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Heterogeneous effects of single monetary policy on unemployment rates in the largest EMU economies

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Heterogeneous Effects of Single Monetary Policy on Unemployment Rates in the Largest EMU Economies

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Abstract

This paper studies the effects of monetary policy on the national rates of unemployment in Germany, France, Italy and Spain, the four largest economies of the European Monetary Union (EMU), since the introduction of the euro in 1999 and before and after the Global Financial Crisis (GFC) of 2007-09. Estimating and simulating a version of a canonical medium-scale New Keynesian dynamic stochastic general equilibrium (DSGE) model with indivisible labor that incorporates unemployment developed by Galí, Smets and Wouters (2012), the paper compares the relative importance of monetary policy shocks, risk premium shocks, wage markup shocks and labor supply shocks and studies their effects on other labor market variables, such as labor force participation and real wages. We find that the same monetary policy of the European Central Bank (ECB) has had heterogeneous effects on unemployment rates and other labor market variables in these four major EMU economies. Moreover, in all of them monetary policy shocks are the second largest source of unemployment rate variability in the short, medium and long run, only preceded by risk premium shocks. Our results also confirm

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that the post-GFC zero lower bound environment has rendered ECB's interest rate policy much less powerful in affecting EMU unemployment rates. In addition to the heterogeneity documented in the effects of monetary policy along various labor market dimensions across the countries in our sample, we also reveal that the EMU economies are, further, characterized by important differences along these dimensions with respect to the United States (US).

Keywords: single monetary policy, European Monetary Union, unemployment rate fluctuations, labor market heterogeneity, New Keynesian DSGE models, Bayesian estimation

JEL codes: D58, E24, E31, E32, E52, F45

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1 Introduction

This paper aims to shed light on the effects of single monetary policy conducted by the European Central Bank (ECB) on unemployment rates in the four largest European Monetary Union (EMU) economies: Germany, France, Italy and Spain, which together account for (just above) 75% of the gross domestic product (GDP) in the EMU.[1] There are at least two profound reasons underlying this research question.

Firstly, the debate around the costs and benefits of a monetary union outlined the key role of the interaction between monetary policy and labor markets. Two perspectives emerged. One view has that, in a monetary union, monetary policy may accentuate regional economic developments. Heterogeneous effects of monetary policy may lead to divergence amongst business cycles, whilst also indicating significant differences in the propagation mechanisms (see, e.g., Mihov, 2001; Mojon and Peersman, 2001; Mojon *et al.*, 2002; van Els *et al.*, 2003). For instance, differences in the industrial structure across countries result in variations on the degree of interest-rate sensitivity, as industries tend to differ in their responsiveness to interest-rate changes. In these circumstances, whereby the effects of the short-term interest rate are asymmetric, a common monetary policy may amplify misalignments: in particular, it will smoothen the union cycle but not the national ones. The other perspective, instead, emphasizes how a single monetary policy could help countries to develop more integrated economies and labor markets. More specifically, the differences in preferences for inflation and unemployment and the underlying differences in labor market institutions are all considered to be detrimental to the effectiveness of a single monetary policy framework. One of the insights, if not the central one, of the theory of optimum currency areas is that countries with high differences in unemployment would need a lot of flexibility in labor markets when they belong to a monetary union in order to avoid substantial adjustment problems (Mundell, 1961; McKinnon, 1963). However, with economic integration, the occurrence of asymmetric shocks tends to diminish. Indeed, the possibility of following independent monetary policy has been considered itself as a source of major asymmetric shocks. Figure 1 reports the evolution of unemployment rates in the four largest EMU economies, showing important cross-country differences. The notable aspect of this heterogeneity is that it appears to persist even under the common monetary policy conducted by the ECB since the adoption of the euro in 1999, no matter the harmonization of legislation and the policymakers' efforts to mitigate

[1] Authors' calculation for 2017 based on the online Eurostat database.

the inherited diversity in national labor market institutions and mechanisms. For instance, the peak in the unemployment rate in Spain in 2013 reaches 25% of the labor force, five times larger than the 5% unemployment rate of Germany in the same year.

[Figure 1 about here]

Secondly, the effects of monetary policy shocks on unemployment have been mostly, although not entirely, studied indirectly from the effects on output and outputs gaps, the latter having been very well documented. Indeed, through the Okun's Law, changes in output are easily translated into changes in unemployment. However, the actual effects of monetary policy shocks on unemployment within the context of a monetary union have not been as well documented. More specifically, one strand of the literature, which we directly contribute to, focuses on analyzing the effects of monetary policy shocks on unemployment and other key variables. Ravn and Simonelli (2007) study the effects of monetary policy shocks on labor market indicators in the United States (US). They find that 15-20% of the variance in unemployment is caused by monetary policy shocks, with the maximum effect occurring after 4-5 quarters. Christiano *et al.* (2011c), by using medium-scale dynamic stochastic general equilibrium (DSGE) model versions incorporating unemployment, similarly find that unemployment in the US responds to an expansionary monetary policy shock with high persistence and the maximum effects occur after 4-5 quarters. This strand of literature has also studied European unemployment. Using vector autoregression (VAR) models estimated by the Bayesian approach, Amisano and Serati (2003) compare Sweden, Italy, the UK and the US and find that demand shocks play a dominant role in explaining unemployment fluctuations not only in the short run, but also in the medium and long run. In addition, the effects of demand shocks are highly persistent in Sweden, Italy and the United Kingdom (UK), and less long-lasting in the US. Their paper does not identify shocks to monetary policy separately but the total results for demand shocks can be interpreted as an upper bound on the influence of monetary policy. Karanassou *et al.* (2005) study 11 European Union (EU) countries using dynamic multi-equation models and generalized method of moments (GMM) estimation and find long drawn-out responses of unemployment to monetary policy changes. Alexius and Holmlund (2008), applying a VAR model, examine the Swedish experience of unemployment and monetary policy in comparison with the US study of Ravn and Simonelli (2007) and report that around 30% of the fluctuations in unemployment are caused by monetary policy shocks and the maximum effect occurs after 7-17 quarters. Hence, monetary policy tends to have larger and more persistent effects on unemployment in Sweden than in the US.

It is important to note that none of the studies mentioned has looked at the volatility and persistence of unemployment rates in response to common monetary policy shocks across several countries in the Euro Area (EA). Therefore, a key question arises: what are the effects of the single monetary policy in the EA on a heterogeneous set of economies? This is what we aim to address in this paper.

In order to address this question we employ the baseline medium-scale New Keynesian DSGE model with indivisible labor and unemployment developed by Galí, Smets and Wouters (2012), GSW hereafter, and quarterly observables for the time period 1999Q1 to 2017Q4. To check robustness, we also estimate the model in two subperiods, before (1999Q1-2007Q2) and after (2009Q3-2017Q4) the Global Financial Crisis (GFC). GSW reformulate the medium-scale New Keynesian DSGE model proposed by Smets and Wouters (2007, SW, henceforth) by embedding the theory of unemployment based on Galí (2011a, 2011b). While there are other papers modeling unemployment in DSGE setups differently (see, e.g., Blanchard and Galí, 2007; Chrstiano *et al.*, 2007; Gertler *et al.*, 2008; and Christiano *et al.*, 2011b, 2011c), the GSW framework has the advantage of preserving the convenience of the representative household paradigm and allowing to determine the equilibrium levels of employment, the labor force and the unemployment rate (as well as other macroeconomic variables of interest) conditional on the monetary policy rule in place.

Estimating and simulating a "square model" version of GSW, we study how the unemployment rates in our sample of four EMU economies under a single monetary policy respond to shocks. More specifically, we aim to assess: (i) how important monetary policy shocks are relative to other shocks, particularly risk premium shocks, technology shocks and labor market shocks, such as a wage markup shock and a labor supply shock the GSW framework allows to identify separately; (ii) how heterogeneous the volatility of the unemployment rate is in the four countries; (iii) what the estimated dynamic effects of a monetary policy shock on the unemployment rate are in the four countries. We also look at the comparative estimates of a range of structural parameters that are essential in labor market decisions, as their combined influence underlies the subsequently simulated impulse responses as well as forecast error variance and shock decompositions, including the Frisch elasticity of labor supply, the average wage markup as indication of market power in wage determination, the degree of wage indexation, the strength of wealth effects on labor supply decisions as well as the degrees of Calvo wage and price stickiness.

Our main finding is that the same ECB monetary policy has significant heterogeneous effects on the unemployment rate and the key labor market variables in the four major EMU countries. Importantly, this heterogeneity applies to all the outcomes we have looked at, including the structure of the labor market, as reflected in the estimated structural parameters. In more detail, the following novel results emerge:

(a) We uncover a clear ranking of the exogenous sources of fluctuations in national unemployment rates, with the largest influence exercised by risk premium shocks, followed by monetary policy shocks. The former explain between 45% and 60% of unemployment rate fluctuations, while the latter explain between one-fifth and one-third at 10 and 40 quarters ahead. Monetary policy shocks in the EMU, however, are found to be much more relevant in explaining unemployment rate fluctuations than it is the case in the US, where they explain 11% at 10 quarters and only 4% at 40 quarters in the GSW study.

(b) The influence of risk premium shocks has increased after the GFC, mostly at the expense of monetary policy shocks for all four EMU countries, an indication that the near-zero interest rate environment after the GFC has rendered ECB's conventional monetary policy much less effective.

(c) The assessment of the dynamic responses of the key labor market variables to the single monetary policy of the ECB shows that employment drops in response to tightening of monetary policy, due to the contraction in output, but the labor force rises due to the negative wealth effect. As a result, unemployment rates increase in all four EMU countries after monetary policy tightening.

Before we proceed with motivating and outlining the GSW model we rely upon, it is necessary to justify the choice of the four countries analyzed here. Indeed, Europe's unemployment has received considerable attention since the 1980s. Various studies (see, among others, Blanchard and Summers, 1986; Logeay and Tober, 2006; and Galí, 2015b) have examined the rising and persistent unemployment trend in Europe as well as the fact that unemployment tends not only to rise with every recession but also to remain at levels substantially above the pre-recession rates, which is the essence of the so-called "unemployment hysteresis" effect. Keeping in mind this long-term trend, Figure 1 also shows that the four countries reflect four types of unemployment rate dynamics. Spain is characterized by a sharp rise since the GFC, while Germany displays the opposite evolution, revealing a gradual and sustained decline since 2005, regardless of the negative consequences of the GFC on output and employment in many other countries. The third type of dynamics can be observed in the unemployment rate in Italy, featuring persistent cyclical fluctuations, with two peaks in 1999 and 2014 and a single trough in the heat of the GFC in 2007. Finally, the dynamics of the unemployment rate in France remains relatively stable in the "long-run", captured by the end points of our time period, close to 10% but somewhat below most of the time before the GFC and rising just above 10% after it.

The main contribution of the present paper consists in documenting and examining the heterogeneity of monetary policy shocks across Euro-area countries, in particular these four in our sample, by estimation and simulation of the same medium-scale New Keynesian DSGE model with unemployment proposed recently by Galí, Smets and Wouters (2012). The key findings of such an analysis deepen our understanding of the monetary policy tradeoffs in Europe, especially highlighting the interplay between single monetary policy and its effects on various unemployment histories and dynamics. In this sense, our contribution is mostly empirical and sets out the ground for further refinements and extensions.

The rest of the paper is structured as follows. In the next section, we focus on the microfoundations of unemployment specific to the GSW model and the related log-linearized equations, while section 3 presents the remaining log-linearized equilibrium conditions. Section 4 outlines the data and the Bayesian estimation methodology, and section 5 then reports and interprets our results, mostly in terms of key labor market parameter values, impulse responses, forecast error variance decompositions and shock decompositions. Finally, section 6 concludes with some discussion, while appendix A lists the precise data definitions, sources and transformations.

2 Microfoundations of Unemployment

To assess the dynamic effects of a monetary policy shock on the unemployment rate, the model used in this paper closely follows GSW (2012), for reasons we clarify next. The GSW model proposes a reformulation of the wage-setting block of the SW model. That is, in GSW labor is "indivisible" and all variation in hours worked occurs "on the extensive margin", so that people either work or are unemployed involuntarily, as in Galí (2011 a, b) and broadly consistent with features of the data. By contrast, in SW labor is "divisible" and all variation in labor supply takes place in terms of hours worked, i.e., "on the intensive margin", as in the wage-setting block of the Erceg et al. (2000) model SW build upon.

GSW note that their modified version differs from the original SW model in the following dimensions:

1. It reformulates the wage equation in terms of unemployment.

2. With respect to the data on which the estimation is based, GSW use employment rather than hours worked, and redefine the wage as the wage per worker rather than the wage per hour. This change is implied by the key labor market assumption of the GSW model, where all variation in labor occurs on the extensive margin, in a way consistent with the conventional definition of unemployment. GSW also combine two alternative wage measures in the estimation, obtained via (i) employee compensation and (ii) average wage earnings, and model explicitly their discrepancy.

3. GSW generalize the utility function in a way that allows them to parameterize the strength of the short-run wealth effect on labor supply, as discussed in Jaimovich and Rebelo (2009), which results in a better fit of the joint behavior of employment and the labor force.

4. For simplicity, GSW revert to a Dixit-Stiglitz (1977) price and wage aggregator rather than the Kimball (1995) aggregator used in SW.

In this section, we outline the novel features introduced by GSW, mostly with regard to the utility function and the labor market, and the resulting log-linearized equations.[2] All variables denoted by a "hat" are log-linearized around their respective steady-state values, denoted by a "star" subscript.

The key innovation relative to the huge New Keynesian DSGE literature in GSW involves the utility function. They assume that there is a (large) representative household with a continuum of members represented by the unit square and indexed by a pair $(i, j) \in 0, 1] \times 0, 1]$. Individual utility then is of the following form,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \widetilde{C}_t(i,j) - 1_t(i,j) \chi_t \Theta_t j^{\varphi} \right], \tag{1}$$

where

$$\widetilde{C}_t(i,j) \equiv C_t(i,j) - h\overline{C}_{t-1}.$$

$\overline{C}_{t-1}$ denotes lagged *aggregate* (hence the "bar" notation) consumption (taken as given by each household) so that $h \in 0, 1]$ captures *external* habit in consumption, as is common in New Keynesian DSGE setups.

[2]The microfoundations of the other aspects of the full nonlinear model can be found in GSW and SW, whereas section 3 completes the list of log-linearized equilibrium conditions we then use in estimation.

What is novel in the GSW model, though, relative to this literature is reflected in the second argument of the (additively separable period and intertemporal) utility function. In it, $1_t(i,j)$ is an indicator function specifying the microfoundations of unemployment: it takes a value equal to one if individual (i,j) is employed in period t, and zero otherwise. The first dimension of the unit square, $i \in 0,1]$, that indexes the continuum of individuals in the representative household represents the type of labor service in which a given household member is specialized. The second dimension, indexed by $j \in 0,1]$, determines her disutility from work, which is given by $\chi_t \Theta_t j^{\varphi}$ if she is employed and zero otherwise. $\chi_t > 0$ is an *exogenous* preference shifter we would refer to, following GSW, as a "labor supply shock". Θ_t is an *endogenous* preference shifter, to be defined further down, taken as given by each individual household, and $\varphi \geq 0$ is a parameter determining the shape of the distribution of work disutilities across individuals. Full risk sharing is assumed among households, as in Merz (1995), so that $C_t(i,j) = C_t$ for all $(i,j) \in 0,1] \times \in 0,1]$ and t. Then, GSW derive the household utility as the integral over the utility of the continuum of household members (assuming a special form with a log-consumption component and a complicated disutility-from-work component):

$$\begin{aligned} & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U_t \left(C_t, \{N_t(i)\}\right) \\ \equiv \quad & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \widetilde{C}_t - \chi_t \Theta_t \int_0^1 \int_0^{N_t(i)} j^{\varphi} dj di \right] \\ = \quad & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\ln \widetilde{C}_t - \chi_t \Theta_t \int_0^1 \frac{N_t(i)^{1+\varphi}}{1+\varphi} di \right]. \end{aligned} \tag{2}$$

The term $\int_0^1 \int_0^{N_t(i)} j^{\varphi} dj di$ represents the disutility from work in period t for workers in all labor types i, where $N_t(i) \in 0,1]$ denotes the employment rate in period t among workers specialized in type i labor. $\widetilde{C}_t = C_t - h\overline{C}_{t-1}$ while φ is, now more specifically, given the functional form in (2), also the inverse of the Frisch elasticity[3] of intertemporal substitution in labor supply for those employed in period t.

As mentioned, GSW introduce χ_t as an exogenous preference shifter that affects the marginal disutility from work and refer to it as a "labor supply shock". They also introduce Θ_t as an endogenous preference shifter that affects as well the marginal disutility from work, taken as given by each household and defined by:

$$\Theta_t = \frac{Z_t}{\overline{C}_t - h\overline{C}_{t-1}}, \tag{3}$$

[3]Named after Frisch (1959).

$$Z_t = Z_{t-1}^{1-\upsilon} \left(\overline{C}_t - h\overline{C}_{t-1} \right)^{\upsilon} \tag{4}$$

As GSW suggest, Z_t can be interpreted as a "smooth" trend for (quasi-differenced) aggregate consumption. The preference specification embodied in (3) and (4) implies a "consumption externality" on labor supply: during aggregate consumption booms (when $\overline{C}_t - h\overline{C}_{t-1}$ is above its trend value Z_t), it can be seen from (3) that individual (and representative household) marginal disutility from work declines (at any given level of employment) and labor supply in consequence increases.

GSW emphasize that the specification above generalizes the preferences assumed in SW by allowing for an exogenous labor supply shock χ_t as well as for an endogenous labor supply preference shifter Θ_t. This formal modeling of labor supply preferences plays an important role that implies a corresponding economic interpretation: it helps reconcile the existence of a long-run balanced growth path with an arbitrarily small short-term wealth effect. The importance of this wealth effect is determined by the parameter $\upsilon \in 0, 1]$. GSW argue that this model feature, which is related, but not identical, to the one proposed in Jaimovich and Rebelo (2009), is needed to match the joint behavior of the labor force, consumption and the wage (per worker) over the business cycle.

As in SW, being the ultimate owner of firms and the capital stock, the representative household chooses (real) consumption C_t, investment in physical capital I_t, financial wealth in the form of savings in one-period discount bonds B_t, and the degree of capital utilization v_t, now also choosing to enter or not the labor force (rather than how many hours to work), so as to maximize the specified objective function (2) subject to a sequence of period budget constraints written in real terms,

$$C_t + I_t + \frac{B_t}{\varepsilon_t^b R_t P_t} - T_t \leq \frac{B_{t-1}}{P_t} + \frac{W_t N_t}{P_t} + \frac{\Pi_t}{P_t} + \left(\frac{R_t^k v_t \overline{K}_{t-1}}{P_t} - a\left(v_t\right) \overline{K}_{t-1} \right), \tag{5}$$

and to a sequence of capital accumulation equations

$$K_t = (1-\delta) K_{t-1} + \varepsilon_t^i \left[1 - \Psi\left(\frac{I_t}{I_{t-1}} \right) \right] I_t. \tag{6}$$

The sources of real income in the right-hand side of (5) consist of four components: income from past-period savings $\frac{B_{t-1}}{P_t}$, labor income $\frac{W_t N_t}{P_t}$, dividends from the profits of firms distributed by the labor unions $\frac{\Pi_t}{P_t}$, and the return from renting the real capital stock $\frac{R_t^k v_t \overline{K}_{t-1}}{P_t}$ minus the cost associated with variations in the degree of capital utilization, $a\left(v_t\right) \overline{K}_{t-1}$. T_t is net (lump-sum) transfers (taxes or subsidies) from the government. R_t is the gross nominal interest rate paid on the discount bonds and ε_t^b is an exogenous premium in the return to bonds that may capture –

as SW suggest – inefficiencies in the financial sector generating a premium of the deposit rate over the risk free policy rate set by the central bank, or a risk premium that households require to hold the discount bond. This risk premium, as most of the exogenous stochastic processes in the SW and GSW models, is assumed to follow an AR(1) law of motion in natural logs, $\widehat{\varepsilon}_t^b \equiv \ln \varepsilon_t^b$, that is:

$$\widehat{\varepsilon}_t^b = \rho_b \widehat{\varepsilon}_{t-1}^b + \eta_t^b, \text{ with } \eta_t^b \sim \mathcal{N}\left(0, \sigma_b\right). \tag{7}$$

As is standard, in (6) δ is the rate of depreciation of the capital stock, $\Psi(\cdot)$ is the investment adjustment cost function, with $\Psi(\tau) = \Psi'(\tau) = 0$, where τ denotes the balanced (gross) trend growth rate of the economy, but $\Psi''(\cdot) > 0$. ε_t^i is a stochastic shock to the price of investment relative to consumption goods, and follows the same process in natural logs, $\widehat{\varepsilon}_t^i \equiv \ln \varepsilon_t^i$, as $\widehat{\varepsilon}_t^b$ in (7) but with superscripts and subscripts i replacing b.

Under the GSW preferences outlined above, the marginal rate of substitution, $MRS_t(i)$, between consumption and employment that is relevant to households for type i workers in period t is given by

$$\begin{aligned} MRS_t(i) &\equiv -\frac{U_{n(i),t}}{U_{c,t}} \\ &= \chi_t \Theta_t \widetilde{C}_t N_t(i)^{\varphi} \\ &= \chi_t Z_t N_t(i)^{\varphi}, \end{aligned}$$

where the last equality results in the symmetric equilibrium with $\overline{C}_t = C_t$. Next, by integrating over all labor types, GSW derive in log-linear approximation the average (log) marginal rate of substitution $mrs_t \equiv \int_0^1 mrs_t(i)\, di$ as

$$mrs_t = z_t + \varphi n_t + \xi_t, \tag{8}$$

where $n_t \equiv \int_0^1 n_t(i)\, di$ is (log) aggregate employment and $\xi_t \equiv \ln \chi_t$. GSW further assume that nominal wages are set by "unions" for each type i, and acting in an uncoordinated way. Their modelling follows Calvo (1983) and Erceg et al. (2000), and implies partial indexation of wages to past price inflation, in a way that parallels price-setting and price inflation indexation. Log-linearizing around a perfect foresight steady state the first-order condition associated with the wage-setting problem and the aggregate wage index and combining the resulting expressions, GSW derive the following equation for wage inflation, $\pi_t^w \equiv w_t - w_{t-1}$:

$$\pi_t^w = (1-\beta)\left[(1-\gamma_w)\,\pi_* + \tau\right] + \gamma_w \pi_{t-1}^p + \beta \mathbb{E}_t \left\{\pi_{t+1}^w - \gamma_w \pi_t^p\right\} - \tfrac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\varepsilon_w\varphi)} \left(\mu_{w,t} - \mu_{w,t}^n\right), \tag{9}$$

where γ_w measures the degree of wage indexation to past price inflation, π_{t-1}^p, defined as $\pi_t^p \equiv p_t - p_{t-1}$, π_* is the steady-state (net) price inflation rate[4]; further, β is the time-discount factor applied by households, θ_w is the Calvo degree of wage stickiness, $\varepsilon_{w,t}$ is the period t elasticity of substitution across differentiated specialized labor types in a Dixit-Stiglitz (1977) aggregator, defining the (log) *natural* (optimal or desired) wage markup under monopolistic competition in labor markets (i.e., the wage markup that would result by optimal labor supply decisions of households in an economy with fully flexible prices and wages),

$$\mu_{w,t}^n \equiv \ln \mathcal{M}_{w,t}^n \equiv \ln \frac{\varepsilon_{w,t}}{\varepsilon_{w,t}-1} \tag{10}$$

and

$$\mu_{w,t} \equiv \ln \mathcal{M}_{w,t} \equiv \ln \frac{W_t}{P_t} - \ln MRS_t = (w_p - p_t) - mrs_t \tag{11}$$

is the (log) *average* wage markup in the economy (i.e., the log difference between the average real wage and the average marginal rate of substitution between consumption and employment in period t), with $\varepsilon_w \equiv \frac{\mathcal{M}_w}{\mathcal{M}_w - 1}$ and, equivalently, $\mathcal{M}_w \equiv \frac{\varepsilon_w}{\varepsilon_w - 1}$ being the steady-state constant (gross) wage markup. Equation (9) shows how changes in wage inflation above and beyond those resulting from indexation to past price inflation arise from deviations of the average wage markup from its natural level. The intuition GSW suggest is that these deviations put pressure on workers who currently set their wages to adjust them accordingly.

Unemployment is, next, introduced by GSW into the SW model in the following way. Using household welfare as a criterion and taking as given current labor market conditions, as summarized by the prevailing wage for her labor type, an individual specialized in type i and with disutility of work $\chi_t \Theta_t i^\varphi$ will find it optimal to participate in the labor market in period t if and only if

$$\frac{1}{\widetilde{C}_t} \frac{W_t(i)}{P_t} \geq \chi_t \Theta_t i^\varphi, \tag{12}$$

[4] GSW denote π_* as π^p in that equation, their eq. (3) on p. 335; and also use π^χ in it instead of τ to denote the (gross) steady-state growth rate of productivity in the economy.

that is, she will stay in or enter the labor force only if the benefit for her, captured by the product of the marginal utility of consumption and the real wage for her type of labor i in (12), outweighs the utility cost. The above condition is, then, evaluated at the symmetric equilibrium as

$$\frac{W_t\left(i\right)}{P_t} = \chi_t Z_t L_t\left(i\right)^{\varphi},$$

with the marginal supplier of type i labor denoted as $L_t\left(i\right)$. Taking logs and integrating,

$$w_t - p_t = z_t + \varphi l_t - n_t, \tag{13}$$

where $l_t \equiv \int_0^1 l_t\left(i\right) di$ can be interpreted, as GSW suggest, as the aggregate (log) participation rate or labor force. Following Galí (2011 a, b), the unemployment rate is defined in a standard way as

$$u_t \equiv l_t - n_t. \tag{14}$$

Equation (14) defines *involuntary* unemployment, since it includes individuals who would like to work, given the current labor market conditions as summarized by the real wage, but cannot find employment. Combining (11), (13) and (14), GSW also derive a simple link between the average wage markup in the economy and the unemployment rate, via the inverse of the Frisch elasticity of labor supply:

$$\mu_{w,t} = \varphi u_t. \tag{15}$$

Similarly,

$$\mu_{w,t}^n = \varphi u_t^n, \tag{16}$$

i.e., the natural rates of the average wage markup and the unemployment rate are proportional, via φ, too.

Further combining (9) and (15), GSW obtain an equation relating wage inflation to price inflation, the unemployment rate and the natural wage markup:

$$\begin{aligned} \pi_t^w &= (1-\beta)\left[(1-\gamma_w)\,\pi_* + \tau\right] + \gamma_w \pi_{t-1}^p + \beta \mathbb{E}_t\left\{\pi_{t+1}^w - \gamma_w \pi_t^p\right\} \\ &\quad - \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\varepsilon_w\varphi)}\varphi u_t - \frac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\varepsilon_w\varphi)}\mu_{w,t}^n. \end{aligned} \tag{17}$$

Equation (17) derived in GSW[5] provides a key novelty and insight into the dynamics of wage inflation as related to the unemployment rate and the natural wage markup: differently from SW and related papers, the error term in (17) captures exclusively shocks to the natural wage markup, and not preference shocks (no matter that the latter have been considered in the GSW model). This novel feature in reformulating the wage inflation equation has enabled GSW to use the unemployment rate as another observable in estimation. This has further allowed them to overcome the identification problem raised by Chari et al. (2009) in their criticism of New Keynesian models and to obtain better estimation results with this additional observable variable relative to SW. We employ this feature, and the estimation based on observed unemployment rates it empowers, in our own empirical application of the GSW model to evaluate the heterogeneous effects of single monetary policy in the largest EMU economies in the present study.

3 Estimated Log-Linearized Model

The remaining equations that complete the description of the log-linearized equilibrium conditions in the GSW model are presented next, in a denser summary. As GSW point out, they are identical to the respective equations in the SW model but now specialized to logarithmic consumption utility.

For households, and as standard, the dynamics of consumption is given by (a model-consistent variant of) the consumption Euler equation

$$\widehat{c}_t = \frac{\frac{h}{\tau}}{1+\frac{h}{\tau}}\widehat{c}_{t-1} + \frac{1}{1+\frac{h}{\tau}}\mathbb{E}_t\left\{\widehat{c}_{t+1}\right\} - \frac{1-\frac{h}{\tau}}{1+\frac{h}{\tau}}\left(\widehat{r}_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\} + \widehat{\varepsilon}_t^b\right). \qquad (18)$$

Current consumption $\widehat{c}_t$ depends on a weighted average of past and expected future consumption and on the ex-ante real interest rate $\widehat{r}_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\}$, as well as on an exogenous stochastic process interpreted as risk premium shock, $\widehat{\varepsilon}_t^b \equiv \ln \varepsilon_t^b$. As is common in the DSGE literature, and as was mentioned, the parameter h captures external habit in consumption and is incorporated in order to improve model fit, while τ denotes the trend (gross) growth rate of the economy (as well as of labor-augmenting technological progress in production). The risk premium drives a wedge between the interest rate controlled by the central bank and the return on assets held by the households. A positive shock to this wedge increases the required return on assets and reduces current consumption. At the same time, it also increases the

[5] Again, GSW use a slightly different notation, replacing in their identical eq. (8), p. 336, π_* by π^p and τ by π^χ.

cost of capital and reduces the value of capital and investment. As is standard, this risk premium shock is assumed to follow an AR(1) process with an IID-Normal innovation term – see eq. (7).

The dynamics of investment is given by (a variant of) the investment Euler equation

$$\widehat{i}_t = \frac{1}{1+\beta}\widehat{i}_{t-1} + \frac{\beta}{1+\beta}\mathbb{E}_t\left\{\widehat{i}_{t+1}\right\} + \frac{1}{1+\beta}\frac{1}{\tau^2\Psi}\widehat{q}_t + \widehat{\varepsilon}^q_t, \tag{19}$$

where β is the time discount factor used by households and Ψ is the elasticity of the capital adjustment cost function. As in Christiano et al. (2005), a higher elasticity of the cost of adjusting capital reduces the sensitivity of investment $\widehat{i}_t$ to the real value of the existing capital stock $\widehat{q}_t$. $\widehat{\varepsilon}^q_t$ is the exogenous stochastic process for investment-specific technology assumed to follow an AR(1) process with an IID-Normal innovation: $\widehat{\varepsilon}^q_t = \rho_q\widehat{\varepsilon}^q_{t-1} + \eta^q_t$.

The corresponding arbitrage equation for the value of capital is given by:

$$\widehat{q}_t = \left[1 - \frac{r^k}{r^k + (1-\delta)}\right]\mathbb{E}_t\left\{\widehat{q}_{t+1}\right\} + \frac{r^k}{r^k + (1-\delta)}\mathbb{E}_t\left\{\widehat{r}^k_{t+1}\right\} - \left(\widehat{r}_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\} + \widehat{\varepsilon}^b_t\right). \tag{20}$$

The current value of the capital stock $\widehat{q}_t$ depends positively on its expected future value and the expected real rental rate on capital $\mathbb{E}_t\left\{\widehat{r}^k_{t+1}\right\}$, and negatively on the ex-ante real interest rate and the risk premium shock.

Goods market clearing implies

$$\widehat{y}_t = \frac{c_*}{y_*}\widehat{c}_t + \frac{i_*}{y_*}\widehat{i}_t + \frac{r^k_* k_*}{y_*}\widehat{v}_t + \widehat{\varepsilon}^g_t = \mathcal{M}_p\left[\alpha\widehat{k}_t + (1-\alpha)\,\widehat{n}_t + \widehat{\varepsilon}^a_t\right]. \tag{21}$$

Output is produced using capital services $\widehat{k}_t$ and labor services, employment $\widehat{n}_t$. Disturbances in neutral technology, or total factor productivity (TFP), are captured by the stochastic process $\widehat{\varepsilon}^a_t = \rho_a\widehat{\varepsilon}^a_{t-1} + \eta^a_t$, which follows an AR(1) law of motion with an IID-Normal innovation term η^a_t. $\mathcal{M}_p$ denotes the degree of returns to scale, GSW assume it to correspond to the price markup in steady state. The term $\frac{r^k_* k_*}{y_*}\widehat{v}_t$ measures the cost associated with variable capital utilization, where r^k_* is the steady-state rental rate of capital and $\widehat{v}_t$ is the capital utilization rate. Following GSW, we assume that $\widehat{\varepsilon}^g_t$ captures not only government expenditure, but rather all exogenous components of aggregate demand and follows an AR(1) process with an IID-Normal error term also affected by TFP shocks: $\widehat{\varepsilon}^g_t = \rho_g\widehat{\varepsilon}^g_{t-1} + \eta^g_t + \rho_{ga}\eta^a_t$. As GSW note, the latter is empirically motivated by the fact that, in estimation, exogenous spending also includes net exports, which may be affected by domestic productivity developments. In this sense, the GSW model is not a closed-economy New Keynesian DSGE model in a strict sense, but indeed captures an open-economy channel through the exogenous component of exports and imports of goods and services. It is, accordingly, useful as well in estimation and analysis of open economies such as the four EMU countries in our sample.

Price-setting under the Calvo model with indexation to past inflation results in the following NKPC for price inflation:

$$\widehat{\pi}_t^p - \gamma_p \widehat{\pi}_{t-1}^p = \beta \mathbb{E}_t \left\{ \widehat{\pi}_{t+1}^p - \gamma_p \widehat{\pi}_t^p \right\} - \tfrac{(1-\beta\theta_p)(1-\theta_p)}{\theta_p(\mathcal{M}_p - 1)\varepsilon_p} \left(\widehat{\mu}_{p,t} - \widehat{\mu}_{p,t}^n \right), \tag{22}$$

where ε_p (analogous to ε_w) measures the curvature of the Dixit-Stiglitz (1977) price aggregator, and the other variables and parameters parallel those in the analogous wage inflation equation (9) introduced earlier.

The average and natural price markups are, respectively,

$$\widehat{\mu}_{p,t} = -(1-\alpha)\widehat{\omega}_t - \alpha \widehat{r}_t^k + \widehat{\varepsilon}_t^a, \tag{23}$$

where $\omega_t \equiv w_t - p_t$ defines the (log) real wage, and

$$\widehat{\mu}_{p,t}^n = 100 \times \widehat{\varepsilon}_t^p. \tag{24}$$

Wage-setting under the Calvo model with indexation to past price inflation, as already discussed in more detail in the preceding section, results in the following NKPC for wage inflation, now written in deviations from steady-state values (with "hats"):

$$\widehat{\pi}_t^w - \gamma_w \widehat{\pi}_{t-1}^p = \beta \mathbb{E}_t \left\{ \widehat{\pi}_{t+1}^w \right\} - \tfrac{(1-\beta\theta_w)(1-\theta_w)}{\theta_w(1+\varepsilon_w \varphi)} \left(\widehat{\mu}_{w,t} - \widehat{\mu}_{w,t}^n \right). \tag{25}$$

The average and natural wage markups and the natural rate of unemployment are, respectively,

$$\widehat{\mu}_{w,t} = \widehat{\omega}_t - \left(\widehat{z}_t + \widehat{\varepsilon}_t^\chi + \varphi \widehat{n}_t \right), \tag{26}$$

and

$$\begin{aligned} \widehat{\mu}_{w,t}^n &= 100 \times \widehat{\varepsilon}_t^w && (27) \\ &= \varphi \widehat{u}_t^n, && (28) \end{aligned}$$

where

$$\widehat{z}_t = (1-\upsilon)\widehat{z}_{t-1} + \upsilon \left[\frac{1}{1-\frac{h}{\gamma}} \widehat{c}_t - \frac{\frac{h}{\gamma}}{1-\frac{h}{\gamma}} \widehat{c}_{t-1.} \right] \tag{29}$$

Capital accumulation evolves according to

$$\widehat{\bar{k}}_t = \left(1 - \frac{i_*}{\bar{k}_*}\right) \widehat{\bar{k}}_{t-1} + \frac{i_*}{\bar{k}_*} \widehat{i}_t + \frac{i_*}{\bar{k}_*} (1 + \beta) \tau^2 \Psi \widehat{\varepsilon}_t^q, \tag{30}$$

and capital services used in production are defined as

$$\widehat{k}_t = \widehat{v}_t + \widehat{\bar{k}}_{t-1}. \tag{31}$$

The optimal capital utilization condition reads,

$$\widehat{v}_t = \frac{1 - \psi}{\psi} \widehat{r}_t^k, \tag{32}$$

where ψ is the elasticity of capital utilization cost function with respect to capital inputs. The optimal input choice is given by

$$\widehat{k}_t = \widehat{\omega}_t - \widehat{r}_t^k + \widehat{n}_t. \tag{33}$$

Finally, the monetary authority follows an empirically motivated generalized Taylor rule in setting the short-term (gross) nominal interest rate $\widehat{r}_t$ (in log-deviation from the (gross) steady-state nominal interest rate) in response to the lagged interest rate, current price inflation, and the current level and change in the output gap; in addition to this systematic component of monetary policy, an exogenous stochastic shock capturing monetary policy "surprises" is assumed to follow an AR(1) process with an IID-Normal innovation, $\widehat{\varepsilon}_t^r = \rho_r \widehat{\varepsilon}_{t-1}^r + \eta_t^r$:

$$\widehat{r}_t = \rho_r \widehat{r}_{t-1} + \left(1 - \rho_r\right) \left[r_\pi \widehat{\pi}_t^p + r_y \left(\widehat{y}_t - \widehat{y}_t^n\right)\right] + r_{\Delta y} \left[\left(\widehat{y}_t - \widehat{y}_t^n\right) - \left(\widehat{y}_{t-1} - \widehat{y}_{t-1}^n\right)\right] + \widehat{\varepsilon}_t^r. \tag{34}$$

ρ_r captures the degree of interest rate smoothing, and r_π, r_y and $r_{\Delta y}$ capture the policy feedback to, respectively, price inflation $\widehat{\pi}_t^p$, the output gap, $\widehat{y}_t - \widehat{y}_t^n$, and the change in the output gap, $\left(\widehat{y}_t - \widehat{y}_t^n\right) - \left(\widehat{y}_{t-1} - \widehat{y}_{t-1}^n\right)$.

4 Data and Estimation Methodology

The log-linearized model presented in sections 2 and 3 is estimated with Bayesian techniques, based on the data for four major EMU countries, namely, France, Germany, Italy and Spain. For each country, the data set consists of eight key macroeconomic quarterly time series: the log difference of real GDP, the log difference of real consumption, the log difference of real investment, the log difference of the

GDP deflator (i.e., a measure for price inflation), the ECB interest rates on lending facilities (i.e., a measure for the central bank policy rate), log employment (relative to a base quarter), the unemployment rate (defined in the standard way, as difference between the labor force and those employed), and the log difference of the real wage rate (i.e., a measure for wage inflation).[6] The full sample period covers 1999Q1–2017Q4 (76 quarterly observations) for all variables.[7] We also compare two subsamples, pre-GFC, 1999Q1–2007Q2 (34 quarterly observations), and post-GFC, 2009Q3–2017Q4 (equally, 34 quarterly observations), leaving the 8 quarters spanning the most turbulent period of the GFC (2007Q3–2009Q2) out of the estimation by subsample.

The corresponding measurement equations are:

$$Y_t = \begin{bmatrix} dy \\ dc \\ dinve \\ pinfobs \\ robs \\ empobs \\ unempobs \\ dw \end{bmatrix} = \begin{bmatrix} \overline{\tau} \\ \overline{\tau} \\ \overline{\tau} \\ \overline{\pi} \\ \overline{r} \\ \overline{n} \\ \overline{u} \\ \overline{\tau} \end{bmatrix} + \begin{bmatrix} \hat{y}_t - \hat{y}_{t-1} \\ \hat{c}_t - \hat{c}_{t-1} \\ \hat{\imath}_t - \hat{\imath}_{t-1} \\ \hat{\pi}_t \\ \widehat{r}_t \\ \hat{n}_t \\ \hat{u}_t \\ \hat{w}_t - \hat{w}_{t-1} \end{bmatrix}, \tag{35}$$

where $\overline{\tau}$=100 × $(\tau - 1)$ is the common quarterly trend growth rate for real GDP, consumption, investment and wages, in % per quarter; $\overline{\pi} = 100 \times (\Pi_* - 1)$ is the quarterly steady-state inflation rate, in % per quarter; and $\overline{r} = 100 \times \left(\beta^{-1}\tau\Pi_* - 1\right)$ is the steady-state nominal interest rate, in % per quarter. $\overline{n} = 100 \times n_*$ and $\overline{u} = 100 \times u_*$ are, respectively, the steady-state employment and unemployment rates, in % of the labor force.

To ensure a higher degree of comparability and since most of these prior shapes and values are common or similar in Bayesian estimation of DSGE models, we use the same priors for all estimated parameters as GSW do, summarized in Table 1. Note that, differently from SW, GSW replace the Inverse Gamma prior for the

[6] The aggregate real variables (real GDP, real consumption, real investment and employment) are expressed per capita by dividing with the population over 15. We use only one of the two measures of the real wage rate in GSW, namely the total compensation of employees that is available for the EMU countries on a comparable basis (as GSW note, their results using two real wage measures do not differ much if they use just the measure we use too). All series are seasonally adjusted at source and are downloaded from the Eurostat and the ECB. A more detailed description of the data, with definitions and transformations, is given in appendix A.

[7] Our estimation period begins from the first quarter of 1999, when the ECB started to assume responsibility for monetary policy decision-making in the EMU, and the data for the key ECB interest rates are only available since then.

standard deviations of the innovations to the shock processes by a Uniform prior, which is in fact an agnostic prior allowing more influence of the data in determining the posterior. As is standard, in a first stage we estimate via Laplace approximation (assuming Gaussian innovations) the mode of the posterior distribution by maximizing the log posterior function, which applies Bayes rule in combining the prior information on the parameters with the likelihood of the data. Then, in a second stage, the Random Walk Metropolis-Hastings Markov Chain Monte Carlo (RWMH-MCMC) algorithm is used to sample from the posterior distribution and to evaluate the marginal likelihood of the model.[8] Based on the estimated parameters, the model is simulated and impulse responses to shocks, variance decompositions and historical shock decompositions are reported and discussed, for the full sample and by subsample.

[Table 1 about here]

5 Estimation and Simulation Results

Our empirical application in the present paper employs the GSW model – with a minor modification when estimating, as we clarify next – and fits it to data from the four largest EMU economies during the period of operation of a single monetary policy by the ECB since January 1999. While GSW estimate their model on US data with two measurement errors, for the two respective measures of wages mentioned above, in addition to the eight shock processes and eight observables, we estimate a slightly simpler version which (i) uses only the employee compensation wage proxy and (ii) assumes away its measurement error. Thereby, we estimate a "square model" version of GSW, as our baseline estimation, with eight observables and eight stochastic shock processes (and no measurement errors). As a robustness check, we have also estimated an alternative version where the employee compensation proxy for wages is measured instead with error: the results we obtain in these two estimated versions are quantitatively very close, so we present in what follows only the baseline estimates (that is, without the measurement error).[9]

5.1 Estimated Parameter Posteriors

Table 2 reports the mean and standard deviation (SD) of the posterior distribution of the estimated parameters over the full sample, 1999Q1–2017Q4, or 76

[8] All estimations are done with Dynare. A RWMH-MCMC sample of 1,000,000 draws was simulated, with the first 20% of it discarded, to minimize the influence of initial values.

[9] Our alternative estimates are, of course, available upon request.

observations in the measurement equations (35). Overall, the estimated values for the structural parameters are broadly consistent with their respective typical value ranges known from related work, e.g., most closely to GSW, SW and Merola (2015). In our analysis and interpretation hereafter, we mainly focus on the estimates of the parameters and shock processes that are of direct importance for the labor market and monetary policy. As a robustness check, and due to the sharp nature and long-lived influence on economic activity of the GFC, we also present and discuss briefly analogous results by subsample, that is, in our pre-GFC subsample, 1999Q1–2007Q2 or 34 observations in Table 3, and in our post-GFC subsample, 2009Q3–2017Q4 or another exactly 34 observations in Table 4. We have chosen on purpose, for comparability reasons, to work with the same number of observations in the two subsample periods, and leave the 8 quarters of the strongest impact of the GFC, 2007Q3–2009Q2 out of the estimation.

[Table 2 about here]

5.1.1 Structural Parameters

Starting with the structural parameters in the top panel of Table 2, our estimates show some heterogeneity in the intertemporal substitution in the supply of labor across the EMU. The full-sample estimates of the inverse of the Frisch elasticity of labor supply φ range from 2.78 in Italy, through 2.98 in Germany and 3.94 in France, to 4.31 in Spain, all below the GSW estimate for the US in 1966Q1–2007Q4, 4.35. Our results, further, uncover substantial heterogeneity in the degree of market power in wage determination for differentiated labor. The steady-state (gross) wage markup $\mathcal{M}_w$ is estimated to be the lowest, 18% (in net terms) in Germany, whereas in Spain it is the highest, 54%, with those for Italy, 22%, and France, 35%, falling in-between. This heterogeneity further implies, by the theory embodied in eq. (15), a corresponding heterogeneity in average unemployment rates, as also documented by the data. It is reassuring that the model-implied average unemployment rates, calculated using our estimates of φ and $\mathcal{M}_w$ in eq. (15), predict pretty closely the corresponding mean values from the full sample. The highest estimate of the inverse of the Frisch elasticity in intertemporal labor supply and the highest estimate of the steady-state wage markup correspond to the highest average unemployment rate, in Spain, about 13% according to eq. (15) and about 16% in our full sample. The average unemployment rate in Germany is the lowest in our sample, about 6% by the model prediction in (15) and about 7% according to the sample mean of our data. The model does best along this aspect in predicting the average unemployment rate in France, 9% according to both model and data. For Italy, the model implied average rate of unemployment is about 8% while in the sample it is about 9%. Note that in the US the average unemployment rate has been historically (much) lower, about 5% in the GSW sample, than in the major European economies, and this corresponds to model-implied average of about 5% too.[10]

Turning attention to the parameters related to the wage Phillips curve, the estimated degree of wage indexation γ_w ranges from 19% in Germany, 22% in France, 23% in Italy, and 26% in Spain, which is higher than that corresponding estimate for the US in GSW, 18%. The estimated degree of (Calvo) wage rigidity θ_w ranges from 0.65 in Germany, through 0.74 in Italy and 0.76 in France, to 0.84 in Spain. Again, Spain exhibits a relatively higher wage stickiness in the labor market, corresponding to an average duration of wage contracts of about seven quarters, whereas in Italy and France this duration is of about four quarters and in Germany of almost three quarters. Note that, on this account again, all our four EMU countries exhibit a (much) higher degree of estimated wage rigidity than the US estimate of 0.55 in GSW, corresponding to an average wage contract duration of, roughly, two quarters. Along this dimension again, we clearly see, first, the likely effect in the estimated parameters reflecting the widely-discussed difference in labor market institutions between the US and Europe; and, second, the considerable heterogeneity across the four largest EMU economies in our sample.

Then, the parameter that governs the short-term wealth effects on labor supply, υ, estimated very low in the US data of GSW, at 0.02, consistent with Greenwood-Hercowitz-Huffman (1988, GHH) preferences assuming $\upsilon = 0$, displays much higher values, with some heterogeneity, in the four EMU countries in our sample, but overall much more in agreement with the specification of the utility function in King-Plosser-Rebelo (1988, KPR) assuming $\upsilon = 1$. As we shall see later on, in the analysis of the impulse response functions conditional on a monetary policy shock, employment and the labor force commove negatively in all our four sample countries, as implied by the KPR preferences case reported too in GSW and since our estimates, consistent with a strong wealth effect, are empirically (much) closer to that KPR class, whereas in their US baseline with estimated approximately

[10]Interestingly, labor markets are quite different on this account, being more competitive and more diverse nationally, with the exception of Spain, compared to an analogous measure of market power in differentiated product markets, where our estimates for the steady-state (gross) price markup $\mathcal{M}_p$ in three of these four countries cluster tightly from 42% (net) in Germany, through 44% in Italy, to 52% in France. Spain is, again estimated as an extreme case from our four EMU economies, now being at the opposite end of having the most competitive goods markets, with the lowest steady-state (net) price markup of 13%. For a comparison, GSW report a considerably higher market power in differentiated product markets in the US, 74%, compared to all our four EMU countries.

GHH preferences this comovement is positive. Germany reveals the largest value of estimated υ, 0.83, followed by Spain and Italy with close values of 0.76 and 0.78, respectively, revealing a stronger short-term wealth effect on labor supply than in France, where our estimate is the lowest, at 0.64. This is another important heterogeneity across the labor-market preferences we uncover for the major EMU economies. Nevertheless, the four European economies are still much closer to each other in terms of estimated υ, which still distinguishes them as a group quite a lot from the US case reported in GSW.

As for the monetary policy reaction function parameters, the long-run feedback coefficient to inflation r_π is estimated to be slightly higher in France (1.31) and Spain (1.38) while relatively lower in Italy (1.14) and Germany (1.20) – but all these values, while satisfying by far the Taylor principle, are much lower than the analogous feedback parameter in US monetary policy reported in GSW (1.89). Moreover, monetary policy reacts moderately to the output gap r_y (0.11–0.20) and minimally to changes in the output gap $r_{\Delta y}$ (0.02–0.05) in all four EMU countries, and with a much weaker feedback along the second dimension compared to the US case in GSW (0.16 and 0.25, respectively). All in all, and as might be expected for a single monetary policy in a monetary union, the estimated feedback coefficients are pretty much clustered for all four EMU member-states we examine. In addition, it appears from this comparison that the data assign a more aggressive monetary policy stance to the US Fed relative to the ECB with regard to all estimated policy reaction coefficients.

Finally, the steady-state estimates for inflation and trend growth reveal some further differences across the four EMU economies. The lowest steady-state inflation is in Germany and amounts to 1.8% per annum (pa), while the highest is in Spain, 2.5% pa, with France, 2.0% pa, and Italy, 2.2% pa, falling in-between. These measures, while somewhat dispersed, are not that far from the inflation target of 2.0% pa, on average, the ECB has announced and pursues in the conduct of its monetary policy. In terms of estimated steady-state trend growth, France comes first, with 0.8% pa, followed by Spain, 0.7% pa, Germany 0.5% pa, and Italy 0.2% pa. The dispersion of trend growth rates we estimated for the four major EMU countries may not be huge, yet it appears quite distinct so as to make a common monetary policy by the ECB also responding to change in output growth (as captured by the $r_{\Delta y}$ coefficient in the policy rule (34)) somewhat challenging and involving national tradeoffs.

5.1.2 Shock Process Parameters

The second and third panels in Table 2 report the estimates of the parameters that enter the exogenous shock processes, that is, their persistence and volatility, respectively. For all four EMU countries, the wage markup processes, together with the monetary policy shock, are estimated to be the least persistent, with AR(1) coefficients of 0.21 (Italy), 0.48 (Germany and Spain), and 0.52 (France). These are all, nevertheless, much lower than the high persistence GSW estimate in the US data, 0.98, the highest persistence too, together with that of the productivity shock, in the US case. In the case of our EMU countries, the shocks with the highest persistence are the TFP, risk premium and spending shocks, above 0.90 for all EMU sample countries (with two minimal exceptions).

It is also worth noting that the estimated means of the standard deviation of the shock to the wage markup process and the labor supply shock in Italy and Spain are impressively higher in relative terms, 2.57% and 2.68% in Italy and 3.55% and 3.15% in Spain, respectively. These two shocks are the most volatile in the mentioned two countries. Similarly, in France (1.58%) and Germany (2.26%) the labor supply shock comes out as the most volatile overall, followed by the price markup shock, 1.01% in France and 1.76% in Germany. The analogous estimate for the labor supply shock in the US data of GSW is close to that for France, 1.17%, and in the US this is the second largest shock volatility after that of the risk premium shock, 1.60%. Furthermore, the monetary policy shock exhibits the lowest estimated mean standard deviation in all four EMU countries, tightly clustered in the 0.07-0.09% range, versus 0.22% in the US in GSW, which is combined – as was mentioned – with a low persistence of this shock too, in the range of 0.30-0.43, versus 0.10 in the US.

5.1.3 Summary of the RWMH-MCMC Bayesian Estimation

Finally, the bottom panel in Table 2 provides summary statistics for the RWMH-MCMC Bayesian estimation. In particular, it reports the acceptance rate of the two chains used in the posterior simulation and the log data density, also known as the marginal likelihood for the estimated model given the observed sample. There is no any narrow-range recommendation regarding the acceptance rate, but it is consensual in the Bayesian estimation literature that it should be between 20% and 50%.[11] On this account, the acceptance rates in Table 2 are reliable. The log data density, in its turn, is indicative that the data for France have ensured the best fit

[11] See, e.g., Koop (2006) or Herbst and Schorfheide (2016).

of the GSW model, in our implementation of the estimation as a "square model" with eight shocks and eight observables without measurement errors, whereas the data for Italy are on the other end, exhibiting the worst fit. We have also checked carefully the univariate and multivariate MCMC convergence criteria as well as the shapes of the posteriors for each estimated parameter, and have concluded that all four estimation results per country are of a good quality overall.[12]

5.1.4 Robustness by Subsample

Tables 3 and 4 provide the same estimates as those reported already for the full sample in Table 2, but now by pre- and post-GFC subsample, respectively. This is a way to check robustness, and further infer whether the GFC has changed in some important way the estimates of the key labor market and monetary policy parameters as well as the ensuing dynamic responses and variance and shock decompositions. Comparing the respective estimates in these three tables, one can see that the most significant changes across the structural parameters affect the inverse Frisch elasticity φ in France (falling to 2.96 pre-GFC) and Spain (dropping similarly to 3.52 pre-GFC and 3.61 post-GFC) as well as the wealth effect parameter υ in Spain (plunging to 0.02, the same near-zero value as in the GSW estimate for the US implying GHH preferences). The steady-state employment estimates also change in both the pre- and post-GFC subsamples in almost all four EMU countries relative to the full sample, which is not astonishing given the strong influence of the GFC on the labor market variables.

[Tables 3 and 4 about here]

Among the estimated persistence parameters, ρ_q falls in Spain pre-GFC to 0.21 while ρ_a drops in France to 0.37 pre-GFC, and there are some other modifications in the estimates throughout that are of a smaller magnitude. Among the mean standard deviations estimated for the innovations of the shock, the largest modifications concern the risk premium shock and the price markup shock pre-GFC as well as both markup shocks and the labor supply shock post-GFC, which also makes sense.

Among the summary statistics for the RWMH-MCMC Bayesian estimation, the acceptance rates fall minimally below 20% for France and Spain post-GFC. The log

[12] The only exception, which arises commonly in such Bayesian estimation of medium-scale DSGE models attempting to estimate around 30-50 parameters, is that on a couple of occasions or so per country a posterior is not unimodal or nicely shaped. This relates, however, exclusively to estimated means of standard deviations of the shock processes (whose prior was agnostic, assumed Uniform), and does not impair in general estimates for the more important, and better identified, structural parameters or shock persistence parameters.

density still favors the best fit of the model for France, in both subsamples, whereas the worst fit post-GFC is now for Spain, with Italy keeping the worst fit in the pre-GFC subsample.

All these larger and smaller changes captured by our sensitivity analysis by subsample warrants a more careful check and comparison by subsample, as we shall do, of the dynamic responses, variance and shock decompositions implied by these estimated parameters through the subsequent simulation of the model.

5.2 What Drives Unemployment Fluctuations in the EMU Countries?

To address this main question of our study, and in effect assess how influential monetary policy shocks might be when compared to other types of shocks in determining unemployment variability in the four EMU member-states in our sample, we look first into the forecast error variance decomposition (FEVD) in the short, medium and long run, and then into the historical shock decomposition, of the unemployment rate.

5.2.1 Variance Decomposition in the Short, Medium and Long Run

Table 5 presents the contribution of each shock to the forecast error variance of the unemployment rate in each country. This decomposition provides insights into the main forces driving unemployment fluctuations. The contribution of each of the structural shocks to the conditional forecast error variance of the national unemployment rate in each sample country is reported in the "short run" (1-quarter horizon), "medium run" (10-quarter horizon) and "long run" (10-year horizon).

[Table 5 about here]

For all four EMU member-states, we identify a clear common ranking of the sources of unemployment fluctuations. At any horizon, the biggest fraction of the variations in the unemployment rate is explained by risk premium shocks, whose contribution ranges from about one-third to almost a half in the short run, to about 45-60% in both the medium and long run. Especially at the two longer horizons, these risk premium shocks are more important, accounting for about 10 percentage points (pp) more, in the "high debt – high risk premium" EMU countries in our sample, Italy and Spain, relative to the "low debt – low risk premium" EMU economies, France and Germany. This is not the case in the US, where GSW find that the dominant type of shocks driving unemployment fluctuations are wage markup shocks, accounting for 41% at 10 quarters and 80% at 40 quarters. By contrast, in the EMU economies we consider, wage markup shocks have only a negligible influence (below 6%) on the variability of the unemployment rate at all horizons. Risk premium shocks still matter in the US sample, where GSW report them to account for 7% of the unemployment rate volatility in the long run, which makes this type of shock the second in importance after wage markup shocks, although more than 10 times less influential.

In all four sample countries too, monetary policy shocks come next in importance, accounting for about one-fifth to one-third of the fluctuations in the unemployment rate at 10 and 40 quarters ahead, although in the short run of 1 quarter their importance is somewhat reduced, to between 8% and 22%. This result highlights another important difference of all our European economies relative to the US case in GSW, where monetary policy shocks explain 11% of the variability of the unemployment rate at 10 quarters and only 4% at 40 quarters. Monetary policy in the EMU countries thus turns out to be much more relevant when influencing unemployment compared to the US, and this has strong policy implications too, especially bearing in mind as well the heterogeneity of its effects along many dimensions we have been describing in the present study.

Similarly to the wage markup shock, the other labor market shock the GSW methodology enables us to identify separately, the labor supply shock does not really matter in the medium and long run for unemployment variability in all four EMU countries, as it does not account for more than 1% to 4% of the fluctuations in the unemployment rate. It matters more in the short run, however, ranging between 5% and 17% across these countries, and especially in Italy, where it comes third in relevance at that horizon, and Spain, where it comes fourth.

Checking for robustness by subsample – compare tables 6 and 7 – we note that the influence of risk premium shocks has generally increased post-GFC (to 65-81%) relative to pre-GFC (from 30-46%) mostly at the expense of monetary policy shocks (falling from 14-46% to 4-14%) for all countries, but preserving much heterogeneity across the four EMU member-states. This evidence favors the well-known narrative that the zero lower bound (ZLB) environment prevailing after the GFC has made interest rate policy less effective, and such has been the case too with the power of ECB's monetary policy to affect the unemployment rate and the other central labor market variables.

[Tables 6 and 7 about here]

5.2.2 Historical Shock Decomposition

Figures 2–5 present the historical decomposition of the rate of unemployment in terms of estimated contributions to its evolution by the underlying latent shock processes the GSW model considers in each of the EMU countries over the full sample.

[Figures 2–5 about here]

Taking France first, we clearly see in Figure 2 that the dominant shocks affecting the rate of unemployment have been risk premium shocks and monetary policy shocks, which is consistent with the FEVD analysis we summarized. In particular, what is worth noting is that in the pre-GFC subsample low risk premium shocks have generally depressed the unemployment rate, whereas the relatively expansionary monetary policy has contributed to its increase, especially in the early 2000s. In the post-GFC subsample, however, these roles have reversed, with the ZLB policy depressing unemployment, but higher risk premium shocks increasing it.

Looking next at Germany, Figure 3 convincingly illustrates again the dominance of risk premium and monetary policy shock contributions to the fluctuations in the unemployment rate. As in the case of France, the role of monetary policy is reversed pre- versus post-GFC, for the same reasons. Analogous interpretation would apply to the risk premium, but its reversal from a brake on unemployment to a driver of unemployment seems to have occurred somewhat earlier, before the GFC. It is worth noting that, as in France, the contribution of risk premium shocks has been negative during the GFC followed by the Greek crisis (these are the observations between 30 and 40 on the x-axis).

Taking now Italy, the same two dominant types of shocks are evident in Figure 4, but now the contribution of risk premium shocks post-GFC is twice more pronounced in pushing unemployment up. This coincides with the repercussions of the Greek crisis and the spillovers of perceived sovereign risk on other EMU "high-debt" countries, such as Italy and Spain in our sample. By contrast, the ZLB policy at the ECB has contributed to lower unemployment rate in Italy during most of the post-GFC subperiod, although reversing this influence in the final three years.

Checking the historical decomposition for Spain in Figure 5, we see again the dominance of risk premium and monetary policy shocks, but now both these types of shocks are very important in pushing the unemployment rate up after the GFC. This highlights the Spanish high-debt crisis and the associated higher risk premium prevailing in the post-GFC subsample, as well as the heterogeneity of the effects of ECB's policy on national unemployment rates across the four countries in our sample. Among these countries and along the historical decomposition analyzed here, Spain is very specific, with contributions of the two key types of shocks of the order of 7-8 pp each (see the vertical scale), and Italy comes close to it in the post-GFC subsample when monetary policy reverses into positive contributions to unemployment (but the order of magnitude of these contributions is about 2-3 times lower – see the vertical scales); while France and Germany are on the other side, of mild shocks compared to those in Spain, though not too far from their range in Italy (see the vertical scales). Note as well that the outlined heterogeneity in the post-GFC subperiod is much smaller across all four countries in the pre-GFC subperiod.

To summarize, monetary policy shocks are the second important driving force, after risk premium shocks, behind unemployment fluctuations for all countries in our EMU sample. This is confirmed in a quite unambiguous and robust way by both the FEVDs and the historical decompositions we analyzed. These conclusions on the drivers of the unemployment rate in the four largest EMU economies are quite different with regard to what GSW report for the US case, where monetary policy shocks, with 4% in the FEVDs, are not important in the long run, whereas wage markup shocks dominate overwhelmingly, with 80%, followed – by far – by risk-premium shocks, with only 7%.

5.3 Dynamic Effects of the Key Driving Shocks on the Rate of Unemployment

To study the dynamic responses of the unemployment rate – and the related labor market variables – in the four EMU countries of our sample, we now look at the impulse response functions (IRFs) to the key driving shocks that were simulated after estimation. We begin with the shock to monetary policy because our main interest is in the heterogeneous effects on unemployments rates in the EMU that the single monetary policy implemented by the ECB could possibly have, and also because our FEVD analysis as well as historical shock decompositions did indeed highlight this type of shock as the second largest source of variability in the unemployment rate. We report as well IRF-implied impact elasticity and lag-length in persistence until return to steady state (of zero) of EMU unemployment rates with respect to (w.r.t.) one standard deviation innovation in the shock to the nominal interest rate in the generalized Taylor-type monetary policy rule assumed. We then look at the IRFs to the type of shock with the strongest influence on EMU unemployment rates we identified, namely the risk premium shock. These two types of shocks represent demand shocks more generally in the classification of GSW. Finally, we also consider the effects of the two types of labor market shocks, the wage markup shock and the labor supply shock, that the GSW framework allows to separately identify and estimate, no matter that these turned out to be much less important in driving unemployment rate fluctuations in the largest EMU economies relative to other shocks as well as to the US case in GSW. We focus on our full-sample results, and note only some important differences by subsample, insofar relevant.

5.3.1 Monetary Policy Shocks

Figure 6 illustrates the estimated impulse responses of output, output growth, inflation, the real wage, the interest rate, employment, the labor force, the unemployment rate and the output gap to a positive monetary policy shock in the four sample countries. This is, therefore, a contractionary monetary policy shock, as it increases unexpectedly the nominal interest rate and corresponds to a rise in the innovation to the interest rate process by one standard deviation (SD) above its steady-state value (of zero), leading to a temporary decline in output (via a corresponding decline in consumption and investment, not shown in Figure 6). Table 8 is complementary to Figure 6 (for the full sample, and to the respective figures 7 and 8 by subsample) in that it provides numerical values for the estimated one standard deviation innovations and the corresponding IRF-implied impact elasticities, lag of maximum effects and lag-length in persistence until return to steady state of national unemployment rates in the EMU countries w.r.t. policy rate innovations for the full sample and each subsample.

[Figure 6 about here]

GSW refer to this monetary policy shock, together with the risk premium, investment-specific and exogenous spending shocks, as demand shocks because all four of them imply a positive comovement of output, inflation and the real wage. The GSW result on positive comovement in the US data is confirmed for our four EMU economies, here in Figure 6 following a monetary policy shock (and later on in Figure 9 following a risk premium shock). With regard to inflation, we confirm another well-known stylized fact but for three of our sample countries, except France: namely, the presence of "inflation persistence", that is, a long-lived subsequent drop in inflation after a surprise contraction in monetary policy (e.g., Ravn and Simonelli, 2007), the highest in Italy.[13]

[13] Interestingly, our full-sample (and pre-GFC subsample, see Figure 7) IRFs do not capture any visible effect of monetary policy shocks to inflation in France – it appears only in the post-GFC

[Table 8 about here]

Concerning the labor market variables, employment drops in response to the tightening of monetary policy, due to the contraction in output. But the labor force rises, because of the negative wealth effect. Observe the heterogeneity in the depth and persistence of the drop in employment, strongest and most persistent in Spain, close to 0.7 pp below steady state (SS) at its trough (for an interest rate shock of about 0.05 pp above SS on impact, so in highly elastic way), and more than two times weaker and less persistent in France (but still implying an elastic response). Similarly to the US case under KPR preferences in GSW, the negative correlation between employment and the labor force following a monetary policy shock leads to unemployment fluctuations, by construction, mostly driven by employment fluctuations and not labor force fluctuations, since the magnitudes along the vertical axis of the IRFs are, roughly, two times higher for the former relative to the latter.[14] As a result, the unemployment rate increases in all four EMU economies after an unexpected rise in the interest rate, displaying IRFs that mirror those for employment, but with the opposite sign. Again, heterogeneity in the effect of ECB's monetary policy on national unemployment rates in the EMU is clearly seen in Figure 6 (and its version by subsample in figures 7 and 8), and made quantitatively explicit and comparable in the corresponding numerical values reported in Table 8. Spain is the most affected within our sample countries, as the unemployment rate rises on impact (i.e., in quarter 1 in the figures and tables) to 0.48 pp above SS (implying the highest elasticity of 9.5 in our four EMU countries, given the estimated 1 SD of the innovation to the policy rate over the full sample), and further to a maximum effect of 0.74 pp above SS in quarter 3, and with lag-length in persistence until return to SS (i.e., dropping below 0.01%) exceeding 20 quarters. By contrast, in France the impact, maximum and persistence effects are, roughly, twice lower, and the implied impact elasticity is the lowest, 3.8. Germany and Italy fall in-between, but still exhibiting distinguishable profiles of high elasticity in the response on impact (of the order of 7.9 and 6.0, respectively), and in terms of persistence. Note also that price inflation and the real wage both move procyclically conditional on the monetary policy shock, in all four countries in our sample as in the baseline US case in GSW; that is, the real wage declines in all our four EMU countries following a contractionary monetary policy surprise by the ECB, as a result of the downward pressure of rising unemployment on nominal

subsample of ZLB – and even negative – interest rate environment (see Figure 8), yet is the lowest among the four EMU countries.

[14] While for the US this magnitude difference on impact is even much higher than in the EMU countries examined, of the order of 10 times – see GSW, Fig. 6, p. 344.

wages. However, the heterogeneity in the real wage IRFs is the largest among all depicted ones in the nine respective panels of Figure 6: the real wage in France is affected relatively weaker, down to about 0.1 pp below SS after about 6 quarters (but elastically, given the magnitude of the interest rate change on impact) and then recovers fast; Spain's response of the real wage is very similar, but more persistent; the real wage in Italy bottoms out after about two years and a half and after a drop three times stronger than that in France or Spain, also displaying the highest persistence (or slowest recovery); finally, on this account Germany experiences the strongest effect of monetary policy on real wages, down nearly by 0.4 pp below SS some two years after the shock.

The essence of the described IRF profiles of the labor market variables following a monetary policy shock of 1 SD does not change when we look over the subsamples in figures 7 and 8. However, it is worth stressing that the magnitude of the effects on all four labor market variables considered is approximately two times weaker in all four EMU sample economies (visible on the respective pairs of vertical axes) in the post-GFC subsample of ineffective interest rate policy at the ZLB (or even below) and the additional stimulus via quantitative easing (which the GSW model we employ here does not attempt to capture). This result on the magnitude of the impulse responses indicates that monetary policy by the ECB has lost some of its power to affect the unemployment rate, as well as employment, labor force participation and the real wage, in the examined EMU countries during the ZLB environment after the GFC relative to the pre-GFC subperiod. On the other hand, as it becomes clear from the respective values in Table 8, this does not mean that the IRF-implied impact elasticity of national unemployment rates w.r.t. 1 SD interest rate shock has necessarily declined as well post-GFC relative to pre-GFC: this is true, slightly, only for Germany; while for France the impact elasticity has remained stable close to its full-sample estimate of 3.8, for Italy and Spain our estimates show slight increase. In the latter sense, as measured by the IRF-implied impact elasticity, one could also argue that – especially in these two countries, but also in France and Germany to a lesser extent – the effectiveness of (even the smaller) interest rate changes post-GFC has not been lower than pre-GFC.

[Figures 7 and 8 about here]

5.3.2 Risk Premium Shocks

We, next, consider briefly the role of risk premium shocks, as these came out in the FEVDs and the historical shock decompositions as the most influential determinant of the variability of the unemployment rate in all four EMU countries in our sample at all horizons. The IRFs in Figure 9 depict qualitatively a lot of similarity in our EMU economies as a group and the US case documented in GSW: output (and the output gap, which coincide when the natural output is not affected by shocks, as in the analysis in the present subsection), inflation, the real wage, the interest rate and employment all comove positively, while the unemployment rate comoves negatively, conditional on the risk premium shock, as in the US data; however, differently from the US case, the labor force drops on impact (by about 0.2 pp below SS in all four EMU economies except Italy, where it falls twice deeper) and does not recover for about a year in France and Germany and for about 2 years in Italy and Spain. The positive risk premium shock thus seems to be associated with a likely wealth effect that makes households to perceive themselves as richer and to want to work less, exiting the labor force; at the same time both employment and – as a mirror image – the rate of unemployment fluctuate 2-3 times stronger than the labor force, with magnitudes on impact exceeding 1 pp up for employment and 1 pp down for the unemployment rate in the most affected countries, Italy and Spain, displaying as well much heterogeneity in persistence with respect to France and Germany.

Looking by subsample period in figures 10 and 11 further shows that the effects on all labor market variables are now magnified post-GFC relative to pre-GFC. This is the opposite finding with regard to what we noted when analyzing the analogous effects of monetary policy shocks. The heterogeneity across our four sample countries is more than evident in terms of both magnitudes and time profiles of the dynamic responses to the risk premium shock, and various countries end up at the opposite extremes in different panels, with nuances across subperiods too.

5.3.3 Labor Market Shocks

We, finally, turn to the impulse responses of the unemployment rate and the key related variables to shocks originating in the labor market, as per the classification in GSW. Following these authors, our analysis highlights two such shocks, identified and estimated separately in the GSW model: the wage markup shock depicted in figures 12 (full sample), 13 (pre-GFC) and 14 (post-GFC); and the labor supply shock illustrated in figures 15 (full sample), 16 (pre-GFC) and 17 (post-GFC).

[Figures 12, 13 and 14 about here]

Differently from the US case in GSW, where both labor market shocks generate a negative comovement of inflation and the real wage with output, this is true in the case of our EMU sample only for the comovement between the real wage and output conditional on a labor supply shock. The dynamics after wage markup shocks in Figure 12 is more complicated and more varied across countries. Similarly to the US case, a positive wage markup shock generates high inflation – but only in Spain, of a comparable magnitude of about 0.1 pp above the SS but with much less persistence; for the other three countries in our EMU sample the effect of wage markup shocks on inflation is negligible. Checking by subsample, the inflation in Italy pre-GFC and France post-GFC is also affected, thus exhibiting country and time heterogeneity. As far as the unemployment rate is concerned, a wage markup shock increases it, as in the US case: considerably and persistently in Spain, much less so in France and Germany, and in the strongest way on impact in Italy, about 0.3 pp above SS, but with a fast return to it after 3-4 quarters. At the same time, and as in the US case, the wage markup shock generates persistent negative effects on output, employment and the output gap (although the impact is slightly positive, but plunges quickly), therefore not generating a tradeoff for policymakers in all four EMU economies and across both subsamples in each of them.

[Figures 15, 16 and 17 about here]

By contrast, and much more in agreement with the US case, an adverse labor supply shock – as in Figure 15 – has negative effects on output and employment but positive effects on the output gap, which rises on impact in all countries in our full sample by about 0.2 pp above SS, and unemployment, which drops on impact in all four EMU economies from 0.2 to 0.4 pp below SS but then recovers for about two years. It is also worth noting that among the four key driving forces behind fluctuations in the rate of unemployment in the sample EMU member-states only the labor supply shock affects the natural level of output, thereby driving a wedge between the dynamic responses of output and the output gap. More precisely, a positive labor supply shock (a sudden rise of χ in the utility function) increases the disutility to work, so people move out of the labor force, and as can be seen in the IRFs, employment drops with a stronger magnitude on impact and with very high persistence, while unemployment drops less on impact and only temporarily, for a year or so. This results in a drop in actual output, but even more so in natural output, i.e., output that would have prevailed under the counterfactual scenario of fully flexible prices and wages and a constant desired wage markup, thereby generating a positive output gap on impact that exhausts itself in about a year.

Most importantly, and as GSW point out, we see in the EMU economies again the same different effect on the unemployment rate and the output gap associated with the two labor market shocks that makes their separate identification and estimation important from an academic as well as policymaking perspective. Looking at subsamples, pre-GFC in figures 13 and 16 and post-GFC in figures 14 and 17, does not change this latter conclusion regarding the value of the separation of these two labor market shocks (lumped together in earlier work), yet introduces further nuances and heterogeneities across countries and sometimes time subperiods that may need deeper investigation – which is a task beyond the scope of the present paper.

6 Discussion and Concluding Remarks

This study estimated and simulated a canonical medium-scale New Keynesian DSGE model that incorporates unemployment with indivisible labor as in GSW using observable quarterly data from the four largest EMU countries – France, Germany, Italy and Spain – to assess the differences in the effects of monetary policy shocks on the national rates of unemployment since the introduction of the euro in January 1999. We also compared the relative importance of other types of structural shocks in driving the variability and the dynamics of national unemployment rates and analyzed the behavior of a few other central labor market variables, such as employment, the labor force and the real wage. To judge about the robustness of our full-sample results, these were reproduced as well by time subperiod, pre- and post-GFC.

Some novel empirical results emerge from our analysis.

First, we uncovered a clear common ranking of the sources of national unemployment rate fluctuations in the largest four EMU economies. At any horizon examined, the biggest fraction of the variability in the unemployment rate is explained by risk premium shocks, whose contribution ranges from about one-third to almost a half in the short run, to about 45-60% in both the medium and long run. It is worth noting that, at the two longer horizons, these risk premium shocks are more important, accounting for about 10 pp more, in the "high debt – high risk premium" EMU countries in our sample, Italy and Spain, relative to the "low debt – low risk premium" EMU economies, France and Germany. Monetary policy shocks are the second largest exogenous force, accounting for about one-fifth to one-third at 10 and 40 quarters ahead, although in the short run of 1 quarter their importance is somewhat reduced, to between 8% and 22%. This result highlights an important difference of all our European economies relative to the US case in GSW, where monetary policy shocks explain 11% of the variability of the unemployment rate at

10 quarters and only 4% at 40 quarters. Monetary policy in the EMU countries thus turns out to be much more relevant when influencing unemployment compared to the US. This has strong policy implications, especially bearing in mind the heterogeneity of its effects along many dimensions our present study also revealed. These conclusions are supported by robust evidence in all four examined countries by both the FEVDs and the historical decompositions we analyzed. Thus, the drivers of the unemployment rate in the major EMU economies are quite different from those for the US reported by GSW (in a different sample period), where monetary policy shocks are not important in the long run, whereas wage markup shocks dominate overwhelmingly, followed by risk premium shocks.

Second, when comparing the subsample FEVDs pre- and post-GFC, we found that the influence of risk premium shocks has generally increased post-GFC (to 65-81%) relative to pre-GFC (from 30-46%), mostly at the expense of monetary policy shocks (falling from 14-46% to 4-14%) for all countries. The heterogeneity across the four EMU member-states, however, has not been affected. This evidence is consistent with the common narrative that the post-GFC ZLB environment has rendered interest rate policy much less effective. Consequently, our FEVD findings pre- and post-GFC confirm that the power of ECB's monetary policy to affect the unemployment rate and the other central labor market variables has been clearly reduced.

Third, turning to the dynamic responses of the key labor market variables to the single monetary policy conducted by the ECB, we documented that employment falls in response to the tightening of monetary policy, due to the contraction in output, but labor force participation increases, because of the negative wealth effect. Similarly to the US case under KPR preferences in GSW, the negative correlation between employment and the labor force following a monetary policy shock leads to unemployment fluctuations, mostly driven by employment fluctuations and not labor force fluctuations. As a result, the unemployment rate increases in all four EMU economies after a monetary policy tightening, exhibiting time profiles that mirror those for employment, but with the opposite sign. The heterogeneity in the effect of ECB's monetary policy on national unemployment rates in the EMU is evident in the dynamic responses too: Spain is the most affected, as the unemployment rate rises to about 0.7 pp above SS at its maximum; in France the impact, maximum effect and persistence are, roughly, twice lower than in Spain; Germany and Italy fall in-between, but still exhibiting distinguishable profiles of response. Price inflation and the real wage both move procyclically conditional on the monetary policy shock, in all four countries in our sample as in the baseline US case in

GSW. In particular, the real wage declines in all our four EMU countries, as a result of the downward pressure of rising unemployment on nominal wages. However, the heterogeneity revealed in the dynamic response of the real wage by countries is considerable too, with France and Spain affected by 1 pp drop on impact, Italy affected three times stronger and also displaying the slowest recovery, and Germany experiencing the strongest effect of monetary policy on real wages, down to a trough of 0.4 pp below SS two years after the shock.

Fourth, the magnitude of the effects of monetary policy shocks on all four labor market variables considered has fallen approximately by two times in all four EMU sample economies in the post-GFC subsample of ineffective interest rate policy at the ZLB relative to the pre-GFC subperiod. This result of a twice reduced influence, in terms of impulse responses, of ECB's monetary policy on national labor markets in general and unemployment rates in particular is parallel to a doubling in the influence of risk premium shocks post-GFC. However, the IRF-implied impact elasticity of the unemployment rate w.r.t. 1 SD interest rate shock has not declined as well post-GFC relative to pre-GFC: while for France, and less so Germany, the impact elasticity has remained stable close to its respective full-sample estimates, for Italy and Spain it has slightly risen. According to such an IRF-implied impact elasticity measure, the effectiveness of (even the smaller) interest rate changes post-GFC has not been lower than pre-GFC.

Fifth, the historical decompositions confirmed the dominance of risk premium and monetary policy shock contributions to the fluctuations in the unemployment rate. In the "low-debt" EMU countries, France and Germany, mild risk premium shocks have generally depressed the unemployment rate in the pre-GFC subperiod, whereas the relatively expansionary monetary policy has contributed to its increase. In the post-GFC subperiod, however, these roles have reversed, with the ZLB policy depressing unemployment, but higher risk premium shocks – as repercussions from the Greek crisis – increasing it. Somewhat differently, in the "high-debt" EMU countries, Italy and Spain, the dominance of risk premium and monetary policy shocks has been uncovered again, but now both these types of shocks came out as very important in pushing the unemployment rate up after the GFC. This reflects, particularly in Spain, the high-debt crisis and the associated higher risk premium prevailing in the post-GFC subsample.

Sixth, our structural parameter estimates revealed substantial heterogeneity across the four largest EMU economies in the degree of market power in wage determination for differentiated labor. This heterogeneity further implied a corresponding heterogeneity in average unemployment rates, as also documented by the data. Notably, the model-implied average unemployment rates, calculated using our estimates of the elasticity of labor supply and of the wage markup, predicted quite precisely the corresponding mean values from the full sample. Moreover, the parameter governing the wealth effects on labor supply revealed values ranging from 0.64 (France) to 0.83 (Germany), much closer to the specification of the utility function in King-Plosser-Rebelo (1988, KPR). These are much higher values than those estimated in the US data by GSW, 0.02, which are empirically consistent with Greenwood-Hercowitz-Huffman (1988, GHH) preferences. Our impulse response analysis conditional on a monetary policy shock confirmed further that employment and the labor force commove negatively in all our four sample countries, as implied by KPR preferences, in agreement with a strong wealth effect, absent in the US case reported by GSW.

Essentially, this paper found that the same ECB monetary policy has quite heterogeneous effects on the unemployment rate and the key labor market variables in the four major EMU countries. The reasons for such a heterogeneity in the effects of single monetary policy on unemployment and employment, and also on the labor force participation rate and on equilibrium real wages, are most likely related to the differences in the functioning of the labor market institutions each of these countries has inherited before joining the euro. The major contribution of this paper lies, therefore, in estimating a New Keynesian DSGE model, building on Galí-Smets-Wouters (2012), to document and examine the heterogeneity of the effects of monetary policy shocks across Euro-area countries. The findings we highlighted enhance and deepen our understanding of monetary policy issues in Europe and the monetary policy - unemployment interplay. We do acknowledge that our contribution is principally empirical and related to the application of the question we pose, which, naturally, might lead to think that other considerations might be relevant. For instance, *in primis*, the role of country-specific labor markets and their institutional characteristics but, also concerns about the ZLB and the EU debt crisis. We believe it is not feasible to deal with all such interrelated aspects in one paper and we aim, with our paper, to set the scene for further research on those important aspects.

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For Online Publication: Supplementary Appendix

A Data Description

A.1 Definitions and Sources of the Original Data

1. GDPC05: Real Gross Domestic Product – Millions of Chained 2005 Euro, Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Economy and Finance, National Accounts, Quarterly National Accounts, Main GDP Aggregates.

2. GDPDEF: Gross Domestic Product – Implicit Price Deflator – 2005=100, Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Economy and Finance, National Accounts, Quarterly National Accounts, Main GDP Aggregates.

3. CONS: Actual Individual Consumption – Millions of Chained 2005 Euro, Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Economy and Finance, National Accounts, Quarterly National Accounts, Main GDP Aggregates.

4. GFCF: Gross Fixed Capital Formation – Millions of Chained 2005 Euro, Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Economy and Finance, National Accounts, Quarterly National Accounts, Main GDP Aggregates.

5. WAGE: Compensation Per Employee – Compensation of All Employees divided by the Number of Employees, Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Economy and Finance, National Accounts, Quarterly National Accounts, Main GDP Aggregates and Auxiliary Indicators.

6. ECBr: The Interest Rates on ECB's Lending Facilities (Averages of Daily Figures), % per anuum. Source: European Central Bank, Statistic, ECB/Eurosystem policy and exchange rates, Official interest rates.

7. POPULATION: Total Population – Age: 15 years and over– Number in Millions, Seasonally Adjusted.Source: Eurostat, Database, Database by Themes, Population and Social Conditions, Labor Market (labor), Employment and Unemployment (Labor Force Survey), LFS Series-Detailed Quarterly Survey Results.

8. POPUindex: POPULATION (2005:1)=1

9. EMP: Employment – Age: 15 years and over – Number in Millions, Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Population and Social Conditions, Labor Market (labor), Employment and Unemployment (Labor Force Survey), LFS Series-Detailed Quarterly Survey Results.

10. UNEMP: Unemployment Rate –Age: from 15 to 64 years – Pre-2005 is estimated data and Post-2005 is observed data[15], Seasonally Adjusted. Source: Eurostat, Database, Database by Themes, Population and Social Conditions, Labor Market (labor), Employment and Unemployment (Labor Force Survey), LFS Series-Detailed Quarterly Survey Results.

A.2 Definition of the Transformed Data

1. consumption = ln(CONS/POPUindex)×100

2. investment = ln(GFCF/POPUindex)×100

3. output = ln(GDPC05/POPUindex)×100

4. real wage = ln(WAGE/GDPDEF)×100

5. inflation = ln(GDPDEF/GDPDEF(−1))×100

6. employment = ln(EMP/POPUindex)×100

7. unemployment rate = UNEMP

8. interest rate = ECBr/4

A.3 Definition of the Data Variables Used in the Measurement Equations

1. dc = consumption − consumption(−1)

2. $dinve$ = investment − investment(−1)

[15] The unemployment rate data used in this paper is from Eurostat, which is mainly based on the results of the European Labor Force Survey (EU-LFS). The EU-LFS initially conducts an annual spring survey from 1998 to 2004. Since 2005, a transition from an annual spring survey to a quarterly continuous survey provides quarterly data on the labor market. Thus, our data for the pre-2005 period is the estimated quarterly unemployment rate and thereafter is the observed data.

3. dy = output − output(−1)
4. $empobs$ = employment − base quarter (close to sample average employment)
5. $unempobs$ = unemployment rate
6. dw = real wage − real wage(−1)
7. $pinfobs$ = inflation
8. $robs$ = interest rate

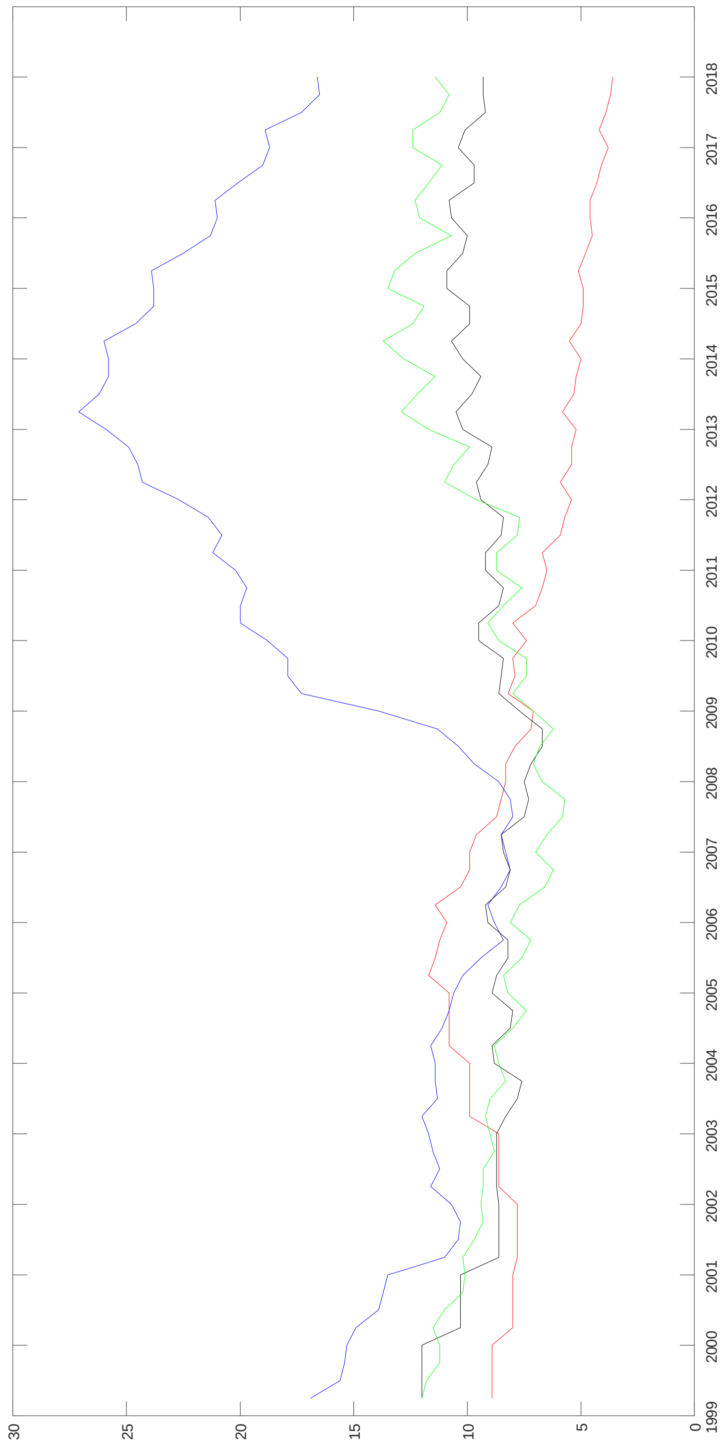

Figure 1: Evolution of the Unemployment Rate in the EMU Largest Countries, Full Sample (1999Q1–2017Q4, 76 observations); y-axis: % of labor force; France black; Germany red; Italy green; Spain blue; Seasonally Adjusted. Source: Eurostat, Database, Labor Force Survey (LFS), Series-Detailed Quarterly Survey Results, seasonally adjusted.

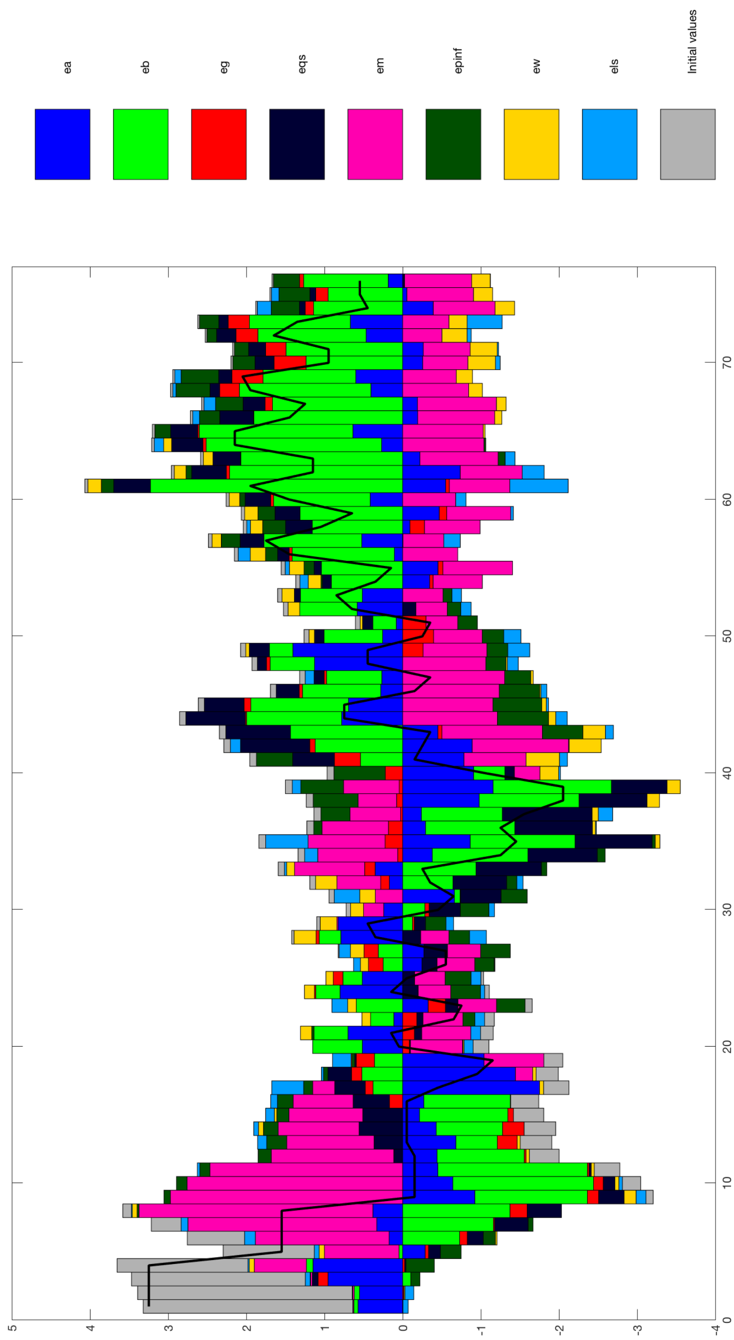

Figure 2: France – Historical Shock Decomposition, Full Sample (1999Q1–2017Q4)

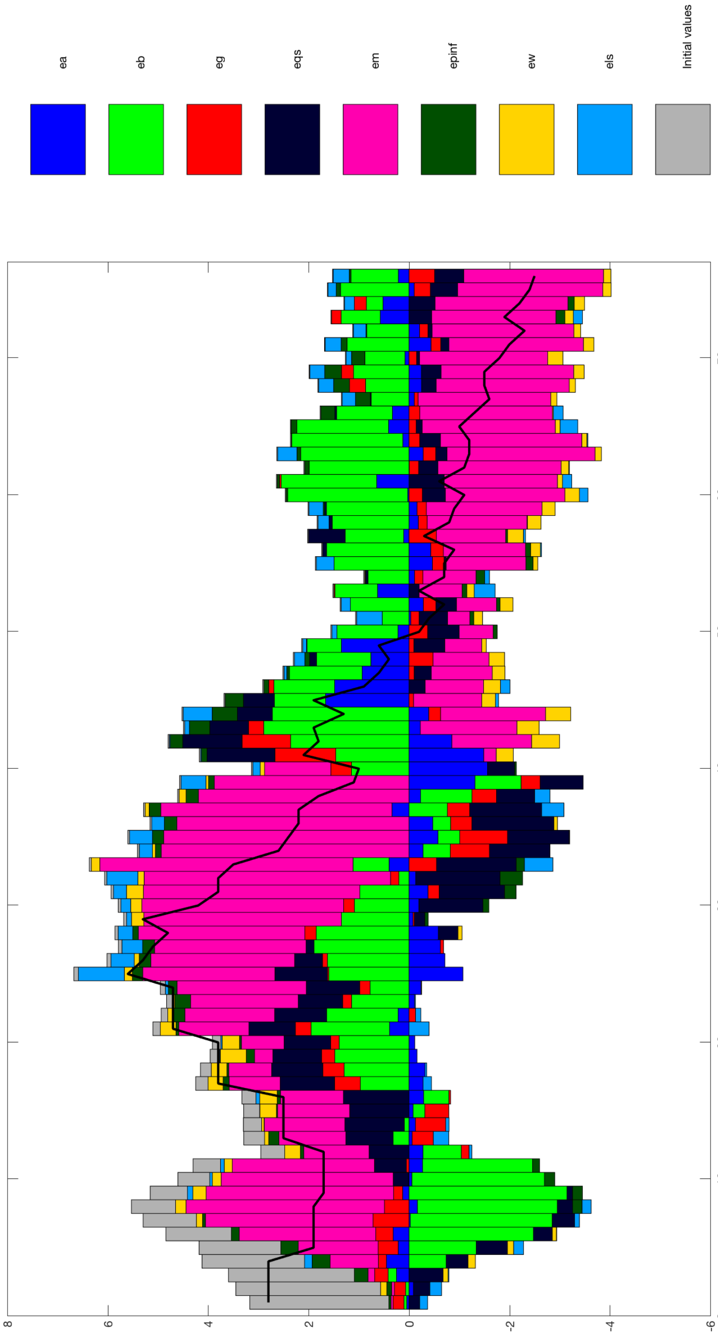

Figure 3: Germany – Historical Shock Decomposition, Full Sample (1999Q1–2017Q4)

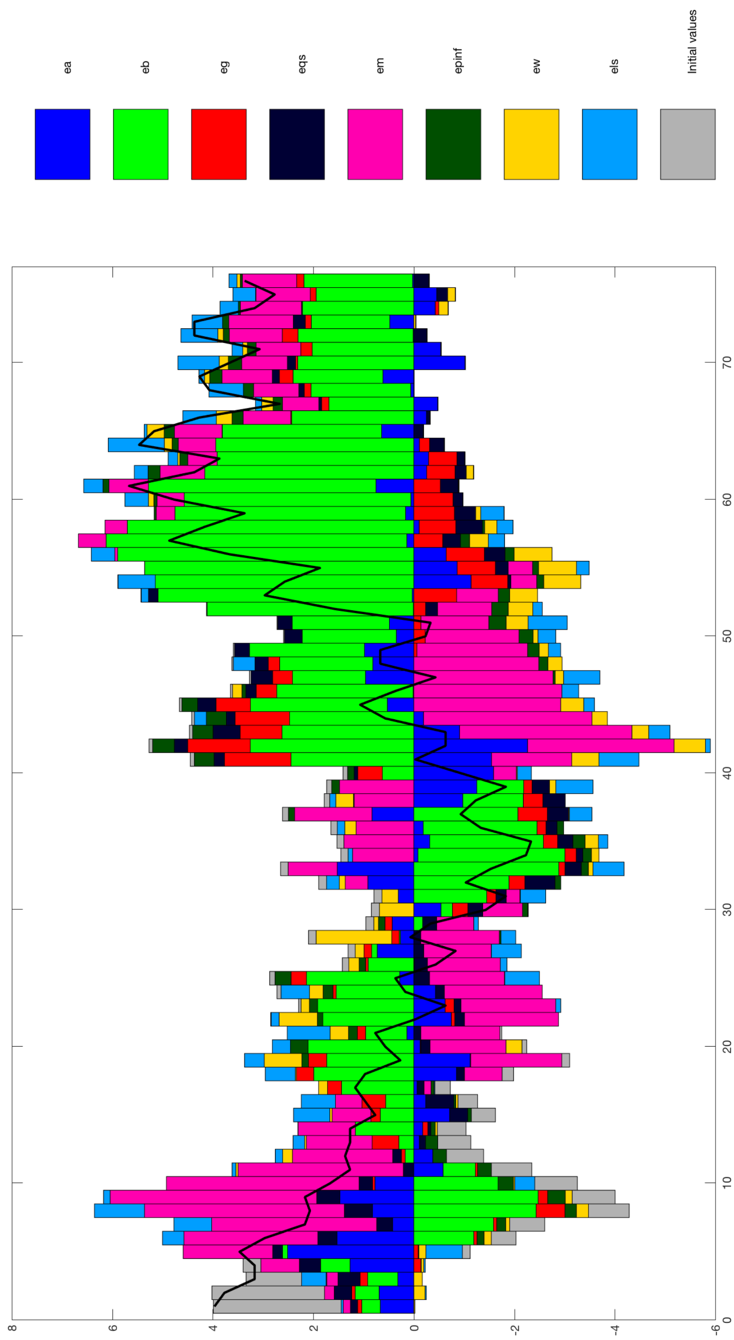

Figure 4: Italy – Historical Shock Decomposition, Full Sample (1999Q1–2017Q4)

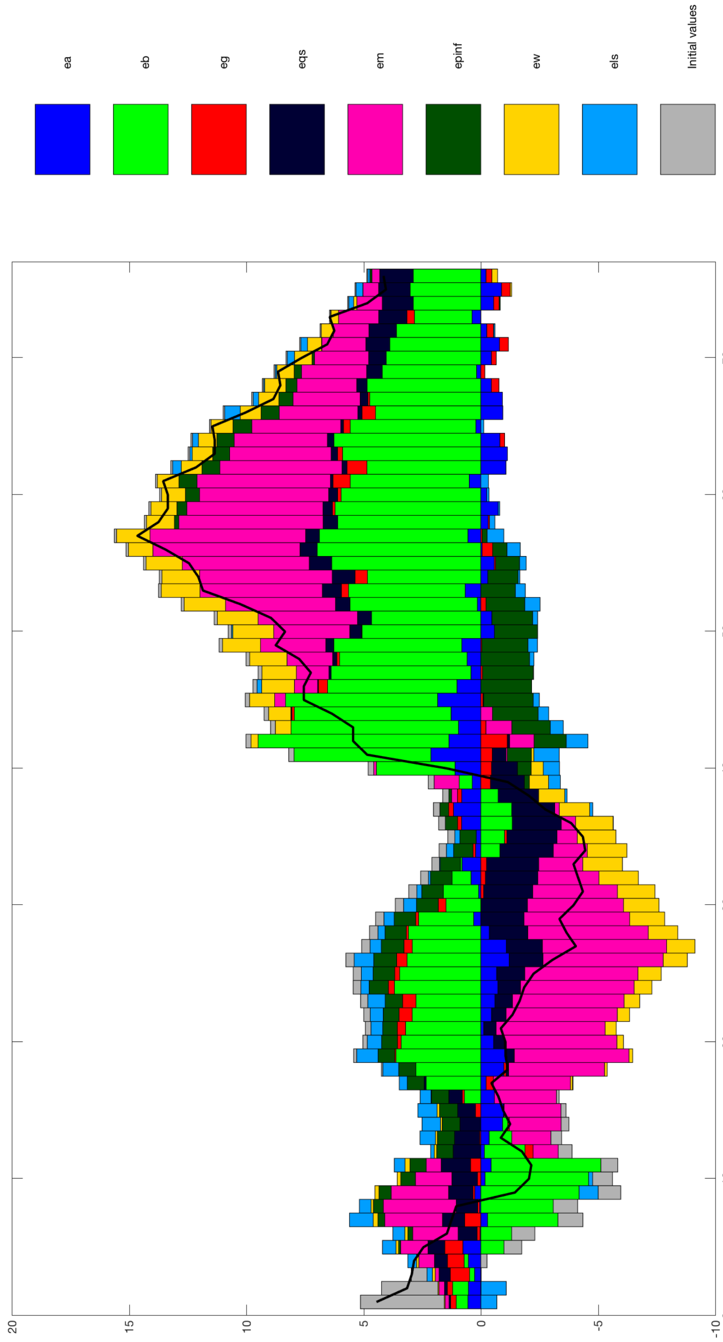

Figure 5: Spain – Historical Shock Decomposition, Full Sample (1999Q1–2017Q4)

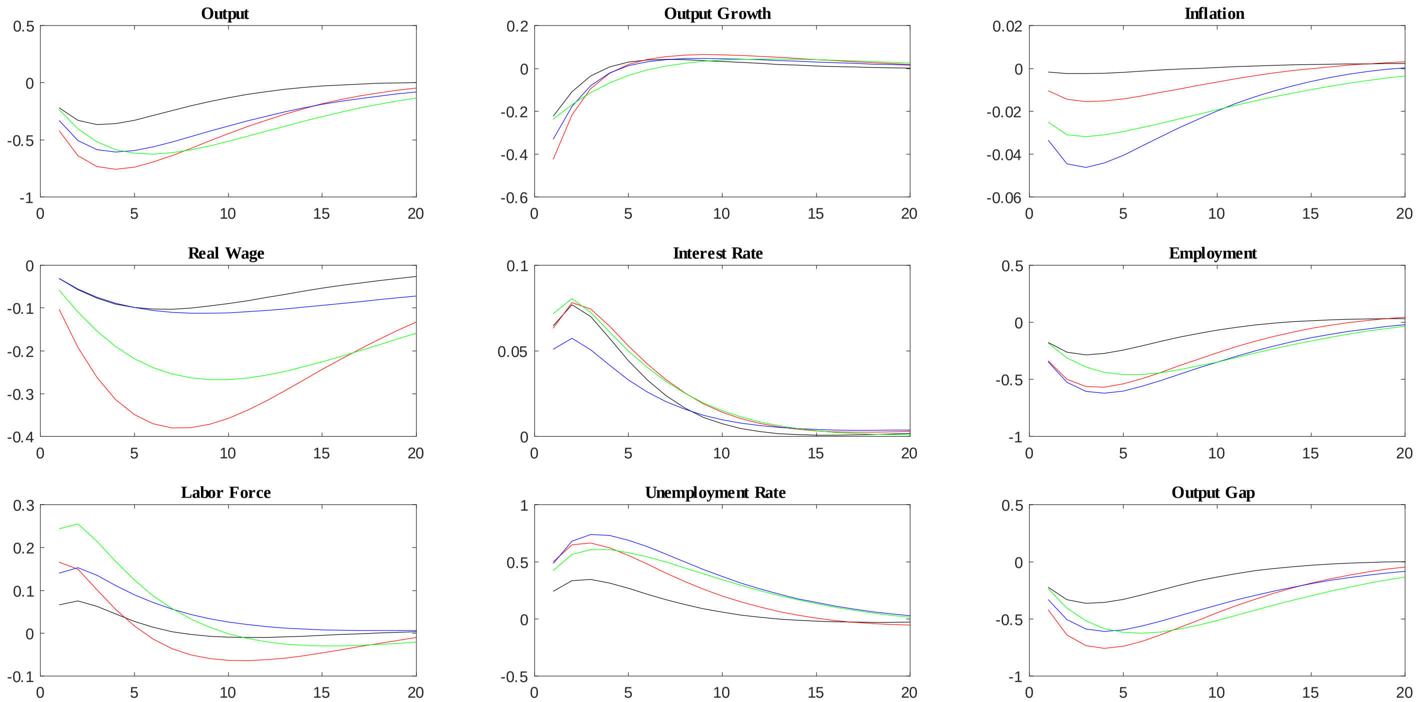

Figure 6: Dynamic Responses to a Positive Monetary Policy Shock of 1 SD, Full Sample (1999Q1–2017Q4, 76 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

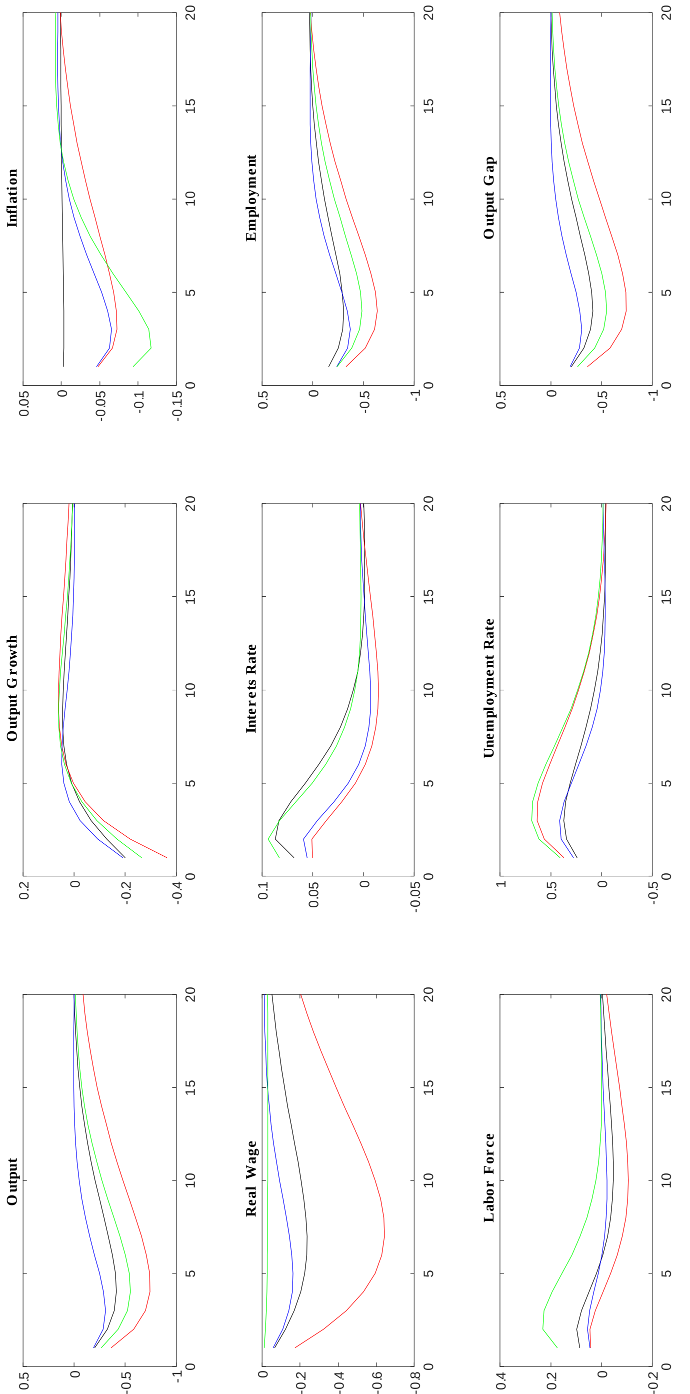

Figure 7: Dynamic Responses to a Positive Monetary Policy Shock of 1 SD, Pre-GFC Subsample (1999Q1–2007Q2, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

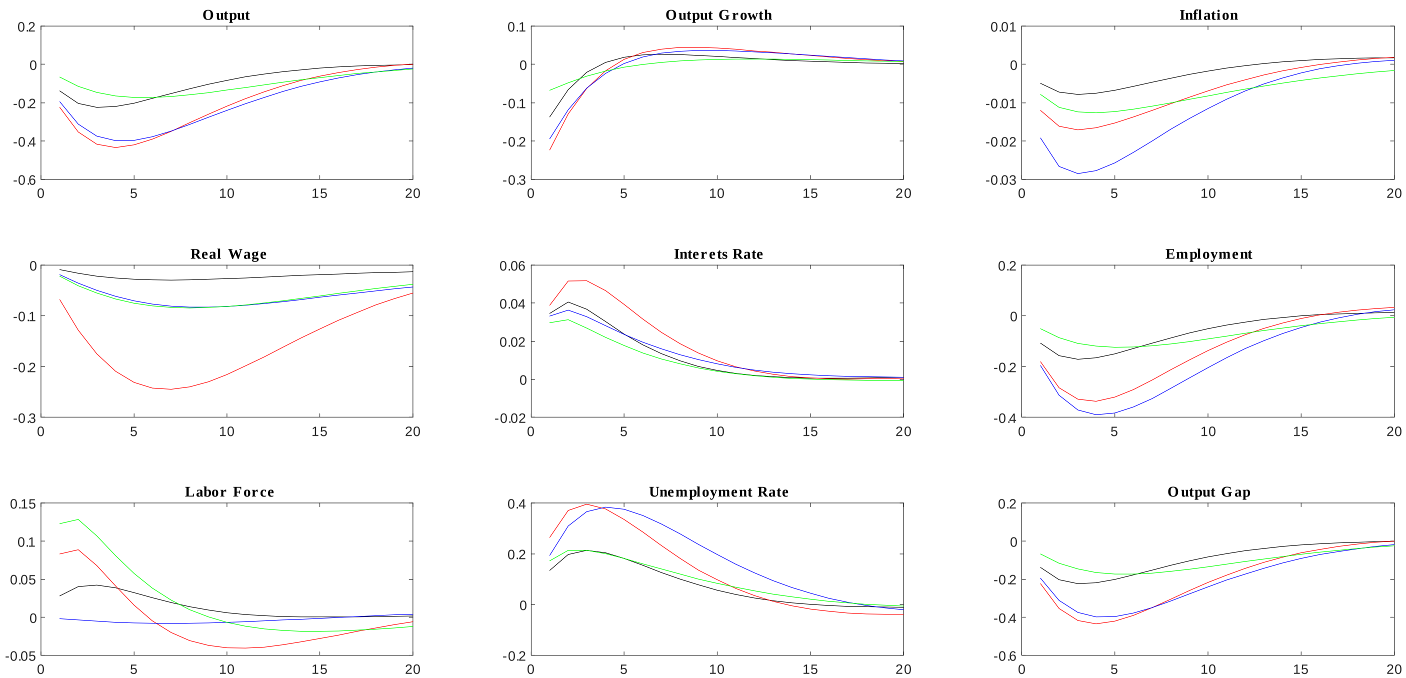

Figure 8: Dynamic Responses to a Positive Monetary Policy Shock of 1 SD, Post-GFC Subsample (2009Q3–2017Q4, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

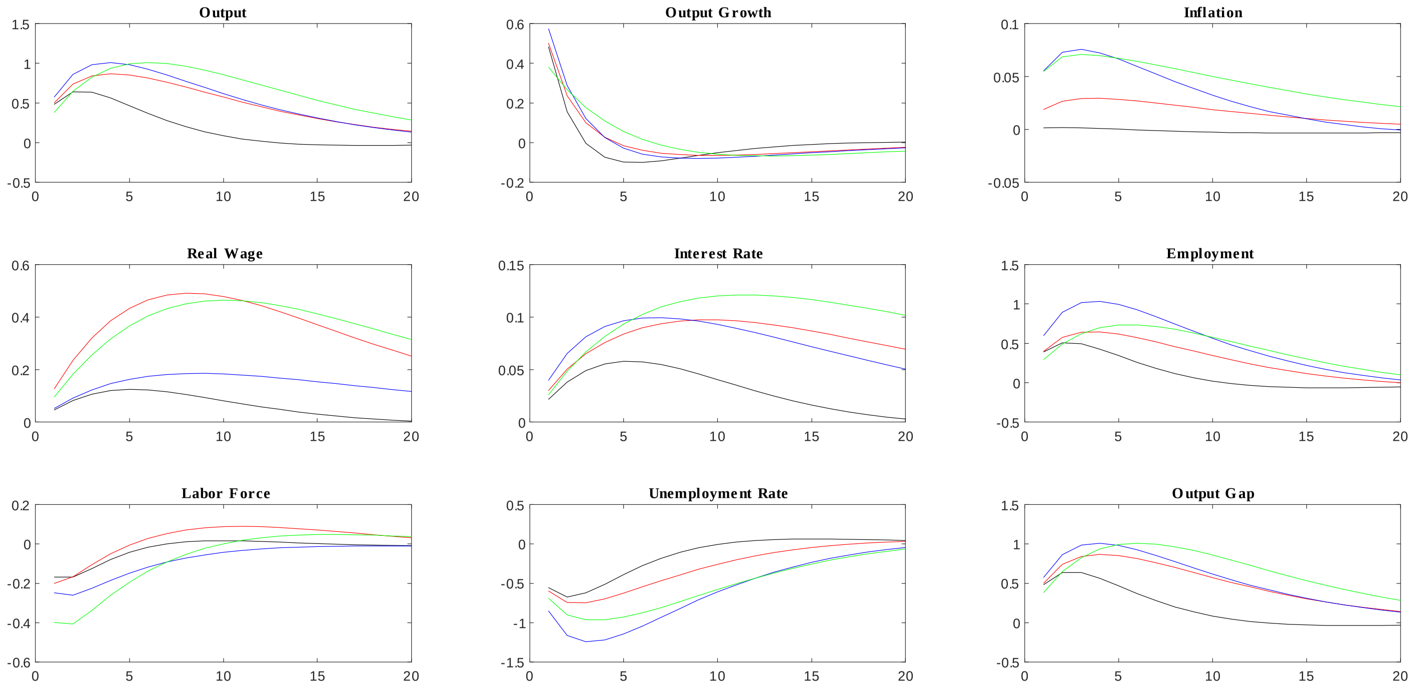

Figure 9: Dynamic Responses to a Positive Risk Premium Shock of 1 SD, Full Sample (1999Q1–2017Q4, 76 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

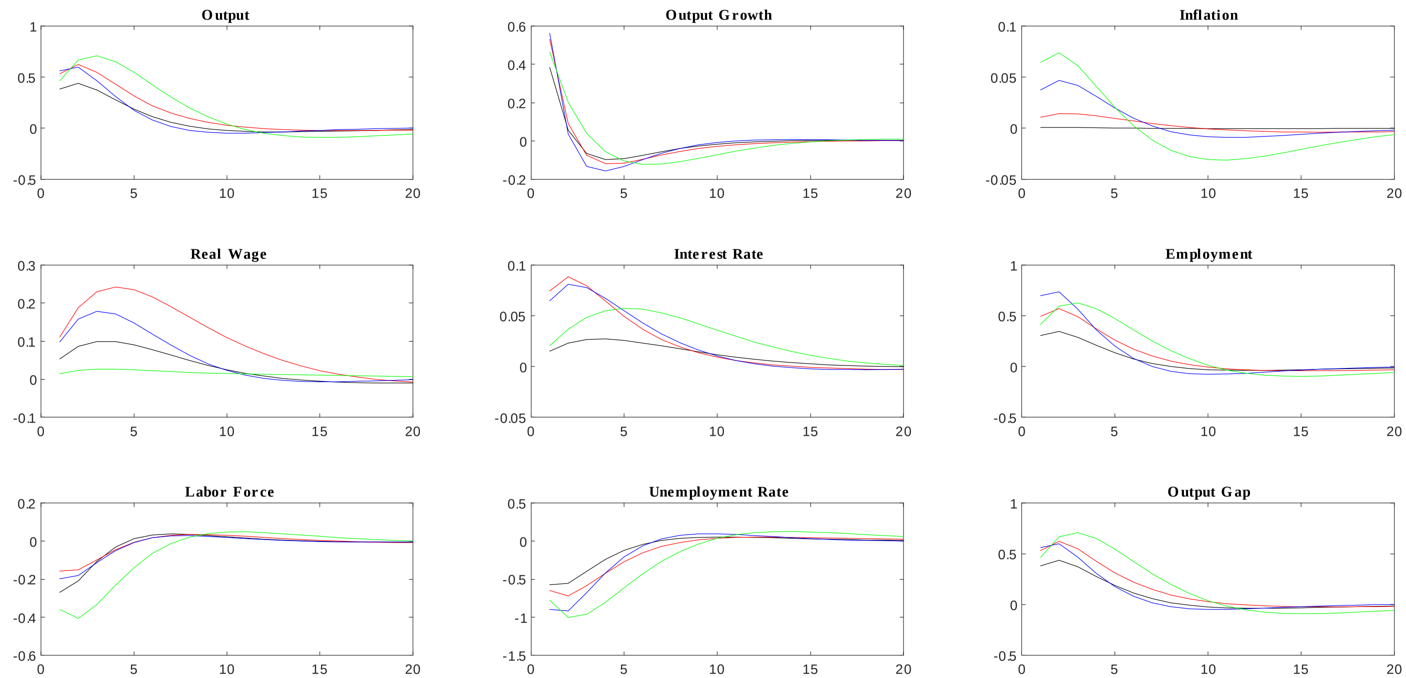

Figure 10: Dynamic Responses to a Positive Risk Premium Shock of 1 SD, Pre-GFC Subsample (1999Q1–2007Q2, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

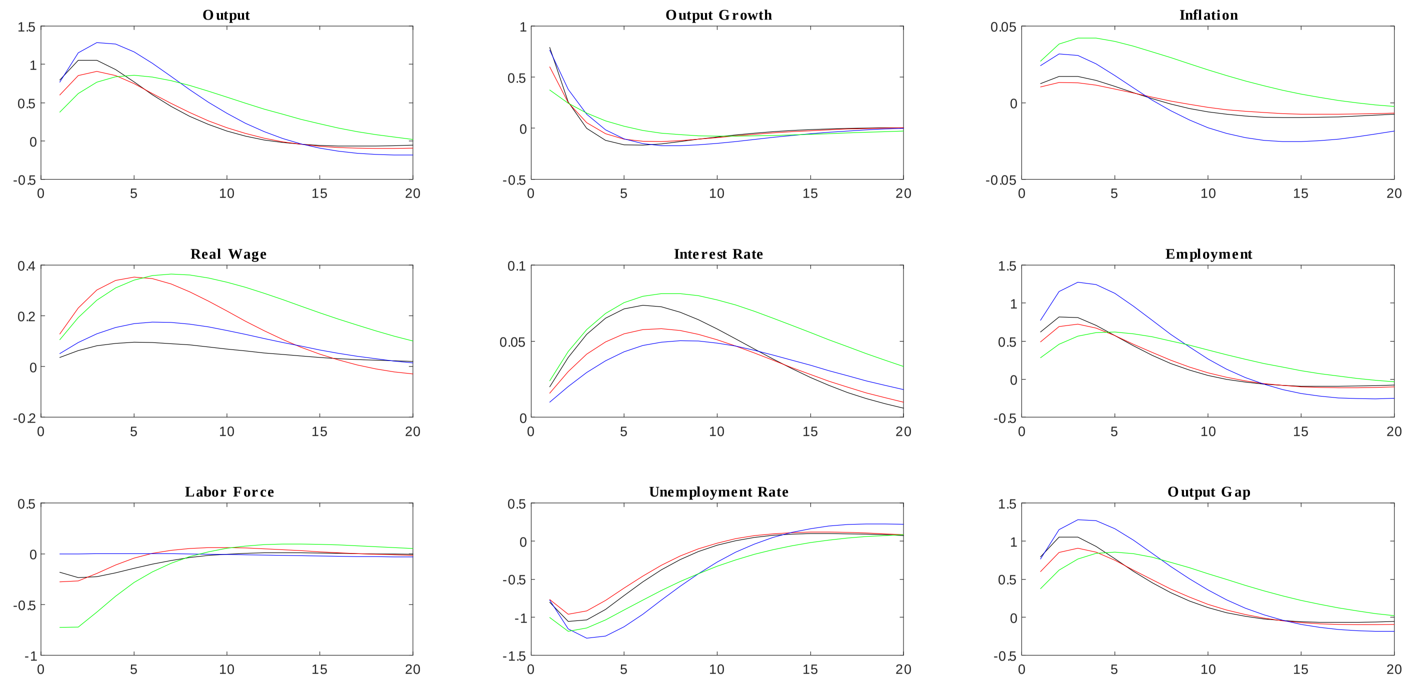

Figure 11: Dynamic Responses to a Positive Risk Premium Shock of 1 SD, Post-GFC Subsample (2009Q3–2017Q4, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

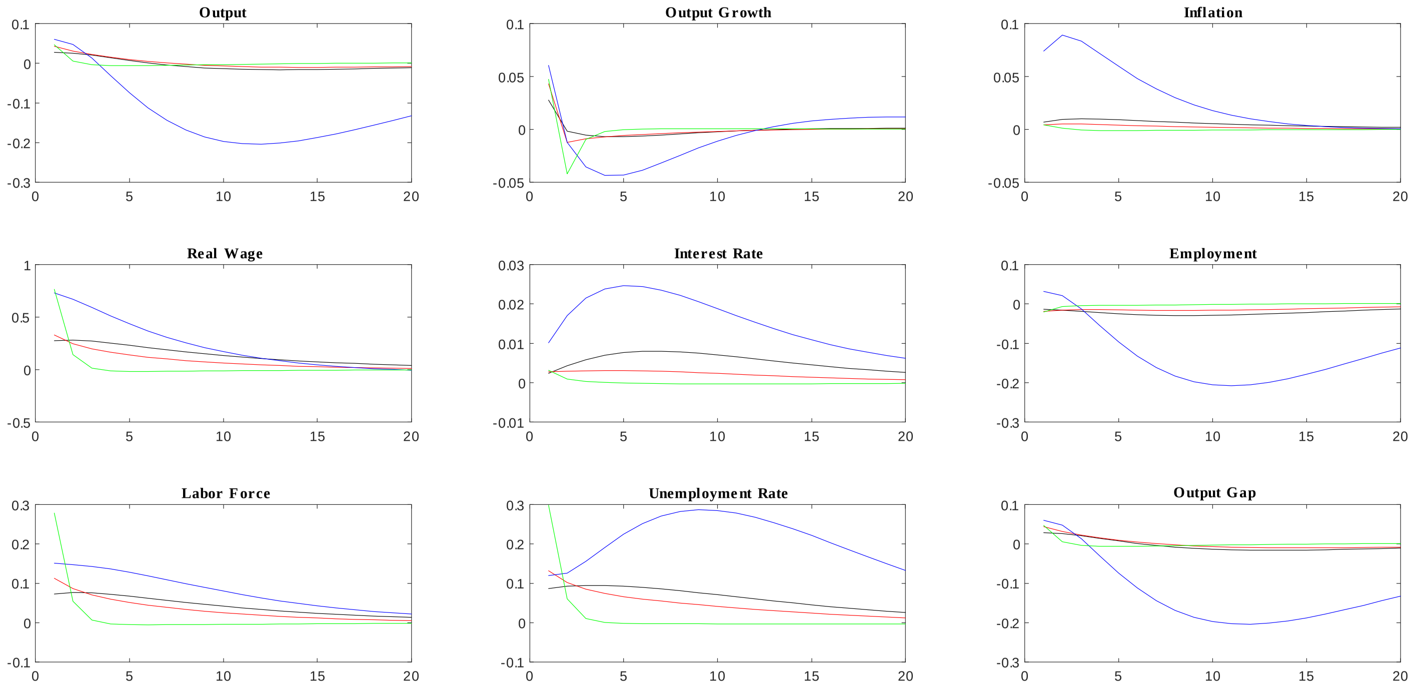

Figure 12: Dynamic Responses to a Positive Wage Markup Shock of 1 SD, Full Sample (1999Q1–2017Q4, 76 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

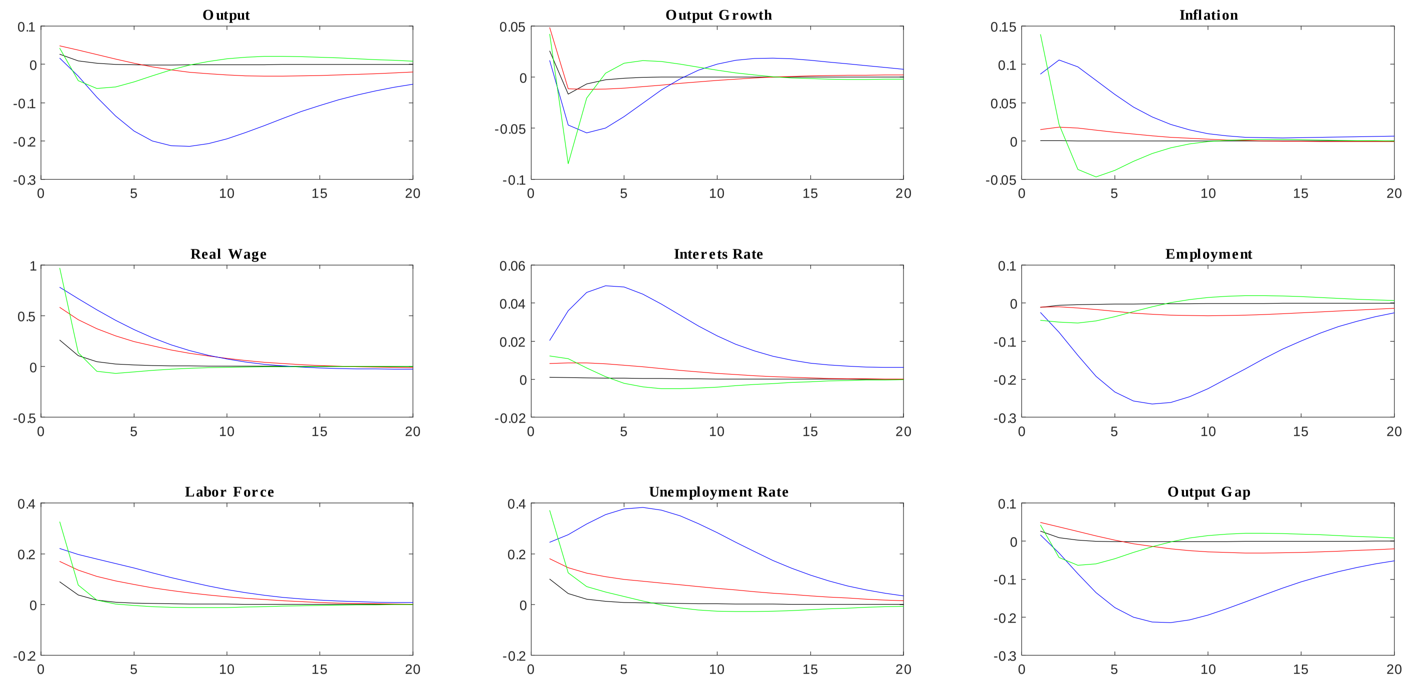

Figure 13: Dynamic Responses to a Positive Wage Markup Shock of 1 SD, Pre-GFC Subsample (1999Q1–2007Q2, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

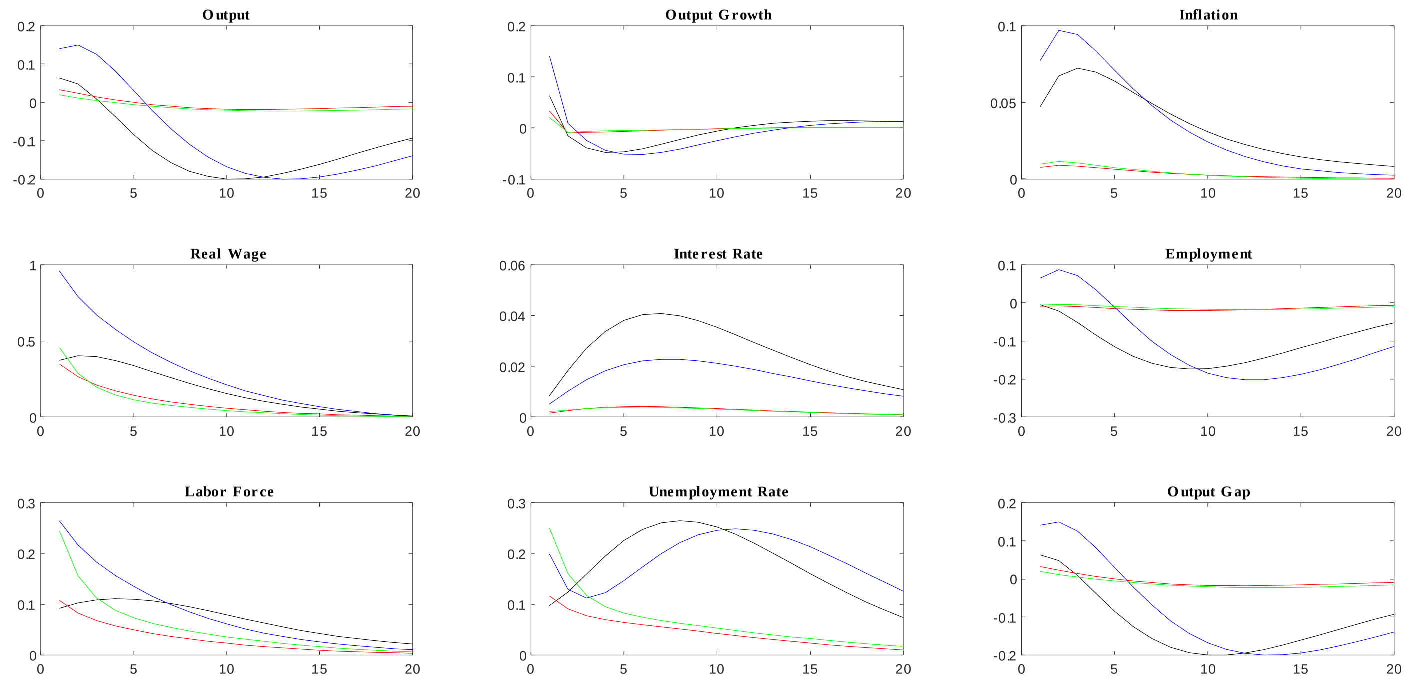

Figure 14: Dynamic Responses to a Positive Wage Markup Shock of 1 SD, Post-GFC Subsample (2009Q3–2017Q4, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

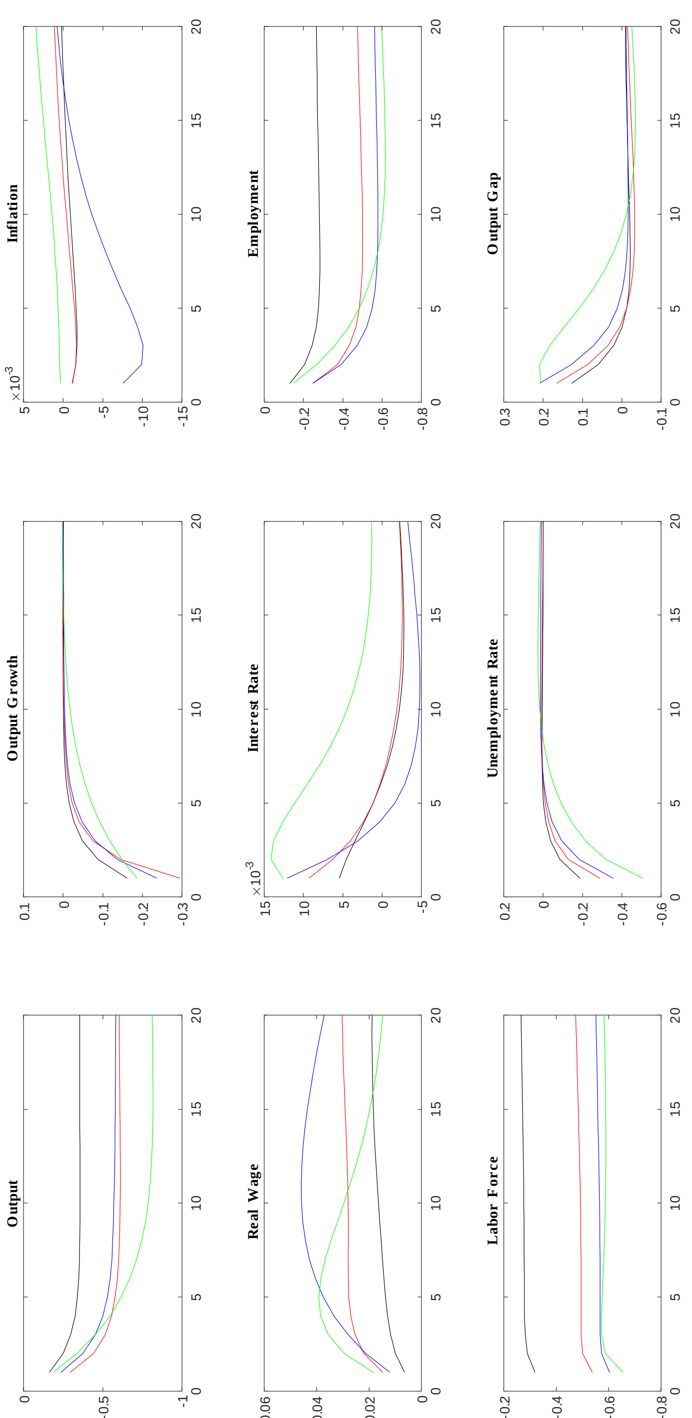

Figure 15: Dynamic Responses to a Positive Labor Supply Shock of 1 SD, Full Sample (1999Q1–2017Q4, 76 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

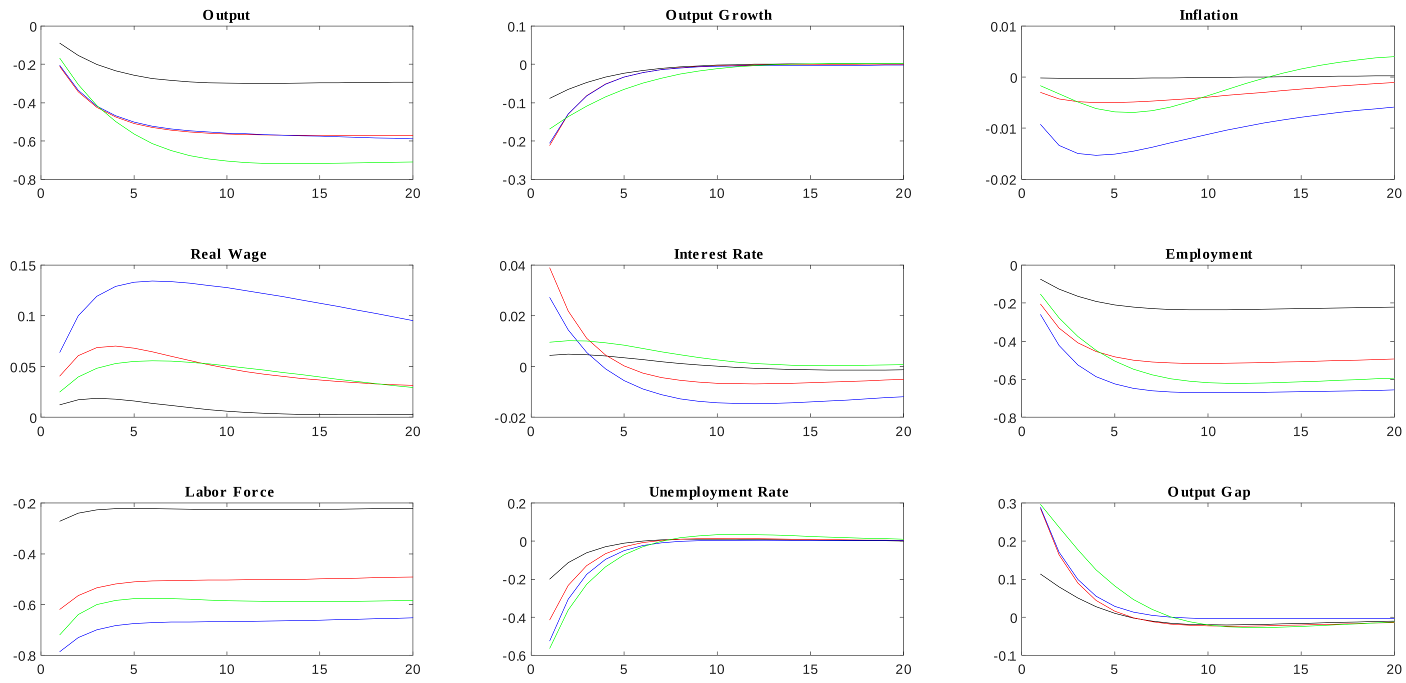

Figure 16: Dynamic Responses to a Positive Labor Supply Shock of 1 SD, Pre-GFC Subsample (1999Q1–2007Q2, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

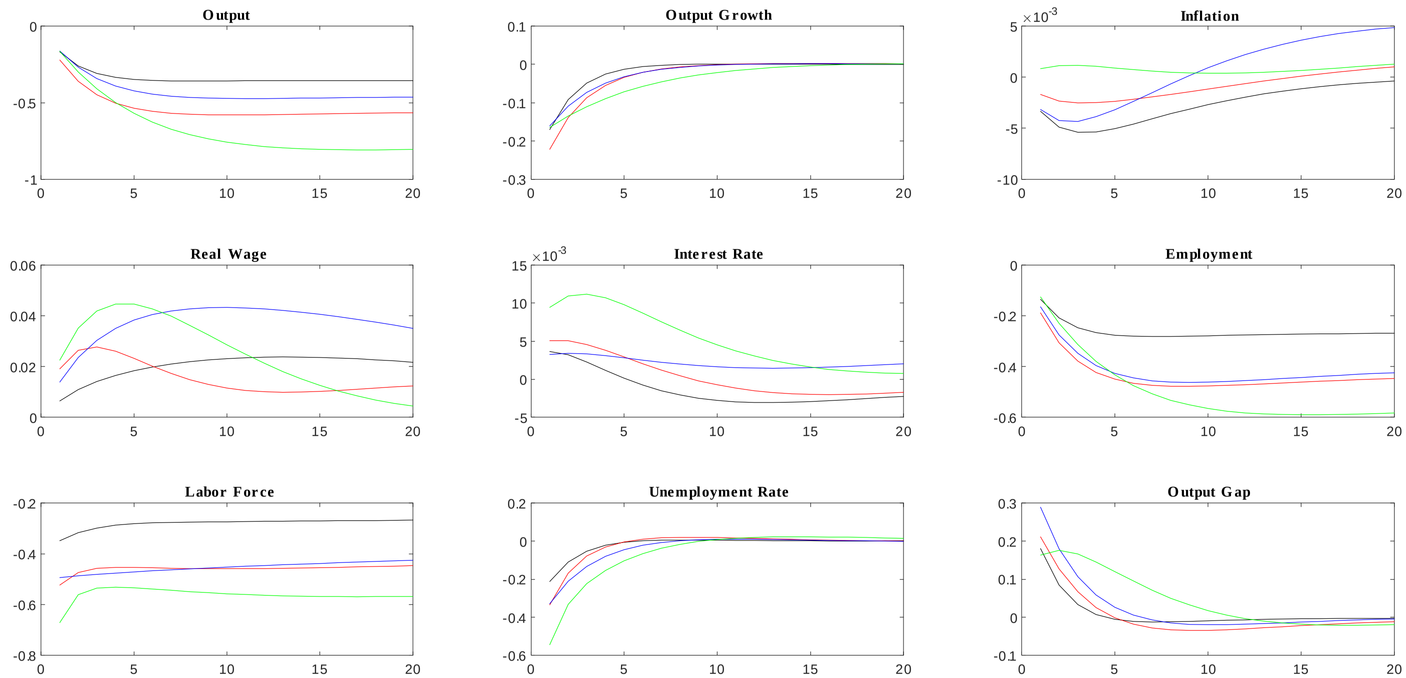

Figure 17: Dynamic Responses to a Positive Labor Supply Shock of 1 SD, Post-GFC Subsample (2009Q3–2017Q4, 34 observations); y-axis: quarterly % deviations from steady-state value; x-axis: number of quarters after shock (impact in quarter 1); France black; Germany red; Italy green; Spain blue

	Notation	Economic Interpretation	Prior Distribution		
No			pdf	mean	SD
Structural Parameters					
1	Ψ	elasticity of capital adjustment cost	$\mathcal{N}$	4.00	1.00
2	h	external habit	$\mathcal{B}$	0.70	0.10
3	φ	inverse Frisch elasticity of labor supply	$\mathcal{N}$	2.00	1.00
4	υ	short-term wealth effect on labor supply	$\mathcal{B}$	0.50	0.20
5	θ_p	Calvo price stickiness	$\mathcal{B}$	0.50	0.15
6	θ_w	Calvo wage stickiness	$\mathcal{B}$	0.50	0.15
7	γ_p	price indexation	$\mathcal{B}$	0.50	0.15
8	γ_w	wage indexation	$\mathcal{B}$	0.50	0.15
9	ψ	capital utilization	$\mathcal{B}$	0.50	0.15
10	$\mathcal{M}_p$	(gross) price markup	$\mathcal{N}$	1.25	0.25
11	$\mathcal{M}_w$	(gross) wage markup	$\mathcal{N}$	1.25	0.25
12	ρ_r	interest-rate smoothing	$\mathcal{N}$	0.75	0.10
13	r_π	policy feedback to inflation	$\mathcal{N}$	1.50	0.25
14	r_y	policy feedback to output gap	$\mathcal{N}$	0.12	0.05
15	$r_{\Delta y}$	policy feedback to change in output gap	$\mathcal{N}$	0.12	0.05
16	$\overline{\pi}$	steady-state inflation	Γ	0.62	0.10
17	$100\left(\beta^{-1}-1\right)$	steady-state time discount factor	Γ	0.25	0.10
18	$\bar{l}$	steady-state employment	$\mathcal{N}$	0.00	2.01
19	τ	trend growth rate	$\mathcal{N}$	0.40	0.10
20	α	contribution of capital in production f-n	$\mathcal{N}$	0.30	0.05
Persistence of the Exogeneous Shock Processes: $\rho = AR\,(1)$, $\mu = MA\,(1)$					
21	ρ_a	neutral technology (TFP)	$\mathcal{B}$	0.50	0.20
22	ρ_b	risk premium	$\mathcal{B}$	0.50	0.20
23	ρ_g	aggregate net spending	$\mathcal{B}$	0.50	0.20
24	ρ_q	investment-specific technlogy	$\mathcal{B}$	0.50	0.20
25	ρ_r	monetary policy	$\mathcal{B}$	0.50	0.20
26	ρ_p	price markup	$\mathcal{B}$	0.50	0.20
27	ρ_w	wage markup	$\mathcal{B}$	0.50	0.20
28	μ_p	price markup	$\mathcal{B}$	0.50	0.20
29	μ_w	wage markup	$\mathcal{B}$	0.50	0.20
30	ρ_{ga}	spillover of TFP shocks on net spending	$\mathcal{N}$	0.50	0.25
Standard Deviation of the Innovations to the Exogenous Shock Processes					
31	σ_a	neutral technology (TFP)	$\mathcal{U}$	2.50	1.44
32	σ_b	risk premium	$\mathcal{U}$	2.50	1.44
33	σ_g	aggregate net spending	$\mathcal{U}$	2.50	1.44
34	σ_q	investment-specific technology	$\mathcal{U}$	2.50	1.44
35	σ_r	monetary policy	$\mathcal{U}$	2.50	1.44
36	σ_p	price markup	$\mathcal{U}$	2.50	1.44
37	σ_w	wage markup	$\mathcal{U}$	2.50	1.44
38	σ_{ls}	labor supply	$\mathcal{U}$	2.50	1.44

Note: The following parameters are not identified by the estimation procedure, and are therefore calibrated as in GSW: capital depreciation $\delta = 0.025$; curvature of price aggregator $\varepsilon_p = 10$; persistence of labor supply shock $\rho_{ls} = 0.999$.

Table 1: Prior Distribution Assumed for Model Parameters

		France		Germany		Italy		Spain	
No	Notation	mean	SD	mean	SD	mean	SD	mean	SD
Structural Parameters									
1	Ψ	3.99	0.87	4.04	0.88	5.82	0.76	5.41	0.81
2	h	0.52	0.09	0.47	0.07	0.80	0.03	0.58	0.05
3	φ	3.94	0.63	2.98	0.57	2.78	0.50	4.31	0.59
4	υ	0.64	0.19	0.83	0.11	0.78	0.10	0.76	0.16
5	θ_p	0.89	0.02	0.89	0.03	0.84	0.05	0.82	0.05
6	θ_w	0.76	0.05	0.65	0.05	0.74	0.04	0.84	0.02
7	γ_p	0.47	0.13	0.43	0.14	0.26	0.10	0.36	0.16
8	γ_w	0.22	0.08	0.19	0.07	0.23	0.09	0.26	0.10
9	ψ	0.66	0.12	0.53	0.12	0.63	0.11	0.81	0.09
10	$\mathcal{M}_p$	1.52	0.10	1.42	0.10	1.44	0.10	1.13	0.08
11	$\mathcal{M}_w$	1.35	0.06	1.18	0.04	1.22	0.05	1.54	0.09
12	ρ_r	0.87	0.03	0.93	0.01	0.95	0.01	0.94	0.01
13	r_π	1.31	0.19	1.20	0.16	1.14	0.12	1.38	0.20
14	r_y	0.19	0.04	0.20	0.04	0.20	0.04	0.11	0.04
15	$r_{\Delta y}$	0.02	0.01	0.04	0.02	0.05	0.02	0.05	0.02
16	$\overline{\pi}$	0.51	0.08	0.44	0.07	0.55	0.07	0.63	0.09
17	$100\left(\beta^{-1}-1\right)$	0.20	0.08	0.25	0.10	0.27	0.10	0.21	0.08
18	$\bar{l}$	0.74	0.91	0.48	1.09	0.86	1.10	–3.12	1.30
19	τ	0.20	0.05	0.12	0.04	0.05	0.03	0.17	0.04
20	α	0.30	0.02	0.30	0.03	0.18	0.02	0.19	0.03
Persistence of the Exogeneous Shock Processes: $\rho = AR\,(1)$, $\mu = MA\,(1)$									
21	ρ_a	0.93	0.02	0.92	0.06	0.88	0.04	0.93	0.02
22	ρ_b	0.80	0.16	0.96	0.02	0.97	0.01	0.94	0.02
23	ρ_g	0.95	0.01	0.91	0.03	0.91	0.04	0.96	0.03
24	ρ_q	0.66	0.10	0.46	0.14	0.15	0.08	0.85	0.06
25	$\rho_{_r}$	0.42	0.10	0.43	0.08	0.30	0.08	0.36	0.08
26	ρ_p	0.78	0.14	0.42	0.18	0.19	0.11	0.68	0.18
27	ρ_w	0.52	0.16	0.48	0.16	0.21	0.11	0.48	0.16
28	μ_p	0.90	0.05	0.72	0.07	0.61	0.16	0.59	0.21
29	μ_w	0.45	0.18	0.54	0.19	0.60	0.12	0.45	0.15
30	ρ_{ga}	0.19	0.04	0.36	0.07	0.24	0.05	0.23	0.07
Standard Deviation of the Innovations to the Exogenous Shock Processes									
31	σ_a	0.75	0.07	0.84	0.08	0.89	0.08	0.75	0.07
32	σ_b	0.36	0.26	0.15	0.04	0.16	0.04	0.20	0.06
33	σ_g	0.21	0.02	0.47	0.04	0.41	0.04	0.43	0.04
34	σ_q	0.23	0.04	0.77	0.13	0.77	0.08	0.24	0.04
35	σ_r	0.08	0.01	0.09	0.01	0.09	0.01	0.07	0.01
36	σ_p	1.01	0.24	1.76	0.99	1.52	0.90	0.20	0.16
37	σ_w	0.58	0.29	0.45	0.18	2.57	1.03	3.55	0.90
38	σ_{ls}	1.58	0.28	2.26	0.43	2.68	0.48	3.15	0.44
Key Characteristics of the RWMH-MCMC Bayesian Estimation									
acceptance rate: chain 1		20.0%		38.2%		31.3%		39.8%	
acceptance rate: chain 2		22.0%		39.4%		32.5%		35.7%	
log data density		–252.8		–485.7		–548.1		–501.6	

Note: 1999Q1–2017Q4 (76 observations).

Table 2: Posterior Distribution Estimates for Model Parameters - Full Sample

		France		Germany		Italy		Spain	
No	Notation	mean	SD	mean	SD	mean	SD	mean	SD
Structural Parameters									
1	Ψ	4.43	0.86	4.42	0.88	4.63	0.87	5.28	0.81
2	h	0.72	0.06	0.64	0.07	0.81	0.05	0.64	0.08
3	φ	2.96	0.63	3.42	0.74	3.19	0.70	3.52	0.75
4	υ	0.57	0.14	0.39	0.20	0.50	0.16	0.39	0.22
5	θ_p	0.93	0.02	0.86	0.04	0.46	0.12	0.81	0.06
6	θ_w	0.65	0.08	0.60	0.11	0.73	0.08	0.60	0.14
7	γ_p	0.36	0.12	0.42	0.14	0.32	0.13	0.44	0.15
8	γ_w	0.36	0.13	0.26	0.11	0.29	0.11	0.48	0.15
9	ψ	0.57	0.14	0.70	0.11	0.60	0.15	0.85	0.07
10	$\mathcal{M}_p$	1.43	0.11	1.29	0.09	1.26	0.11	1.06	0.05
11	$\mathcal{M}_w$	1.25	0.06	1.26	0.07	1.26	0.07	1.26	0.07
12	ρ_r	0.87	0.03	0.92	0.02	0.93	0.02	0.85	0.04
13	r_π	1.40	0.21	1.39	0.21	1.17	0.16	1.48	0.21
14	r_y	0.15	0.04	0.14	0.05	0.18	0.05	0.15	0.04
15	$r_{\Delta y}$	0.02	0.01	0.13	0.04	0.02	0.02	0.08	0.03
16	$\overline{\pi}$	0.53	0.04	0.55	0.08	0.59	0.08	0.66	0.09
17	$100\left(\beta^{-1}-1\right)$	0.28	0.09	0.33	0.10	0.29	0.11	0.23	0.07
18	$\bar{l}$	0.05	1.11	–0.04	1.34	–0.30	1.42	0.86	1.71
19	τ	0.24	0.04	0.23	0.05	0.15	0.05	0.03	0.02
20	α	0.25	0.04	0.26	0.03	0.19	0.04	0.29	0.02
Persistence of the Exogeneous Shock Processes: $\rho = AR\,(1)$, $\mu = MA\,(1)$									
21	ρ_a	0.89	0.08	0.67	0.09	0.68	0.11	0.58	0.10
22	ρ_b	0.48	0.15	0.54	0.15	0.73	0.16	0.48	0.18
23	ρ_g	0.91	0.04	0.89	0.05	0.60	0.12	0.68	0.09
24	ρ_q	0.66	0.12	0.44	0.14	0.32	0.14	0.21	0.16
25	$\rho_{_r}$	0.49	0.10	0.44	0.12	0.35	0.11	0.46	0.11
26	ρ_p	0.29	0.13	0.37	0.15	0.42	0.19	0.31	0.16
27	ρ_w	0.38	0.16	0.48	0.17	0.26	0.14	0.85	0.10
28	μ_p	0.52	0.17	0.68	0.12	0.53	0.18	0.61	0.15
29	μ_w	0.60	0.14	0.51	0.20	0.58	0.12	0.82	0.13
30	ρ_{ga}	0.22	0.05	0.52	0.15	0.23	0.07	0.64	0.11
Standard Deviation of the Innovations to the Exogenous Shock Processes									
31	σ_a	0.90	0.13	0.48	0.07	1.02	0.16	0.49	0.08
32	σ_b	0.89	0.38	0.95	0.30	0.80	0.56	1.24	0.61
33	σ_g	0.21	0.03	0.45	0.07	0.36	0.05	0.28	0.04
34	σ_q	0.18	0.05	0.61	0.13	0.64	0.12	0.35	0.07
35	σ_r	0.08	0.01	0.11	0.02	0.10	0.02	0.09	0.01
36	σ_p	2.11	0.99	1.09	0.81	0.06	0.07	0.11	0.07
37	σ_w	0.35	0.19	0.47	0.49	3.06	1.23	0.62	0.59
38	σ_{ls}	1.04	0.26	2.45	0.66	2.79	0.68	3.12	0.72
Key Characteristics of the RWMH-MCMC Bayesian Estimation									
acceptance rate: chain 1		34.5%		37.3%		25.5%		17.8%	
acceptance rate: chain 2		32.2%		40.4%		23.9%		19.8%	
log data density		-111.0		-211.9		-263.7		-185.9	

Note: 1999Q1–2007Q2 (34 observations).

Table 3: Posterior Distribution Estimates for Model Parameters - Pre-GFC Subsample

		France		Germany		Italy		Spain	
No	Notation	mean	SD	mean	SD	mean	SD	mean	SD
Structural Parameters									
1	Ψ	4.41	0.83	4.24	0.89	5.40	0.80	5.05	0.72
2	h	0.52	0.10	0.60	0.09	0.82	0.03	0.65	0.06
3	φ	3.78	0.74	3.22	0.75	1.85	0.51	3.61	0.56
4	υ	0.40	0.19	0.66	0.17	0.76	0.11	0.02	0.03
5	θ_p	0.75	0.10	0.87	0.05	0.84	0.05	0.81	0.07
6	θ_w	0.82	0.09	0.61	0.11	0.67	0.07	0.83	0.03
7	γ_p	0.52	0.14	0.38	0.13	0.45	0.13	0.43	0.16
8	γ_w	0.42	0.14	0.38	0.13	0.43	0.14	0.42	0.13
9	ψ	0.52	0.13	0.57	0.14	0.63	0.13	0.73	0.12
10	$\mathcal{M}_p$	1.47	0.10	1.35	0.11	1.42	0.11	1.20	0.09
11	$\mathcal{M}_w$	1.36	0.11	1.17	0.07	1.13	0.05	1.56	0.11
12	ρ_r	0.90	0.03	0.92	0.02	0.93	0.02	0.96	0.01
13	r_π	1.45	0.21	1.25	0.24	1.38	0.27	1.18	0.15
14	r_y	0.16	0.04	0.16	0.06	0.12	0.04	0.16	0.04
15	$r_{\Delta y}$	0.01	0.01	0.01	0.01	0.05	0.02	0.01	0.00
16	$\overline{\pi}$	0.51	0.09	0.51	0.09	0.45	0.08	0.60	0.10
17	$100\left(\beta^{-1}-1\right)$	0.17	0.08	0.15	0.07	0.25	0.11	0.24	0.09
18	$\bar{l}$	0.96	1.24	2.37	1.77	1.66	1.20	0.51	1.36
19	τ	0.17	0.04	0.11	0.06	0.03	0.02	0.24	0.05
20	α	0.27	0.03	0.22	0.03	0.12	0.03	0.25	0.04
Persistence of the Exogeneous Shock Processes: $\rho = AR(1)$, $\mu = MA(1)$									
21	ρ_a	0.37	0.14	0.64	0.23	0.57	0.16	0.56	0.20
22	ρ_b	0.81	0.17	0.83	0.11	0.89	0.05	0.86	0.10
23	ρ_g	0.88	0.05	0.71	0.10	0.85	0.06	0.71	0.12
24	ρ_q	0.22	0.13	0.25	0.13	0.22	0.13	0.40	0.21
25	$\rho_{_r}$	0.37	0.16	0.52	0.13	0.23	0.13	0.23	0.11
26	ρ_p	0.40	0.16	0.30	0.14	0.41	0.14	0.40	0.18
27	ρ_w	0.65	0.20	0.48	0.19	0.46	0.16	0.35	0.16
28	μ_p	0.63	0.17	0.48	0.16	0.66	0.10	0.55	0.19
29	μ_w	0.53	0.19	0.53	0.20	0.58	0.21	0.38	0.13
30	ρ_{ga}	0.21	0.06	0.16	0.07	0.12	0.06	0.20	0.11
Standard Deviation of the Innovations to the Exogenous Shock Processes									
31	σ_a	0.67	0.10	0.76	0.13	0.77	0.12	0.74	0.13
32	σ_b	0.52	0.44	0.40	0.24	0.34	0.15	0.45	0.28
33	σ_g	0.19	0.03	0.28	0.04	0.22	0.04	0.44	0.06
34	σ_q	0.31	0.05	0.76	0.13	0.80	0.14	0.49	0.12
35	σ_r	0.04	0.01	0.05	0.01	0.03	0.01	0.04	0.01
36	σ_p	0.22	0.20	0.81	0.80	0.71	0.50	0.37	0.27
37	σ_w	1.25	1.30	0.40	0.31	0.64	0.34	3.40	1.02
38	σ_{ls}	1.52	0.36	2.18	0.55	2.07	0.55	1.81	0.34
Key Characteristics of the RWMH-MCMC Bayesian Estimation									
acceptance rate: chain 1		17.7%		20.7%		25.6%		17.5%	
acceptance rate: chain 2		15.8%		28.4%		24.8%		18.6%	
log data density		-97.9		-165.8		-181.5		-227.8	

Note: 2009Q2–2017Q4 (34 observations).

Table 4: Posterior Distribution Estimates for Model Parameters - Post-GFC Subsample

Type of exogenous shock	France	Germany	Italy	Spain
horizon = 1 quarter ("short run"), contribution in %				
Demand shocks				
risk premium	42.6	31.6	31.3	47.7
aggregate net spending	1.9	7.5	4.4	7.2
investment-specific technology	2.9	14.1	2.5	1.3
monetary policy	8.1	22.1	11.9	15.5
Supply shocks				
neutral technology (TFP)	37.2	14.4	27.7	18.8
price markup	1.5	1.4	0.1	0.2
Labor market shocks				
wage markup	1.0	1.5	5.4	1.0
labor supply	4.8	7.3	16.9	8.4
horizon = 10 quarters ("medium run"), contribution in %				
Demand shocks				
risk premium	54.1	45.2	61.8	60.5
aggregate net spending	0.7	2.2	1.4	1.6
investment-specific technology	6.0	10.7	0.9	5.6
monetary policy	18.2	34.4	23.9	21.8
Supply shocks				
neutral technology (TFP)	14.5	4.3	6.9	3.3
price markup	2.8	1.0	0.3	3.0
Labor market shocks				
wage markup	2.4	0.8	0.8	3.2
labor supply	1.4	1.5	4.0	1.1
horizon = 40 quarters ("long run"), contribution in %				
Demand shocks				
risk premium	51.7	44.8	62.6	58.3
aggregate net spending	0.7	2.1	1.3	1.4
investment-specific technology	5.8	10.6	0.8	5.8
monetary policy	17.3	34.0	23.8	21.1
Supply shocks				
neutral technology (TFP)	15.8	5.2	6.9	3.7
price markup	4.5	1.0	0.2	3.1
Labor market shocks				
wage markup	3.0	0.9	0.8	5.6
labor supply	1.3	1.4	3.7	1.0

Note: 1999Q1–2017Q4 (76 observations).

Table 5: Variance Decomposition of the Unemployment Rate - Full Sample

Type of exogenous shock	France	Germany	Italy	Spain
horizon = 1 quarter ("short run"), contribution in %				
Demand shocks				
risk premium	35.7	38.4	27.2	56.1
aggregate net spending	2.2	11.3	4.8	7.5
investment-specific technology	1.1	8.8	2.2	3.3
monetary policy	6.2	12.5	7.7	5.5
Supply shocks				
neutral technology (TFP)	49.4	10.4	37.6	4.1
price markup	0.0	0.2	0.0	0.1
Labor market shocks				
wage markup	1.1	2.9	6.2	4.2
labor supply	4.2	15.5	14.4	19.3
horizon = 10 quarters ("medium run"), contribution in %				
Demand shocks				
risk premium	35.3	30.7	43.4	47.6
aggregate net spending	1.5	4.6	1.6	3.1
investment-specific technology	3.7	8.3	1.8	2.3
monetary policy	27.7	45.2	30.5	14.7
Supply shocks				
neutral technology (TFP)	28.9	2.9	13.9	1.5
price markup	0.2	1.0	0.9	0.2
Labor market shocks				
wage markup	0.5	2.4	1.9	22.2
labor supply	2.3	4.9	6.0	8.4
horizon = 40 quarters ("long run"), contribution in %				
Demand shocks				
risk premium	34.7	30.3	43.6	46.0
aggregate net spending	1.5	4.5	1.6	3.0
investment-specific technology	3.7	8.2	1.8	2.2
monetary policy	27.5	45.6	30.5	14.2
Supply shocks				
neutral technology (TFP)	29.7	2.9	13.8	1.4
price markup	0.2	1.1	1.0	0.2
Labor market shocks				
wage markup	0.5	2.6	1.9	25.0
labor supply	2.2	4.8	5.9	8.0

Note: 1999Q1–2007Q2 (34 observations).

Table 6: Variance Decomposition of the Unemployment Rate - Pre-GFC Subsample

Type of exogenous shock	France	Germany	Italy	Spain
horizon = 1 quarter ("short run"), contribution in %				
Demand shocks				
risk premium	52.0	41.6	51.8	36.9
aggregate net spending	1.4	3.4	1.1	12.0
investment-specific technology	1.3	5.1	1.0	4.9
monetary policy	1.5	4.9	1.5	2.3
Supply shocks				
neutral technology (TFP)	39.3	36.1	26.1	34.9
price markup	0.0	0.0	0.0	0.0
Labor market shocks				
wage markup	0.8	1.0	3.2	2.4
labor supply	3.7	8.0	15.3	6.6
horizon = 10 quarters ("medium run"), contribution in %				
Demand shocks				
risk premium	76.7	64.8	81.0	74.3
aggregate net spending	0.5	1.3	0.5	2.8
investment-specific technology	0.8	3.6	0.7	2.8
monetary policy	3.9	14.3	3.1	8.3
Supply shocks				
neutral technology (TFP)	9.1	12.1	7.3	6.5
price markup	0.3	0.4	0.3	0.7
Labor market shocks				
wage markup	7.8	0.9	1.6	3.0
labor supply	1.0	2.6	5.6	1.6
horizon = 40 quarters ("long run"), contribution in %				
Demand shocks				
risk premium	73.6	65.1	81.1	72.0
aggregate net spending	0.5	1.3	0.5	2.6
investment-specific technology	0.7	3.6	0.7	2.7
monetary policy	3.8	14.3	3.1	8.2
Supply shocks				
neutral technology (TFP)	8.6	11.9	7.2	6.0
price markup	0.3	0.4	0.3	0.7
Labor market shocks				
wage markup	11.6	1.0	1.7	6.3
labor supply	1.0	2.6	5.5	1.4

Note: 2009Q2–2017Q4 (34 observations).

Table 7: Variance Decomposition of the Unemployment Rate - Post-GFC Subsample

	France	Germany	Italy	Spain
IRF-implied impact (in quarter 1) response of unemployment rate w.r.t. 1 SD of policy rate innovation, %				
full sample	0.2432	0.5017	0.4265	0.4847
pre-GFC	0.2403	0.3720	0.4113	0.2797
post-GFC	0.1354	0.2642	0.1728	0.1942
ratio pre/post GFC	1.8	1.4	2.4	1.4
Estimated 1 SD of policy rate innovation, %				
full sample	0.0648	0.0634	0.0717	0.0512
pre-GFC	0.0685	0.0502	0.0832	0.0557
post-GFC	0.0347	0.0389	0.0298	0.0332
ratio pre/post GFC	2.0	1.3	2.8	1.7
IRF-implied impact (in quarter 1) elasticity of unemployment rate w.r.t. 1 SD policy rate innovation				
full sample	3.8	7.9	6.0	9.5
pre-GFC	3.5	7.4	5.0	5.0
post-GFC	3.9	6.8	5.8	5.9
IRF-implied persistence of unemployment rate w.r.t. 1 SD policy rate innovation (until return to SS), quarters				
full sample	13	15	>20	>20
pre-GFC	13	16	17	11
post-GFC	14	15	17	10
IRF-implied maximum effect on unemployment rate of 1 SD policy rate innovation, respective quarter				
full sample	3	3	3	3
pre-GFC	3	3	3	3
post-GFC	3	3	3	4

Note: full sample: 1999Q1–2017Q4 (76 observations); pre-GFC subsample: 1999Q1–2007Q2 (34 observations); post-GFC subsample: 2009Q2–2017Q4 (34 observations).

Table 8: Impact Elasticity of the Unemployment Rate w.r.t. 1 SD Policy Rate Innovation