{-\zeta_{m,t}} C_{M,T} \tag{C.25}$$

The resulting optimal price (for $1 + \upsilon_{m,t} = \zeta_{m,t}/(\zeta_{m,t} - 1)$) is given by:

$$P^{\circ}_{M,t}(j) = (1+\upsilon_{m,t}) E_t \sum_{T=t}^{\infty} \left[\frac{(\theta_m \beta)^{T-t} \Lambda_{t,T} Y_{M,T|t}(j)}{E_t \sum_{J=t} (\theta_m \beta)^{J-t} \Lambda_{t,J} Y_{M,J|t}(j) \left(\frac{P_{M,J-1}}{P_{M,t-1}}\right)^{\gamma_m}} \right] (1-\iota_m) P^{*}_{M,T} \tag{C.26}$$

Government. The government levies lump sump taxes from households, while it subsidizes intermediate producers, importers, and the unions. Government spending is subject to an exogenous AR(1) spending shock $\upsilon_{g,t}$. The government does not borrow or lend funds and, thus, keeps a balanced budget at all times:

$$T_t = \iota_w \int_0^1 W_{i,t} N_{i,t} di + \iota_h W_t \int_0^1 N_t(i) di + \iota_m P^{*}_{M,t} \int_0^1 C_{M,t}(j) dj + \upsilon_{g,t} \tag{C.27}$$

Market Clearing And Aggregation. Market clearing for domestically produced goods requires total production to be equal to domestic consumption plus exports and government spending: $Y_t \equiv Y_{H,t} = C_{H,t} + C^*_{H,t} + \upsilon_{g,t}$. After using the euro-area market clearing condition ($Y^*_t = C^*_t + \upsilon^*_{g,t}$), the LOOP for domestic goods sold abroad ($P^*_{H,t} = P_{H,t}$), the real exchange rate, and some algebra, aggregate demand reads as

$$Y_t = (P_{H,t}/P_t)^{-\nu} \left[(1-\tau)C_t + \tau Q^{\nu}_t C^*_t\right] + \upsilon_{g,t} \tag{C.28}$$

Aggregate production, in turn, is given by:

$$Y_t \equiv Y_{H,t} = \int_0^1 Y_{H,t}(i)di = exp(\upsilon_{a,t})N_t \tag{C.29}$$

At the symmetric equilibrium, the profits of domestic-good firms are:

$$\Pi_{H,t} = \int_0^1 \Pi_{H,t}(i)di = P_{H,t}Y_{H,t} - (1-\iota_h)W_tN_t \tag{C.30}$$

The profits of importers are:

$$\Pi_{M,t} = \int_0^1 \Pi_{M,t}(j)dj = \left[P_{M,t} - (1-\iota_m)P^*_{M,t}\right] \tau \left(P_{M,t}/P_t\right)^{-\nu} C_t \tag{C.31}$$

After recognizing that $P^*_{M,t} = P^*_t$, and plugging the above in the budget constraint, I obtain

$$C_t \left[P_t - (P_{M,t} - P^*_{M,t})\tau \left(P_{M,t}/P_t\right)^{-\nu}\right] + D_t = D_{t-1}(1+i^*_{t-1})\Phi\left(\cdot\right) + P_{H,t}Y_t - \upsilon_{g,t} \tag{C.32}$$

Euro Area. The euro-area block is the closed economy analogue of the above model (for $\tau = 0$) with two differences: monetary policy is conducted at the euro-area level and euro-area variables are not affected by the small economy's aggregates.

Steady State. The zero growth deterministic steady state considered is symmetric with zero inflation ($\pi = \pi^* = \pi_H = \pi_M = 0$). Domestic and foreign bond holdings are zero, the premium is $\Phi(0; \phi) = 1$, and the uncovered interest rate parity along with the Euler equation yield $i = i^* = \beta^{-1} - 1$. Employment equals output ($Y = N$, $Y^* = N^*$), and unitary real marginal costs appear in production. Distortionary markups are removed thanks to the subsidies. International prices are given by: $S = Q = 1$. The euro-area market clearing yields $Y^* = C^*$ since the postulated exogenous government spending shock has a zero steady state. The budget constraint (C.32) yields $Y = C$, again because of the zero steady state spending shock ($\upsilon_g = 0$). The demand functions for the product varieties imply: $C_H = (1 - \tau)C$ and $C_M = \tau C$. Domestic market clearing (C.28) yields $Y = C_H + C_H^*$. Equation (C.3) yields $Z = U_c^{-1}$, and $\Omega = 1$. After using the wage subsidy (ι_w) to eliminate the distortion in the labor market, the real wage equals the marginal rate of substitution, $W/P = N^{\chi} U_c^{-1}$, where employment is equal to the labor force and is the same for each labor type; there is no unemployment in the steady state.

Log-linearization. The Euler (C.5) yields (3.2). The UIP (C.7) yields (3.4). Labor supply (C.16) becomes (3.18). The pricing conditions for wages, domestically produced and imported goods prices (C.17, C.23, C.26) result in (3.21, 3.9, 3.10). The market clearing condition (C.28) and the budget constraint (C.32) become (3.23) and (3.5), respectively, after scaling the government spending shock as $\upsilon_{g,t} \equiv \upsilon_{g,t}/Y$. First-differencing the logarithm of international prices yields (3.24) and (3.25). Log-linearizing the preference shifter (C.3) yields (3.19). The price aggregator (C.11) yields the log-linearized inflation in the periphery (3.8). Aggregate production (C.29) becomes (3.11). The real wage (C.15) yields (3.17). Unemployment is defined in (3.20).

C.2 Data Overview

C.2.1 Data Sources.

The sample period is 1999Q1–2016Q4 and consists of 10 quarterly data series for the Euro Area (19 economies, fixed composition) and the four southern peripheral economies. Two additional quarterly series are used for the Euro Area in the robustness analysis.

Nine series are common in the Euro Area and the peripheral economies: 1) Real Private Consumption Growth, constant prices, seasonally adjusted (s.a.), from OECD: $[c_t^o/c_t^{mu,o}]$; 2) Real GDP growth, s.a. & working day adj., chain linked volume, from ECB: $[y_t^o/y_t^{mu,o}]$; 3) Percent Change in the CPI, not s.a., from OECD: $[\pi_t^o/\pi_t^{mu,o}]$; 4) Unemployment rate (above 15 years old), s.a., from OECD: $[u_t^o]$ for the peripheral economies, and from ECB for the Euro Area $[u_t^{mu,o}]$; 5) Employment series, s.a. for all economies but Greece, from ECB: $[n_t^o/n_t^{mu,o}]$; 6) Aggregate wages: GDP and main components, wages and salaries, current prices, in mil., s.a., from Eurostat: $[\pi_{w,t}^{wns,o}/\pi_{w,t}^{mu,wns,o}]$; 7) Labor Costs, Compensation per unit of labor, Hourly Compensation, Total Economy, Total – All Activities, Index (a few series are not s.a.), from ECB, Statistical Data Warehouse: $[\pi_{w,t}^{hr,o}/\pi_{w,t}^{mu,hr,o}]$; 8) Labor Costs, Compensation per unit of labor, Compensation per employee, Total Economy, Total – All Activities, Index (a few series are not s.a.), from ECB, Statistical Data Warehouse: $[\pi_{w,t}^{comp,o}/\pi_{w,t}^{mu,comp,o}]$; 9) Private sector, hourly earnings index compiled from surveys, from OECD: $[\pi_{w,t}^{earn,o}/\pi_{w,t}^{mu,earn,o}]$. No data for Greece. Italy's series start in 2000Q1; I replace the four missing observations (1999Q1-1999Q4) with the growth rate of the s.a. hourly earnings index for manufacture from the same source. 10) in the periphery, the percent change in the GDP Deflator, s.a., from OECD: $[\pi_{h,t}^o]$; 10) in the Euro Area, the money market interest rate (percent per annum), from OECD: $[i_t^{mu,o}]$. The two additional series used in the robustness are: 11) the two-year-ahead unemployment forecasts, survey of professional forecasters, from ECB: $[uf_{t,t+h}^o]$; 12) the monthly euro-area shadow rate of Wu and Xia (2017) averaged to a quarterly frequency.

All seasonal effects are removed using the S3x3 filter.

It is worth pointing out that compensation of employees equals to the sum of wages and salaries and employers' social contributions, and serves in the income approach to GDP. Measures 6), 7), and 8) are compiled from administrative data, whereas 9) is compiled from survey data.

The unemployment series are plotted in Fig.(C.2). Nominal wage inflation series are shown in Fig.(C.1), and suggest a degree of country heterogeneity since the series are more correlated in Greece and Italy than in the Euro Area, Portugal, and Spain. The bivariate correlations among those series, and of each of those series with unemployment, are reported in Table (C.1). Three observations associated with the findings of the paper are drawn. First, that correlation varies across wage series. It is higher among the administrate wage measures than between any of those measures and the survey-based earnings. Second, a high correlation between the unemployment rate and a wage series suggests a strong comovement. That comovement plays a pivotal role in the magnitude of the *short-run* impact of wage markup shocks. In the Euro Area, Portugal, and Spain, unemployment is considerably correlated with wages. In Greece, the correlation is a tad weakened across all wage measures. In contrast, in Italy, the correlation is small or moderate across all measures. Third, although the correlation among the wage series does not change considerably when focusing on the 2009Q1–16Q4 period, the correlation of all wage series with the unemployment rate weakens. This weakening suggests a *disconnect* that possibly mirrors downward wage rigidities and an adjustment of the extensive margin of labor supply instead of wages to the underlying economic conditions. The Italian economy constitutes an exception that involves a low correlation of unemployment with all wage series at all times – though, the correlation with earnings becomes moderate during the above time window.

Figure C.1: Measures of Wage Inflation

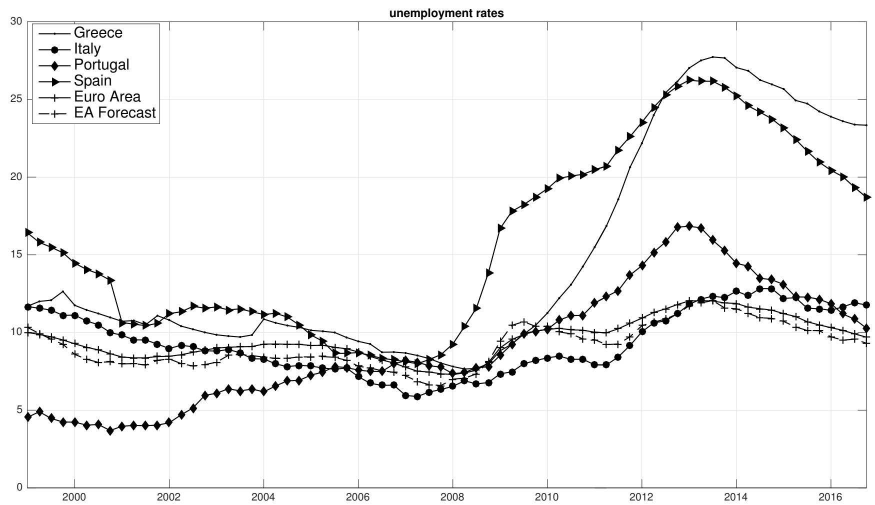
Notes: The figure depicts four seasonally adjusted measures of wage inflation during 1991Q1–2016Q4: (i) economy wide wages and salaries in millions; (ii) hourly compensation index; (iii) compensation per employee; (iv) hourly earnings, private sector index. *Sources:* OECD, Eurostat, ECB.

Table C.1: Measures of Wage Inflation – Correlations

	π_w^{wns}, π_w^{hr}	$\pi_w^{wns}, \pi_w^{comp}$	$\pi_w^{wns}, \pi_w^{earn}$	u, π_w^{wns}	u, π_w^{hr}	u, π_w^{comp}	u, π_w^{earn}
1999Q1-2016Q4							
Greece	0.8	0.7		-0.4	-0.3	-0.0	
Spain	0.6	0.7	0.4	-0.6	-0.4	-0.5	-0.6
Portugal	0.4	0.7	0.1	-0.5	-0.0	-0.4	-0.3
Euro Area	0.2	0.7	0.4	-0.5	-0.4	-0.5	-0.6
Italy	0.7	0.6	0.0	-0.1	-0.2	0.0	-0.3
2009Q1-2016Q4							
Greece	0.8	0.7		-0.1	-0.2	-0.1	
Spain	0.6	0.8	-0.1	-0.1	-0.2	-0.2	-0.4
Portugal	0.5	0.7	0.0	-0.1	-0.0	-0.1	-0.2
Euro Area	-0.3	0.5	0.0	0.1	-0.3	-0.1	-0.2
Italy	0.1	0.6	-0.3	0.2	-0.3	0.1	-0.5

Notes: u: unemployment; π_w^{wns}: economy wide wages and salaries in millions; π_w^{hr}: hourly compensation index; π_w^{comp}: compensation per employee; π_w^{earn}: hourly earnings, private sector index. *Sources:* OECD, Eurostat, ECB.

Figure C.2: Unemployment Rates



Notes: The figure depicts the 1991Q1–2016Q4 unemployment rate of the southern euro-area economies and the Euro Area, and the two-year-ahead private sector forecasts for the euro-area unemployment. *Sources:* ECB, OECD.

C.2.2 Observation equations.

Since the euro-area block is nested in a small open economy model, the observation equations need to incorporate the fact that the euro-area series stem from the sum of the country-specific series. This is taken into account by introducing the parameter λ that is fixed to the sample average ratio of the output of a peripheral economy to the euro-area output. Ultimately, λ accounts for the size of each of the peripheral economies in the Euro Area. The data are obtained from Eurostat. That parameter is 1.8% for Greece, 17% for Italy, 1.8% for Portugal, and 10.5% for Spain. The observation linking the detrended data to the latent states are shown below. When I estimate the euro-area block in an independent run, I only use equations (C.33)–(C.42) and set $\lambda = 0$.

Table C.2: Observation Equations

$i_t^{mu,o} = i_t^*$ (C.33)	$\Delta c_t^o = c_t - c_{t-1}$ (C.43)
$\Delta y_t^{mu,o} = (1-\lambda)\Delta y_t^* + \lambda \Delta y_t$ (C.34)	$\Delta y_t^o = y_t - y_{t-1}$ (C.44)
$\Delta c_t^{mu,o} = (1-\lambda)\Delta c_t^* + \lambda \Delta c_t$ (C.35)	$u_t^o = u_t$ (C.45)
$u_t^{mu,o} = (1-\lambda)u_t^* + \lambda u_t$ (C.36)	$\Delta n_t^o = \Delta n_t$ (C.46)
$\Delta n_t^{mu,o} = (1-\lambda)\Delta n_t + \lambda \Delta n_t$ (C.37)	$\pi_{h,t}^o = \pi_{h,t}$ (C.47)
$\pi_t^{mu,o} = (1-\lambda)\pi_{p,t}^* + \lambda \pi_{p,t}$ (C.38)	$\pi_t^o = \pi_{p,t}$ (C.48)
$\pi_{w2,t}^{mu,wns,o} = (1-\lambda)\pi_{w,t}^* + \lambda \pi_{w,t}$ (C.39)	$\pi_{w,t}^{hr,o} = \alpha^{hr}\pi_{w,t}$ (C.49)
$\pi_{w2,t}^{mu,earn,o} = \alpha^{earn,*}\left[(1-\lambda)\pi_{w,t}^* + \lambda \pi_{w,t}\right]$ (C.40)	$\pi_{w2,t}^{wns,o} = \pi_{w,t}$ (C.50)
$\pi_{w,t}^{mu,hr,o} = \alpha^{hr,*}\left[(1-\lambda)\pi_{w,t}^* + \lambda \pi_{w,t}\right]$ (C.41)	$\pi_{w2,t}^{comp,o} = \alpha^{comp}\pi_{w,t}$ (C.51)
$\pi_{w2,t}^{mu,comp,o} = \alpha^{comp,*}\left[(1-\lambda)\pi_{w,t}^* + \lambda \pi_{w,t}\right]$ (C.42)	$\pi_{w2,t}^{earn,o} = \alpha^{earn}\pi_{w,t}$ (C.52)

C.3 Additional Results

The following figure and tables collect various results that complement the benchmark analysis, and are briefly mentioned in the paper.

Table (C.3) displays the posterior std of the measurement errors for series with a single observable. A tight prior keeps the posterior close to it, and is justified because of the use of a single observable. In that way, the incorporation of such series is equivalent to the traditional way observables are introduced in DSGE models without measurement error.

Fig.(C.3) depicts the historical decomposition of unemployment in the southern economies across the whole sample. It shows that, contrary to the Euro Area, the impact of the initial observation fades out over time, while the impact of wage markup shocks increases as more data points become available.

Table (C.4) reports the FEVD at the prior mean that is discussed in the Robustness Analysis of the paper. It shows that the prior favors demand shocks, and only assigns a small role to wage markup shocks in unemployment fluctuations.

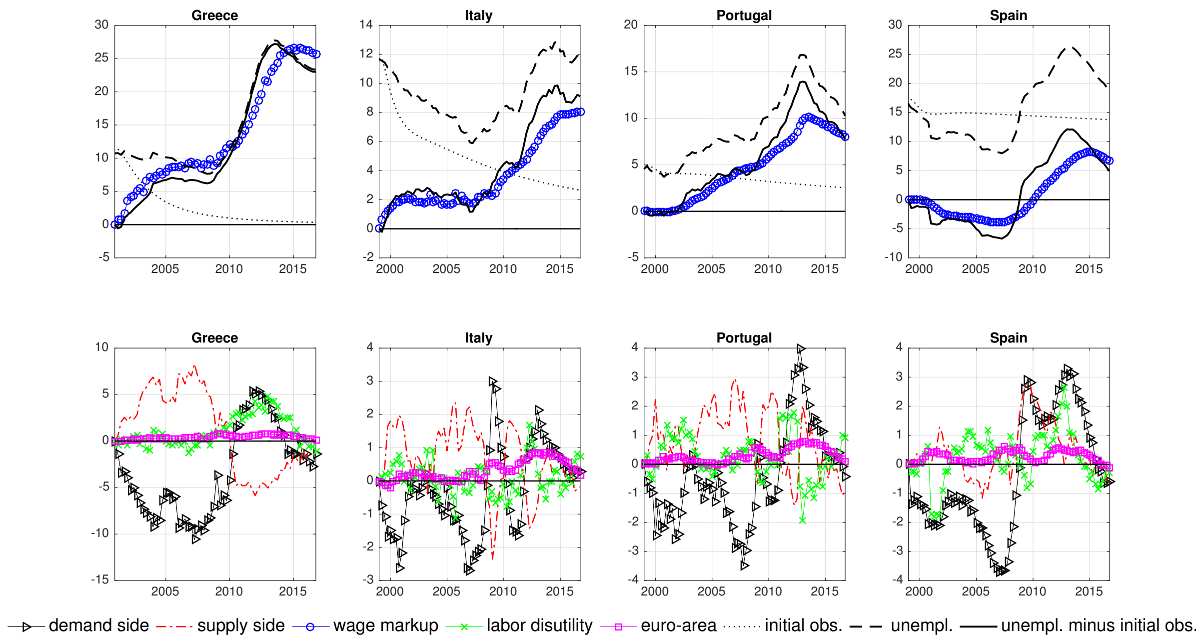
Finally, Table (C.5) provides the posterior estimates for all parameters that pertain to the alternative specifications for the Euro Area in the Robustness Analysis.

Table C.3: Posterior std of Measurement Error for series with a single observable

			Greece	Italy	Portugal
		Prior	**Mean [5-95%]**	**Mean [5-95%]**	**Mean [5-95%]**
m.e. consumption	μ_c	IG (0.01, 0.001)	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]	0.010 [0.008, 0.012]
m.e. output	μ_y	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]
m.e. unempl.	μ_u	IG (0.01, 0.001)	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]
m.e. GDP deflator	μ_{defl}	IG (0.01, 0.001)	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]
m.e. CPI inflation	μ_π	IG (0.01, 0.001)	0.167 [0.146, 0.191]	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]
m.e. employment	μ_l	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]
m.e. int. rate	μ_{i^*}	IG (0.01, 0.001)	[,]	[,]	[,]

			Spain	Euro Area
		Prior	**Mean [5-95%]**	**Mean [5-95%]**
m.e. consumption	μ_c	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]
m.e. output	μ_y	IG (0.01, 0.001)	0.010 [0.009, 0.011]	0.010 [0.008, 0.012]
m.e. unempl.	μ_u	IG (0.01, 0.001)	0.010 [0.008, 0.011]	0.010 [0.008, 0.012]
m.e. GDP deflator	μ_{defl}	IG (0.01, 0.001)	0.010 [0.008, 0.012]	[,]
m.e. CPI inflation	μ_π	IG (0.01, 0.001)	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]
m.e. employment	μ_l	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]
m.e. int. rate	μ_{i^*}	IG (0.01, 0.001)	[,]	0.010 [0.008, 0.011]

Figure C.3: Unemployment – Southern Periphery



Notes: The figure displays the posterior mean contribution of each innovation in the unemployment rate.

Table C.4: The role of the Prior

	Unempl.		Output	
shock	**SOE**	**EA**	**SOE**	**EA**
demand side	69/68	85/85	35/31	82/75
demand	68/67	84/84	32/28	79/72
spending	1/1	1/1	3/3	3/3
supply side	4/4	2/2	11/9	6/5
technology	1/1	1/1	2/2	2/1
price markup	2/2	1/1	8/7	4/4
import markup	0/0	/	0/0	/
labor market	17/17	13/13	18/23	13/20
wage markup	17/17	13/13	15/13	10/9
labor disutility	0/0	0/0	2/10	2/10
euro-area	10/11	100/100	36/37	100/100

Notes: Forecast error variance decomposition at the prior mean 10/40 quarters ahead. *Mnemonics:* EA: Euro Area, SOE: Small Open Economy. Demand shocks in the Euro Area include the impact of monetary policy shocks.

Table C.5: Euro Area Business Cycles – Robustness Checks – Posterior

		Prior	benchmark Posterior	shadow rate Posterior	forecasts Posterior	time variation Posterior
habit	η^*	B (0.70, 0.10)	0.96 [0.94, 0.98]	0.97 [0.96, 0.98]	0.87 [0.84, 0.90]	0.94 [0.90, 0.96]
inverse Frisch elast.	χ^*	N (2.00, 1.00)	1.74 [1.51, 2.04]	1.79 [1.53, 2.20]	1.72 [1.57, 1.90]	1.80 [1.60, 2.06]
wealth effect	ω^*	B (0.50, 0.20)	0.022 [0.012, 0.035]	0.016 [0.009, 0.026]	0.002 [0.001, 0.003]	0.027 [0.012, 0.049]
price indexation	γ_p^*	B (0.50, 0.15)	0.38 [0.17, 0.64]	0.38 [0.17, 0.62]	0.27 [0.11, 0.51]	0.27 [0.12, 0.48]
price stickiness	θ_p^*	B (0.50, 0.10)	0.78 [0.69, 0.87]	0.79 [0.70, 0.88]	0.83 [0.76, 0.89]	0.76 [0.67, 0.85]
wage indexation	γ_w^*	B (0.50, 0.15)	0.16 [0.07, 0.26]	0.17 [0.08, 0.29]	0.12 [0.05, 0.20]	0.32 [0.15, 0.54]
wage stickiness	θ_w^*	B (0.50, 0.10)	0.49 [0.45, 0.54]	0.50 [0.45, 0.54]	0.52 [0.48, 0.57]	0.52 [0.47, 0.58]
MP resp. to interest rate	ρ^*	B (0.75, 0.10)	0.90 [0.87, 0.93]	0.91 [0.88, 0.93]	0.80 [0.77, 0.83]	0.89 [0.85, 0.92]
MP resp. to inflation	ψ_π^*	N (1.50, 0.25)	1.85 [1.55, 2.20]	1.97 [1.67, 2.31]	1.06 [1.03, 1.11]	1.63 [1.15, 2.11]
MP resp. to output gap	ψ^*	N (0.13, 0.05)	0.05 [0.02, 0.09]	0.10 [0.05, 0.15]	-0.03 [-0.04, -0.02]	-0.01 [-0.03, 0.04]
subst. elast. wages	ϵ_w^*	N (3.00, 0.50)	3.02 [2.28, 3.81]	3.01 [2.21, 3.84]	3.05 [2.19, 3.88]	3.10 [2.28, 3.90]
AR demand	ρ_d^*	B (0.60, 0.20)	0.38 [0.28, 0.47]	0.39 [0.29, 0.48]	0.19 [0.08, 0.30]	0.29 [0.16, 0.41]
std demand	σ_d^*	IG (0.15, 1.00)	0.11 [0.09, 0.13]	0.11 [0.09, 0.13]	0.11 [0.09, 0.13]	0.11 [0.09, 0.13]
AR price markup	ρ_p^*	B (0.60, 0.20)	0.90 [0.79, 0.97]	0.92 [0.81, 0.98]	0.82 [0.59, 0.91]	0.89 [0.73, 0.97]
std price markup	σ_p^*	IG (0.15, 1.00)	0.07 [0.05, 0.11]	0.07 [0.04, 0.10]	0.08 [0.05, 0.12]	0.08 [0.06, 0.12]
std labor disutility	σ_x^*	IG (0.15, 1.00)	0.20 [0.15, 0.25]	0.20 [0.15, 0.26]	0.31 [0.26, 0.36]	0.21 [0.16, 0.27]
AR wage markup	ρ_w^*	B (0.60, 0.20)	0.994 [0.988, 0.998]	0.993 [0.987, 0.998]	0.991 [0.988, 0.994]	0.953 [0.924, 0.980]
std wage markup	σ_w^*	IG (0.15, 1.00)	0.05 [0.03, 0.06]	0.05 [0.03, 0.06]	0.04 [0.04, 0.05]	0.10 [0.06, 0.15]
std monetary policy	σ_{mp}^*	IG (0.15, 1.00)	0.09 [0.08, 0.11]	0.12 [0.10, 0.14]	0.12 [0.10, 0.14]	0.10 [0.09, 0.12]
AR technology	ρ_a^*	B (0.60, 0.20)	0.93 [0.88, 0.99]	0.93 [0.88, 0.98]	1.00 [1.00, 1.00]	0.93 [0.86, 0.99]
std technology	σ_a^*	IG (0.15, 1.00)	0.45 [0.39, 0.51]	0.45 [0.39, 0.52]	0.45 [0.39, 0.51]	0.45 [0.39, 0.52]
AR spending	ρ_g^*	B (0.60, 0.20)	0.93 [0.88, 0.97]	0.93 [0.88, 0.97]	0.98 [0.96, 0.99]	0.93 [0.88, 0.97]
std spending	σ_g^*	IG (0.15, 1.00)	0.48 [0.42, 0.55]	0.48 [0.42, 0.55]	0.49 [0.43, 0.55]	0.48 [0.42, 0.55]
factor hourly compensation	α^{hr*}	N (1.00, 0.50)	0.22 [0.07, 0.38]	0.21 [0.06, 0.36]	0.36 [0.17, 0.56]	0.25 [0.08, 0.41]
factor comp. per employee	α^{comp*}	N (1.00, 0.50)	0.39 [0.28, 0.49]	0.38 [0.28, 0.48]	0.44 [0.30, 0.61]	0.42 [0.31, 0.53]
factor hourly earnings	α^{earn*}	N (1.00, 0.50)	0.33 [0.22, 0.44]	0.32 [0.20, 0.44]	0.47 [0.31, 0.63]	0.33 [0.20, 0.46]
meas. error wages and salaries	$\mu_{w^*}^{wns}$	IG (0.15, 1.00)	0.24 [0.20, 0.29]	0.24 [0.20, 0.29]	0.37 [0.32, 0.43]	0.25 [0.20, 0.31]
meas. error hourly comp.	$\mu_{w^*}^{hr}$	IG (0.15, 1.00)	0.29 [0.25, 0.33]	0.29 [0.25, 0.33]	0.28 [0.24, 0.32]	0.28 [0.24, 0.32]
meas. error comp. per employee	$\mu_{w^*}^{comp}$	IG (0.15, 1.00)	0.19 [0.17, 0.22]	0.19 [0.17, 0.22]	0.21 [0.19, 0.25]	0.19 [0.16, 0.22]
meas. error hourly earnings	$\mu_{w^*}^{earn}$	IG (0.15, 1.00)	0.22 [0.19, 0.25]	0.22 [0.19, 0.26]	0.22 [0.19, 0.25]	0.22 [0.19, 0.25]
meas. error output	μ_{y^*}	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]
meas. error consumption	μ_{c^*}	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]	0.010 [0.008, 0.012]
meas. error inflation	μ_{π^*}	IG (0.01, 0.001)	0.010 [0.009, 0.012]	0.010 [0.009, 0.012]	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]
meas. error int. rate	μ_{i^*}	IG (0.01, 0.001)	0.010 [0.008, 0.011]	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]
meas. error employment	μ_{l^*}	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.009, 0.012]	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]
meas. error unempl.	μ_{u^*}	IG (0.01, 0.001)	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]	0.010 [0.008, 0.012]
meas. error unempl. forecasts	μ_{uf^*}	IG (0.01, 0.001)	[,]	[,]	0.010 [0.008, 0.012]	[,]
wage indexation post 2008	γ_w^*	B (0.50, 0.15)	[,]	[,]	[,]	0.27 [0.12, 0.45]
wage stickiness post 2008	θ_w^*	B (0.50, 0.10)	[,]	[,]	[,]	0.53 [0.48, 0.59]
AR wage markup post 2008	ρ_w^*	B (0.60, 0.20)	[,]	[,]	[,]	1.00 [0.99, 1.00]
std wage markup post 2008	σ_w^*	IG (0.15, 1.00)	[,]	[,]	[,]	0.06 [0.04, 0.08]
Marginal Likelihood			-180.7	-203.3	-283.6	-186.3

Appendix D

Wages During Recoveries in Euro-Area Economies. A Structural View

D.1 Model Equilibrium

The equilibrium conditions, log-linearized around the balanced growth steady state path, are collected here. The log-deviation of a generic non-stationary variable (X_t) from its steady state (x), after rendering the former stationary, is denoted by $\widehat{x}_t \equiv ln(X_t/e^{\gamma t}/x)$.

D.1.1 Sticky Price and Wage Equilibrium.

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Aggregate Production Function

$$\widehat{y}_t = (1 + \Phi_y/y)[\alpha\widehat{k}_t + (1-\alpha)\widehat{L}_t + \widehat{z}_t] \tag{D.1}$$

Capital-To-Labor Ratio

$$\widehat{k}_t = \widehat{w}_t^r - \widehat{r}_t^{k,r} + \widehat{L}_t \tag{D.2}$$

Marginal Cost

$$\widehat{mc}_t^r = (1-\alpha)\widehat{w}_t^r + \alpha\widehat{r}_t^{k,r} - \widehat{z}_t \tag{D.3}$$

Rental Rate of Capital

$$\widehat{r}_t^{k,r} = [\psi/(1-\psi)]\widehat{u}_t \tag{D.4}$$

Effective Capital

$$\widehat{k}_t = \widehat{u}_t + \widehat{\bar{k}}_{t-1} \tag{D.5}$$

Capital Accumulation

$$\widehat{\bar{k}}_t = k_1(\widehat{\bar{k}}_{t-1}) + (1-k_1)(\widehat{v}_t^i + \widehat{\tilde{i}}_t) \tag{D.6}$$

where $k_1 = (1-\delta)/e^{\gamma}$.

Price of Capital

$$\widehat{q}_t^k = E_t\left(\widehat{\xi}_{t+1} - \widehat{\xi}_t\right) + q_1 E_t \widehat{r}_{t+1}^{r,k} + (1-q_1)\, E_t \widehat{q}_{t+1}^k \tag{D.7}$$

where $q_1 = \left(r^{k,r}/[r^{k,r} + 1 - \delta]\right)$.

Investment

$$\widehat{i}_t = i_1(\widehat{i}_{t-1}) + (1-i_1)\,(E_t\widehat{i}_{t+1}) + i_2(\widehat{q}_t^k + \widehat{\upsilon}_t^i) \tag{D.8}$$

where $i_1 = 1/[1+\beta]$ and $i_2 = i_1/\left[e^{2\gamma}S''\right]$.

Price Inflation

$$\widehat{\pi}_t = (\pi_1\beta)E_t\widehat{\pi}_{t+1} + (\pi_1\iota_p)\widehat{\pi}_{t-1} + \kappa_p\left(\widehat{mc}_t^r + (1/\lambda_p)\,\widehat{\upsilon}_t^p\right) \tag{D.9}$$

where $\kappa_p = (1-\zeta_p)(1-\zeta_p\beta)/\left[\zeta_p(1+\iota_p\beta)\right]$, $\pi_1 = 1/[1+\iota_p\beta]$, $\widehat{\upsilon}_t^p \equiv log(\upsilon_t^p/\upsilon^p)$, and $1+\upsilon_t^p \equiv \lambda_t^p/(\lambda_t^p - 1)$.

Wage Inflation

$$\widehat{\pi}_t^w - \iota_w\widehat{\pi}_{t-1} = \beta\left[E_t\widehat{\pi}_{t+1}^w - \iota_w\widehat{\pi}_t\right] - \kappa_w\left(\widehat{\mu}_t^w - \widehat{\mu}_t^{w,n}\right) \tag{D.10}$$

where $\kappa_w = (1-\zeta_w)(1-\zeta_w\beta)/\left[\zeta_w(1+\chi\lambda_w)\right]$.

Real Wage

$$\widehat{w}_t^r - \widehat{w}_{t-1}^r = \widehat{\pi}_t^w - \widehat{\pi}_t \tag{D.11}$$

Endogenous Wage Markup,

$$\widehat{\mu}_t^w = \chi \widehat{U}_t \tag{D.12}$$

Exogenous Wage Markup,

$$\widehat{\mu}_t^{w,n} = (1/\lambda_w)\, \widehat{\upsilon}_t^w \tag{D.13}$$

where $\widehat{\upsilon}_t^w \equiv log(\upsilon_t^w/\upsilon^w)$, and $1 + \upsilon_t^w \equiv \lambda_t^w/(\lambda_t^w - 1)$.

Natural Unemployment,

$$\widehat{\mu}_t^{w,n} = \chi \widehat{U}_t^n \tag{D.14}$$

Unemployment,

$$\widehat{U}_t = \widehat{LF}_t - \widehat{L}_t \tag{D.15}$$

Labor Supply,

$$\widehat{w}_t^r = \widehat{\chi}_t + \widehat{\theta}_t + \chi \widehat{LF}_t \tag{D.16}$$

Interest Rate Determination,

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + (1-\rho_r)\left[\psi_\pi \widehat{\pi}_t + \psi_y(\widehat{y}_t - \widehat{y}_t^f) + \psi_{\Delta y}\Delta(\widehat{y}_t - \widehat{y}_t^f)\right] + \epsilon_t^{mp} \tag{D.17}$$

Resource Constraint

$$(c/y)\widehat{c}_t + (i/y)\widehat{i}_t + (g/y)\widehat{g}_t + (r^{k,r}k/y)\widehat{u}_t = \widehat{y}_t \tag{D.18}$$

Lagrange Multiplier

$$-(1-\eta/e^\gamma)\widehat{\xi}_t = \widehat{c}_t - (\eta/e^\gamma)\widehat{c}_{t-1} \tag{D.19}$$

Inter-Temporal Consumption Dynamics

$$\widehat{\xi}_t = E_t\left(\widehat{\xi}_{t+1} + \widehat{\upsilon}_t^b + \widehat{r}_t - \widehat{\pi}_{t+1}\right) \tag{D.20}$$

Shifter

$$\widehat{\theta}_t = (1-\nu)\widehat{\theta}_{t-1} - \nu\widehat{\xi}_t \tag{D.21}$$

D.1.2 Flexible Price and Wage Equilibrium.

The solution of the model in the flexible price and wage equilibrium (variables associated with that equilibrium are denoted with a superscript "f") is obtained from the above set of equations (D.1–D.21) for zero price and wage stickiness.

D.1.3 Stochastic Structure.

The disturbances follow AR(1) processes. A few shocks are scaled: the risk premium shock is scaled in (D.20) after substituting in (D.19), and is adjusted accordingly in (D.7) after substituting in (D.20); the price and wage markup shocks are scaled in equations (D.9) and (D.13), respectively; the government spending shock is scaled in (D.18); the investment shock is scaled in (D.8) and adjusted accordingly in (D.6).

D.2 Observation Equations, State Space, And Data Sources

The observation equations are shown below.

$$dln(GDP_t/ImplicitPriceDeflator_t/Pop_t) = \gamma + \Delta\widehat{y}_t + \mu_t^y \quad \text{(D.22)}$$

$$dln(PrivateCons_t/ImplicitPriceDeflator_t/Pop_t) = \gamma + \Delta\widehat{c}_t + \mu_t^c \quad \text{(D.23)}$$

$$dln(GrossFixedInvestment_t/ImplicitPriceDeflator_t/Pop_t) = \gamma + \Delta\widehat{i}_t + \mu_t^i \quad \text{(D.24)}$$

$$dln(ImplicitPriceDeflator_t) = \pi + \widehat{\pi}_t + \mu_t^\pi \quad \text{(D.25)}$$

$$InterestRate_t = r + \widehat{r}_t + \mu_t^r \quad \text{(D.26)}$$

$$UnemploymentRate_t = u + \widehat{u}_t + \mu_t^u \quad \text{(D.27)}$$

$$ln(Employment_t/Pop_t) = l + \widehat{l}_t + \mu_t^l \quad \text{(D.28)}$$

The mean of the latter's left hand side is normalized to zero.

$$dln\begin{bmatrix} Compensation_t/ImplicitPriceDeflator_t/Employment_t \\ WagesAndSalaries_t/ImplicitPriceDeflator_t/Employment_t \\ NegotiatedWagesIndex_t/ImplicitPriceDeflator_t \\ PrivateEarningsIndex_t/ImplicitPriceDeflator_t/Employment_t \\ HourlyCompensationIndex_t/ImplicitPriceDeflator_t \end{bmatrix} =$$

$$= \begin{bmatrix} \gamma_{cpe} \\ \gamma_{wnspe} \\ \gamma_{neg} \\ \gamma_{priv} \\ \gamma_{cph} \end{bmatrix} + \begin{bmatrix} 1 \\ \Psi_{wnspe} \\ \Psi_{neg} \\ \Psi_{priv} \\ \Psi_{cph} \end{bmatrix} \Delta\widehat{w}_t + \begin{bmatrix} \mu_t^{cpe} \\ \mu_t^{wnspe} \\ \mu_t^{neg} \\ \mu_t^{priv} \\ \mu_t^{cph} \end{bmatrix} \quad \text{(D.29)}$$

The approach to the state space follows Charalampidis (2018).

The data sources are explained below.

- Germany (1991Q1-2017Q4):

  1. Gross Domestic Product, current prices, s.a., Euro, millions, OECD Quarterly National Accounts
  2. GDP Price Deflator, index (2010=100), s.a., OECD Quarterly National Accounts
  3. Gross Capital Formation, current prices, s.a., Euro, millions, OECD Quarterly National Accounts
  4. Private Final Consumption Expenditure, current prices, s.a., Euro, millions, OECD Quarterly National Accounts
  5. 3-Month or 90-day Rates and Yields: Interbank Rates for Germany, Percent, Quarterly, Not Seasonally Adjusted, FRED, Federal Reserve Economic Data
  6. Total Population, persons, thousands, s.a., OECD Quarterly National Accounts
  7. Total Employment, persons, thousands, s.a., OECD Quarterly National Accounts
  8. Harmonized Unemployment Rate: Total: All Persons for Germany, Percent, Quarterly, Seasonally Adjusted, Labour Force Survey, OECD, Key Short-Term Economic Indicators
  9. Compensation of employees, total, current prices, s.a., Euro, millions, OECD Quarterly National Accounts
  10. Wages and Salaries, total, current prices, s.a., Euro, millions, OECD Quarterly National Accounts
  11. Hourly Earnings, index, s.a., Manufacturing (1991Q1-1996Q1), Private Sector (1996Q2-2017Q4), OECD

12. Hourly Compensation, Domestic (home or reference area), Total economy, Total - All activities, Index, Current prices, Non transformed data, s.a., not calendar adjusted, SDW
13. Negotiated wages, Total - Index. Neither seasonally nor working day adjusted, retrieved from SDW. Seasonality is removed with the Census X13 filter.

- France (1991Q1-2017Q4): as above; the unempl. rate is obtained from FRED.
- Italy (1995Q1-2017Q4): as above; 6 from Eurostat and is not seasonally adjusted.
- Spain (1995Q1-2017Q4): as above; no negotiated wages index is available.
- Euro Area 19 (1995Q1-2017Q4): as above; no negotiated wages index is available.

The series matched in the estimation are shown below for each economy.

D.3 Posterior

Table (D.1) collects the posterior distribution of the parameters. The parameters are in general aligned with that is usually obtained in the literature.

Table (D.2) reports the standard deviation of measurement errors for variables with a single observable series. Those are tightly estimated with a low prior mean.

A few parameters are calibrated since they are not identified in the data. δ and g are set at the values chosen in Galí et al. (2012a). β is fixed at 0.998.

In Table (D.1), the prior means for $\{\gamma, \pi, \gamma_{cpe}, \gamma_{wnspe}, \gamma_{neg}, \gamma_{priv}, \gamma_{cph}\}$ are their sample averages:

- $\{.31, .37, .19, .18, .28, .28, .32\}$ for DE,

Figure D.1: Observables, Germany

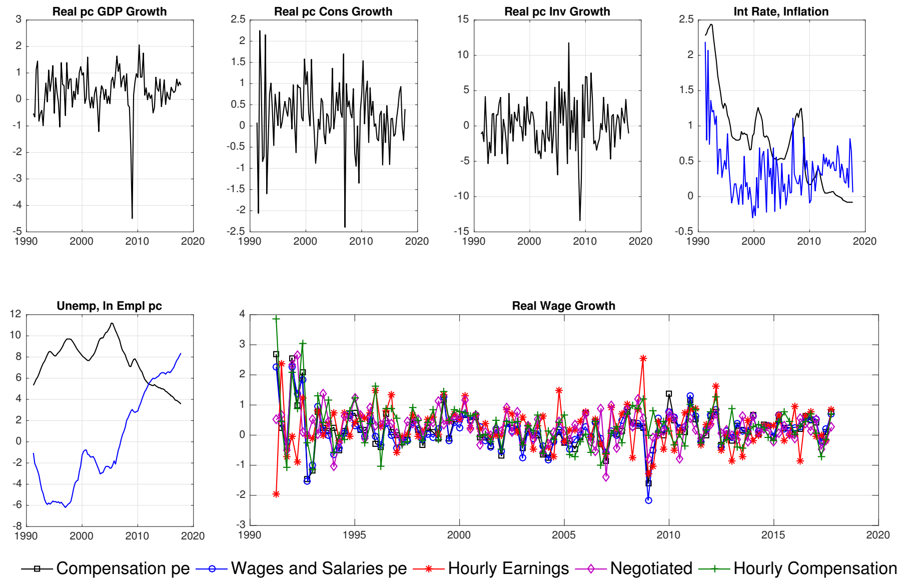
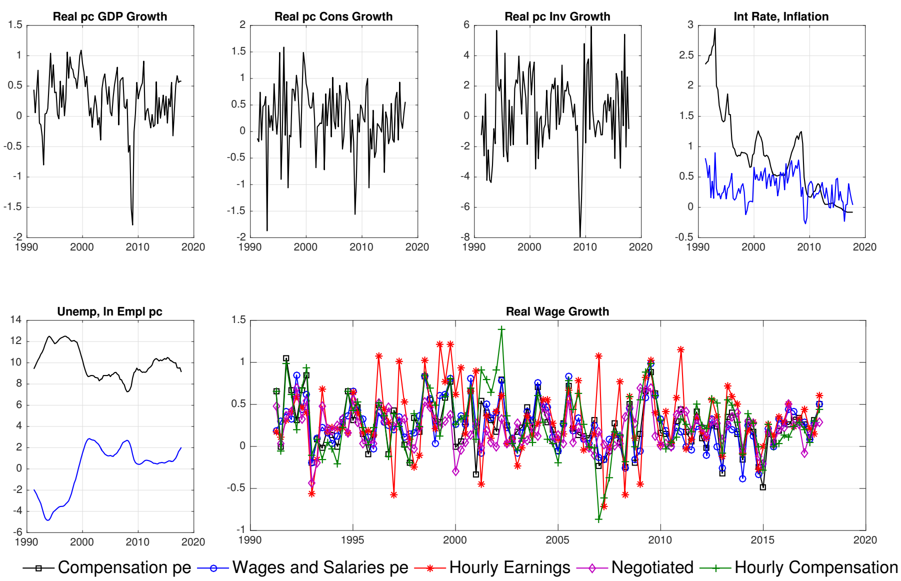


Figure D.2: Observables, France



- $\{.27, .25, .25, .31, .21, .28, .32\}$ for FR,
- $\{.08, .01, .05, .08, .04, .01, .51\}$ for IT,
- and $\{.36, .13, .13, .21, \emptyset, .07, .53\}$ for ES.

Figure D.3: Observables, Italy

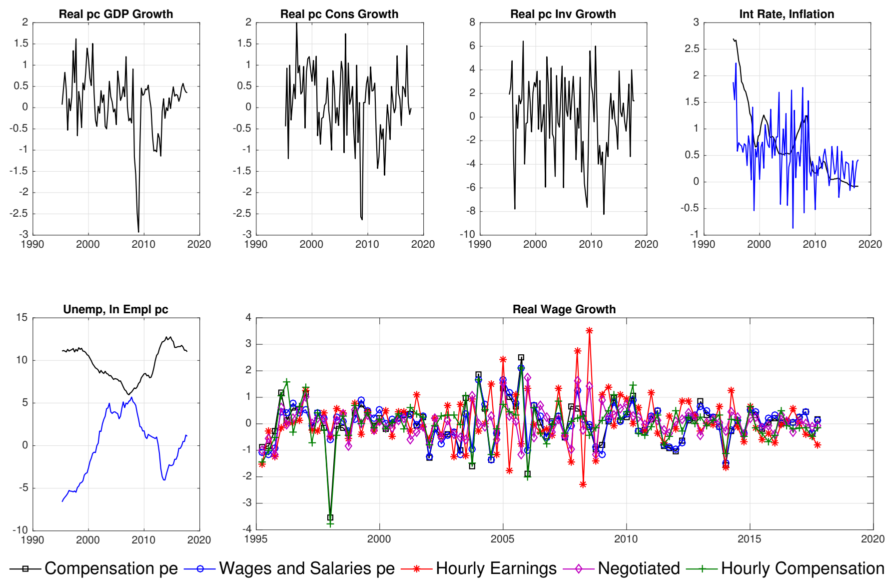


Figure D.4: Observables, Spain

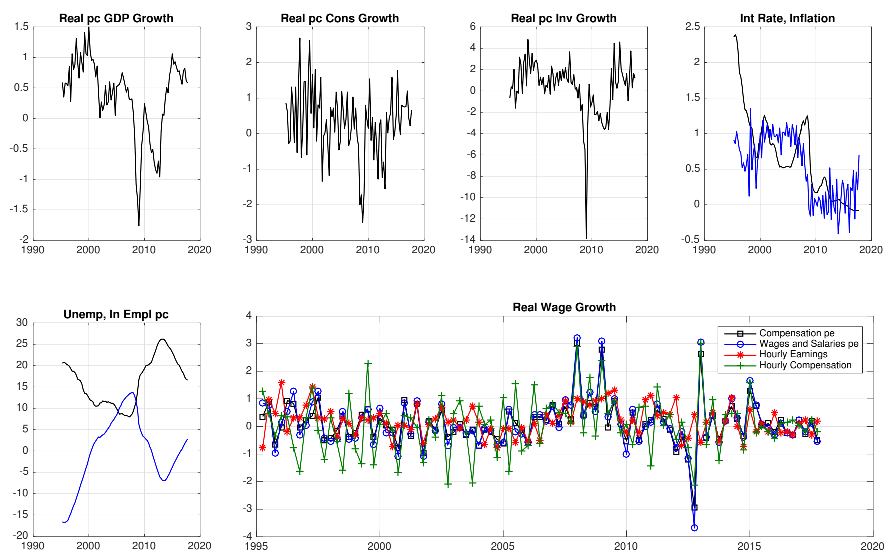


Table D.1: Posterior Distribution (Mean [5-95%])

		Prior	**Germany**	**France**	**Italy**	**Spain**
capital share	α	N (0.30, 0.02)	0.15 [0.13, 0.17]	0.15 [0.14, 0.17]	0.19 [0.16, 0.21]	0.22 [0.20, 0.25]
habit	η	B (0.70, 0.10)	0.36 [0.28, 0.44]	0.45 [0.39, 0.52]	0.79 [0.67, 0.87]	0.46 [0.37, 0.54]
util. cost elast.	ψ	B (0.50, 0.10)	0.30 [0.14, 0.52]	0.44 [0.29, 0.60]	0.67 [0.54, 0.78]	0.51 [0.39, 0.64]
adj. cost elast.	S	N (4.00, 1.00)	3.67 [1.57, 5.60]	4.19 [2.70, 5.69]	5.50 [4.26, 6.85]	4.89 [3.59, 6.27]
price indexation	ι_p	B (0.50, 0.15)	0.13 [0.05, 0.24]	0.23 [0.11, 0.39]	0.17 [0.07, 0.30]	0.17 [0.07, 0.32]
resp. to int.rate	ρ_r	B (0.75, 0.10)	0.90 [0.87, 0.92]	0.83 [0.80, 0.86]	0.92 [0.90, 0.94]	0.92 [0.90, 0.94]
resp. to inflation	ψ_π	N (1.70, 0.25)	2.13 [1.82, 2.43]	2.54 [2.24, 2.84]	1.51 [1.18, 1.87]	1.93 [1.61, 2.26]
resp. to growth	$\psi_{\Delta y}$	N (0.12, 0.05)	0.05 [0.01, 0.10]	0.03 [-0.03, 0.08]	0.19 [0.13, 0.25]	0.07 [0.04, 0.11]
resp. to gap	ψ_y	N (0.12, 0.05)	0.16 [0.08, 0.24]	0.16 [0.08, 0.25]	0.13 [0.05, 0.21]	0.08 [0.01, 0.15]
growth	γ	N (*, 0.03)	0.27 [0.23, 0.30]	0.26 [0.23, 0.28]	0.06 [0.03, 0.09]	0.31 [0.28, 0.35]
inflation	π	N (*, 0.03)	0.42 [0.37, 0.47]	0.35 [0.30, 0.40]	0.54 [0.49, 0.58]	0.55 [0.50, 0.60]
price stickiness	ζ_p	B (0.50, 0.10)	0.65 [0.56, 0.77]	0.61 [0.53, 0.70]	0.95 [0.92, 0.97]	0.84 [0.80, 0.90]
st.st. net P mkp	υ_p	N (0.30, 0.03)	0.34 [0.29, 0.39]	0.35 [0.30, 0.39]	0.33 [0.28, 0.38]	0.27 [0.22, 0.32]
st.st. net W mkp	υ_w	N (0.50, 0.10)	0.33 [0.26, 0.40]	0.43 [0.32, 0.54]	0.27 [0.18, 0.38]	0.33 [0.23, 0.47]
inv. Frisch elast.	χ	N (2.00, 1.00)	5.73 [4.69, 6.95]	3.99 [3.11, 4.90]	2.18 [1.46, 3.00]	1.37 [1.00, 1.89]
wage stickiness	ζ_w	B (0.50, 0.05)	0.42 [0.31, 0.56]	0.48 [0.40, 0.55]	0.54 [0.45, 0.63]	0.40 [0.31, 0.51]
wage indexation	ι_w	B (0.50, 0.15)	0.33 [0.15, 0.53]	0.23 [0.11, 0.37]	0.14 [0.07, 0.22]	0.40 [0.18, 0.65]
wealth effect	ν	B (0.20, 0.20)	0.04 [0.00, 0.14]	0.04 [0.00, 0.10]	0.01 [0.00, 0.02]	0.00 [0.00, 0.01]
st.st. labor	$\bar{l}$	N (0.00, 0.10)	-0.06 [-0.21, 0.09]	-0.33 [-0.49, -0.18]	-0.15 [-0.33, 0.01]	-0.10 [-0.26, 0.07]
AR risk premium	ρ_b	B (0.60, 0.20)	0.96 [0.92, 0.98]	0.95 [0.91, 0.98]	0.35 [0.14, 0.65]	0.93 [0.86, 0.97]
std risk premium	σ_b	IG (0.15, 1.00)	0.06 [0.04, 0.07]	0.06 [0.05, 0.07]	0.29 [0.20, 0.38]	0.07 [0.04, 0.10]
AR technology	ρ_z	B (0.60, 0.20)	0.99 [0.99, 1.00]	0.99 [0.99, 1.00]	0.97 [0.96, 0.99]	0.94 [0.92, 0.96]
std technology	σ_z	IG (0.15, 0.20)	0.58 [0.52, 0.65]	0.29 [0.25, 0.33]	0.84 [0.74, 0.96]	1.58 [1.40, 1.80]
AR investment	ρ_i	B (0.60, 0.20)	0.73 [0.36, 0.94]	0.79 [0.68, 0.88]	0.32 [0.17, 0.46]	0.70 [0.49, 0.85]
std investment	σ_i	IG (0.15, 1.00)	1.14 [0.83, 1.65]	0.66 [0.55, 0.79]	1.35 [1.10, 1.63]	0.53 [0.40, 0.72]
AR price markup	ρ_p	B (0.50, 0.20)	0.86 [0.69, 0.96]	0.88 [0.78, 0.95]	0.11 [0.03, 0.24]	0.90 [0.77, 0.97]
std price markup	σ_p	IG (0.15, 1.00)	0.21 [0.16, 0.29]	0.13 [0.10, 0.17]	0.49 [0.42, 0.56]	0.08 [0.06, 0.11]
AR wage markup	ρ_w	B (0.60, 0.20)	0.86 [0.68, 0.95]	0.91 [0.85, 0.96]	0.93 [0.86, 0.97]	0.85 [0.76, 0.91]
std wage markup	σ_w	IG (0.15, 1.00)	8.83 [4.62, 18.46]	2.28 [1.57, 3.27]	1.58 [0.74, 3.10]	4.60 [2.73, 7.53]
std int rate	σ_r	IG (0.15, 1.00)	0.14 [0.11, 0.16]	0.16 [0.14, 0.19]	0.12 [0.10, 0.13]	0.11 [0.09, 0.13]
AR spending	ρ_g	B (0.60, 0.20)	0.98 [0.96, 1.00]	0.98 [0.97, 0.99]	0.86 [0.76, 0.96]	1.00 [0.99, 1.00]
std spending	σ_g	IG (0.15, 1.00)	0.51 [0.45, 0.57]	0.32 [0.28, 0.36]	0.51 [0.45, 0.59]	0.59 [0.53, 0.67]
tech. resp. to govt	ρ_{gz}	B (0.50, 0.20)	0.27 [0.18, 0.36]	0.07 [0.03, 0.11]	0.09 [0.03, 0.17]	0.20 [0.10, 0.31]
AR labor disutility	ρ_χ	B (0.80, 0.15)	1.00 [0.99, 1.00]	0.99 [0.97, 1.00]	0.94 [0.89, 0.97]	0.92 [0.90, 0.95]
std labor disutility	σ_χ	IG (0.15, 1.00)	1.62 [1.31, 1.99]	0.79 [0.61, 1.00]	1.74 [1.22, 2.38]	2.49 [1.78, 3.44]
LF wages & sal.	Ψ_{wnspe}	N (1.00, 0.50)	1.17 [1.05, 1.29]	0.96 [0.83, 1.09]	0.34 [0.14, 0.53]	1.18 [1.13, 1.23]
LF priv. earnings	Ψ_{priv}	N (1.00, 0.50)	0.39 [0.21, 0.61]	0.91 [0.67, 1.16]	1.18 [0.96, 1.41]	0.23 [0.11, 0.34]
LF negot. wages	Ψ_{neg}	N (1.00, 0.50)	0.66 [0.50, 0.82]	0.52 [0.39, 0.64]	0.93 [0.83, 1.03]	[,]
LF hourly comp.	Ψ_{cph}	N (1.00, 0.50)	1.00 [0.82, 1.19]	1.11 [0.94, 1.29]	0.20 [-0.05, 0.45]	0.87 [0.67, 1.07]
std me comp.	μ^{cpe}	IG (0.15, 1.00)	0.23 [0.20, 0.28]	0.14 [0.12, 0.17]	0.94 [0.83, 1.06]	0.14 [0.07, 0.17]
std me wages & sal.	μ^{wnspe}	IG (0.15, 1.00)	0.17 [0.10, 0.23]	0.13 [0.10, 0.15]	0.66 [0.58, 0.75]	0.09 [0.03, 0.17]
std me priv. earnings	μ^{priv}	IG (0.15, 1.00)	0.65 [0.58, 0.73]	0.32 [0.28, 0.36]	0.64 [0.56, 0.74]	0.52 [0.46, 0.59]
std me negot. wages	μ^{neg}	IG (0.15, 1.00)	0.46 [0.41, 0.52]	0.17 [0.15, 0.19]	0.18 [0.11, 0.23]	[,]
std me hourly comp.	μ^{cph}	IG (0.15, 1.00)	0.56 [0.50, 0.63]	0.22 [0.19, 0.25]	0.79 [0.70, 0.89]	0.82 [0.73, 0.93]
trend comp.	γ_{cpe}	N (*, 0.03)	0.20 [0.17, 0.24]	0.26 [0.23, 0.28]	0.01 [-0.04, 0.05]	0.13 [0.10, 0.17]
trend wages & sal.	γ_{wnspe}	N (*, 0.03)	0.20 [0.17, 0.24]	0.26 [0.23, 0.29]	0.05 [0.01, 0.09]	0.14 [0.10, 0.17]
trend priv. earnings	γ_{priv}	N (*, 0.03)	0.28 [0.23, 0.33]	0.31 [0.27, 0.35]	0.08 [0.03, 0.12]	0.21 [0.17, 0.26]
trend negot. wages	γ_{neg}	N (*, 0.03)	0.28 [0.24, 0.32]	0.21 [0.19, 0.24]	0.04 [0.00, 0.07]	[,]
trend hourly comp.	γ_{cph}	N (*, 0.03)	0.33 [0.28, 0.37]	0.29 [0.26, 0.32]	0.01 [-0.04, 0.06]	0.07 [0.03, 0.12]
logL			-1156	-427	-1301	-1216

Table D.2: Posterior Distribution

	Prior			**Posterior** Mean [5-95%]	
		Germany	**France**	**Italy**	**Spain**
std me output	μ_y (IG, 0.01)	0.001 [0.0100, 0.0086]	0.0116 [0.0100, 0.0084]	0.0117 [0.0100, 0.0085]	0.0119 [0.0100, 0.0085]
std me cons.	μ_c (IG, 0.01)	0.001 [0.0101, 0.0085]	0.0118 [0.0101, 0.0085]	0.0121 [0.0100, 0.0084]	0.0118 [0.0100, 0.0085]
std me inv.	μ_i (IG, 0.01)	0.001 [0.0099, 0.0083]	0.0118 [0.0100, 0.0085]	0.0119 [0.0100, 0.0084]	0.0119 [0.0100, 0.0085]
std me int.	μ_r (IG, 0.01)	0.001 [0.0102, 0.0085]	0.0120 [0.0101, 0.0085]	0.0119 [0.0100, 0.0083]	0.0118 [0.0099, 0.0084]
std me unemp.	μ_u (IG, 0.01)	0.001 [0.0100, 0.0085]	0.0119 [0.0100, 0.0085]	0.0118 [0.0100, 0.0085]	0.0117 [0.0101, 0.0084]
std me labor	μ_l (IG, 0.01)	0.001 [0.0099, 0.0085]	0.0115 [0.0100, 0.0084]	0.0117 [0.0101, 0.0085]	0.0118 [0.0100, 0.0085]
std me infl.	μ_π (IG, 0.01)	0.001 [0.0100, 0.0083]	0.0117 [0.0099, 0.0084]	0.0116 [0.0101, 0.0085]	0.0120 [0.0100, 0.0083]
logL		-1156	-427	-1301	-1216

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