On Unemployment Cycles in the Euro Area, 1999–2018

By Nikolaos Charalampidis*

This paper studies the recurrent sources of unit-root unemployment fluctuations in Greece, Italy, Portugal, Spain, and the Euro Area by integrating wage markup and labor disutility shocks that exhibit permanent euro-area-wide shifts, country-specific trend developments, and stationary changes in an estimated DSGE model. In all economies, these labor market shocks account for a negligible share of unemployment cycles. Demand shocks explain about 40% of them, contribute to the pre-crisis convergence of unemployment rates, and shape the unemployment spikes during the Great Recession. Cross-country relative price distortions and supply factors account for about 40% and 20% of those cycles, respectively.
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I. Introduction

The creation of the Euro Area triggered a gradual convergence of the initially dispersed unemployment rates (in the range of 5-17% in 1999) of the southern economies to the euro-area average at a plateau of 6-8%. The turmoil of the Global Financial Crisis resulted in sizable spikes in the unemployment rates: to 12% in Italy, to 17% in Portugal, and to more than 25% in Spain and Greece in 2013. Despite these swings that generate pressures for policy reaction [Draghi, 2014][1], and studies on fiscal [Erceg and Lindé, 2011], structural [Eggertsson et al., 2014, Gourinchas et al., 2016; Albonico et al., 2017], and financial [in 't Veld et al., 2014; Kollmann et al., 2016; Albonico et al., 2019] dimensions of the Great Recession in the Euro Area and the southern periphery, as well as accumulating evidence pertaining to U.S. unemployment [Galí et al., 2012b; Canova et al., 2013; Casares et al., 2014; Furlanetto and Groshenny, 2016; Rudebusch and Williams, 2016], still little is known about the drivers of unemployment fluctuations in the southern economies from a structural macroeconomic perspective.

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[1] Gerlach and Stuart provide evidence implying that labor market conditions influence policy decisions.

Is it demand side factors calling for stabilization policies? Is it low-frequency supply side factors calling for structural reforms? Are the factors taking place in the core of the Euro Area different from those appearing in the southern economies? Are there spillover effects from the core to the periphery that affect the unemployment rate? Or, if it is a mix of all the above factors, what is the relative importance of each of them? This paper contributes by examining the determinants of the cyclical fluctuations in the unemployment rate of the Euro Area and the southern economies over the 1999-2018 period through structural lenses.

The present work addresses two factors that explain the above void. First, structural models tailored to explain business cycles in small open economies [Adolfson et al., 2005, 2007, 2008; Justiniano and Preston, 2010[2]] do not feature unemployment[3]. As a result, existing analyses of the euro-area labor markets either focus on the micro-level [European Central Bank, 2012] or are empirical at the macro level and accompanied by model simulations that are not tailored to a particular country and do not feature unemployment [Lafourcade et al., 2016]. Second, contrary to the U.S. case, the unemployment rate in the Euro Area exhibits unit root dynamics [Galí, 2015] that pose difficulties in the estimation of DSGE models.

Before building and estimating a structural model, I empirically examine the stationarity of the unemployment rate in each sample economy since neglecting to take into account a unit root – if that exists – could lead to spurious results. Similarly to the results of Galí (2015) for the Euro Area, I find that the unit root hypothesis cannot be rejected in any of the southern economies during both 1999-2018 and 1999-2008. In fact, it cannot be rejected for employment either.

I then turn to a medium-scale small open economy (SOE) DSGE model that allows to place the unemployment fluctuations in a general equilibrium framework[4]. I augment the model of Adolfson et al. (2005, 2007, 2008) with unemployment stemming from nominal wage rigidities à la Galí (2011)[5]. This approach suits the southern economies where labor markets are notoriously rigid and involve staggered wage setting. Due to the unit root in the unemployment rate, however, all shocks cannot be assumed stationary, and the measurement equations of Galí et al. (2012b) involving the level of the unemployment rate cannot be used.

Instead, the unemployment rate in first differences is matched in the estimation, and I consider wage markup and labor disutility shocks that can potentially capture unit root labor market dynamics. The former shocks encapsulate stochastic variations in workers' market power and, thereby, in labor market competitive-

[2]Justiniano and Preston (2010) is the limit of Galí and Monacelli (2005) when the size of the home economy relative to the rest of the world goes to zero as shown in De Paoli (2009).

[3]Christiano et al. (2011) is an exception that incorporates labor search in a model for Sweden.

[4]The Euro Area is viewed as a closed economy along the lines of Smets and Wouters (2003). Kollmann et al. (2016) consider it in a three-region model building on the work of Kollmann et al. (2015).

[5]Galí (2011) introduces the extensive margin of labor supply and heterogeneous labor disutility in Erceg et al. (2000). Involuntary unemployment stems from a wage markup above the competitive wage. In a similar vein, Casares (2010) studies labor supply and demand mismatches due to wage stickiness.

ness as argued in Blanchard and Giavazzi (2003), Justiniano et al. (2013), and Galí et al. (2012b). The latter shocks capture shifts in employment dynamics and the labor force. The novelty is that these shocks feature both permanent shifts captured by random walk processes and stationary shifts captured by autoregressive processes. The non-stationary shifts allow to tackle slowly-evolving trend developments in the unemployment rate and employment. To preserve the existence of a balanced growth path[6] in the southern economies, the non-stationary shifts are further decomposed in two components: (i) permanent euro-area-wide trend changes in labor market institutions and labor supply that spillover to the southern periphery; (ii) stationary, but possibly persistent, country-specific trend developments that differentiate the SOE's trend from the euro-area-wide trend.

Galí (2015) is the first to consider non-stationary wage markup shocks in a calibrated model for the Euro Area. The present paper considers such a process in an estimated model for each southern economy, along with country-specific trend developments in wage markup shocks. In addition, Galí (2015)[7] does not consider non-stationary labor disutility shocks that induce a unit root in employment. The present study, however, does so in order to study the non-stationary dynamics of the unemployment rate and of employment jointly. Chang et al. (2007) are the first among few treating non-stationary labor disutility shocks in an estimated real business cycle model. The present work's joint consideration of stationary and non-stationary shocks is influenced by Adolfson et al. (2005) where both stationary and non-stationary technology shocks are included.

It is worth mentioning that not shutting down apriori the stationary component of wage markup shocks (i) enables to study its implications against those of the non-stationary component, (ii) allows it to manifest its impact which is found to be prominent in the U.S. [Smets and Wouters, 2007][8], (iii) and could help the model match the data since Galí (2015), through model simulations, argues that non-stationary wage markup shocks generate a negative correlation between the unemployment rate and the unemployment rate gap that is at odds with the data.

In order to shed light on the empirically relevant recurrent sources of unemployment cycles in the Euro Area and the southern economies, the SOE DSGE model is estimated on a plethora of data series based on rigorous Bayesian techniques[9].

I find that euro-area-wide trend developments in labor market competitiveness

[6]Balanced growth also requires the same Frisch elasticity in the Euro Area and in the periphery.

[7]Though, he examines shocks to the inflation target as a potential source of the unit root of the unemployment rate, and shows that those shocks cannot account for that behavior.

[8]Following Galí et al. (2012b) in addressing the critique of Chari et al. (2009), I disentangle wage markup from labor disutility shocks by postulating an autoregressive structure for both, and by using the unemployment rate and multiple wage indicators based on administrative and survey data as observables. Justiniano et al. (2013) use multiple indicators too, but postulate white noise wage markup shocks.

[9]Contrary to DSGE estimations along the lines of An and Schorfheide (2006) that feature Kalman filtering, and because the model's state space is large, the present paper operationalizes the computationally efficient approach of Chan and Jeliazkov (2009) in a DSGE context as in Charalampidis (2019).

and labor supply, captured by permanent wage markup and labor disutility shocks, respectively, as well as the country-specific trend developments, are neither persistent nor volatile. In contrast, the transitory wage markup and labor disutility shocks are protracted and volatile. Although the euro-area-wide trend shifts spillover to the southern economies and permanently change the unemployment rate, employment, and output, they generate economic dynamics that are similar to those triggered by their transitory analogues. Thus, both permanent and stationary shocks in wage markups (labor disutility) generate a negative (positive) correlation between output and unemployment. Both permanent and stationary shocks of either type trigger a negative correlation of output with inflation and the real wage.

Euro-area wide and country-specific trend developments have a negligible influence on the business cycle fluctuations both of the non-stationary level and of the stationary quarterly changes of the unemployment rate in the Euro Area and the southern economies. Both types of shocks explain about 1% of these fluctuations. In other words, although permanent shocks in euro-area-wide labor market competitiveness explain the long-run developments in the level of the unemployment rate, their influence falls outside of the spectrum of business cycle frequencies.

The stationary wage markup and labor disutility shocks have a negligible influence (less than 7%) on unemployment and output cycles in all the economies too. The influence of wage markup shocks on output is consistent with the findings of Smets and Wouters (2003) and Albonico et al. (2019) for the Euro Area and of in 't Veld et al. (2014) for Spain. In contrast, Galí et al. (2012b) view the U.S. unemployment rate as stationary and find that shifts in labor market competitiveness account for 41/80% of its short-/long-run cycles. The influence of labor disutility shocks on output is compatible with the 7.9% impact found by Christiano et al. (2011) for Sweden. Altogether, the results suggest that shifts in the unemployment rate and output are driven by cyclical forces other than the labor market shocks. The southern economies are not different from the Euro Area in terms of the cyclical implications of those shocks.

What are, then, the recurrent sources of fluctuations in the unemployment rate? Demand shocks – a combination of risk premium[10], investment, debt premium, monetary policy, and export demand disturbances – account for about 42-57% of the unemployment and output fluctuations. More specifically, domestic risk premium and investment shocks account for 8-25% of unemployment fluctuations in the southern economies and for 55% of the euro-area fluctuations. Demand shocks in the Euro Area spillover to the periphery and explain 2-15% of its unemployment cycles, while export demand shocks account for 15-29% of these cycles. The influence of demand shocks on output is similar to that found by Smets and

[10]Given that the model does not feature a purely financial disturbance, risk premium and investment shocks are likely capturing the effect of such a disturbance that has been shown to be prominent during the Global Financial Crisis by Christiano et al. (2015) and Kollmann et al. (2016).

Wouters (2003) for the Euro Area (about 56%) and compatible to the prominent influence of financial factors in the Euro Area and Spain found by Kollmann et al. (2016) and in 't Veld et al. (2014), respectively. Their influence on unemployment is above that found in Galí et al. (2012b) for the U.S. (about 7-20%).

The effect of supply shocks – in productivity, the price markup, and the relative investment price – on the unemployment rate is in the range of 5-25% and, hence, similar to what Christiano et al. (2011) obtain for the Swedish economy (30%), but above what Galí et al. (2012b) find for the U.S. economy (1-4%). Furthermore, the findings reveal a sizable influence of volatile, albeit ephemeral, cross-country relative price distortions – captured by import and export price markup shocks – on unemployment fluctuations at about 25-50%. Interestingly, the forces behind employment growth are similar to those driving the unemployment rate in all the economies. The corollary of the latter is that the response of the labor force to business cycle shocks is small. Galí et al. (2012b) find similar evidence.

It is worth pointing out the degree of connectedness between the Euro Area and the southern economies: the influence of euro-area disturbances is above the 5% influence of foreign shocks often obtained in SOE models [Justiniano and Preston, 2010], while euro-area shocks and price markup shocks in imports and exports combined explain 36-51% of SOE's output cycles which is a tad above the 32% influence of all foreign shocks on Swedish output in Christiano et al. (2011).

Finally, I pin down the forces – the mix of demand, supply, and labor market disturbances – that shaped the unemployment swings since the creation of the Euro Area and up to 2018. In this way, the present study complements Ireland (2011) and Galí et al. (2012a) who examine the factors behind the trough of the U.S. Great Recession. During the pre-crisis period, the initially high unemployment rates in Greece, Italy and Spain converged to the lower plateau of the euro-area average. Favorable demand conditions shaped that convergence, and positive export price markups played a small role too. In contrast, the unemployment rate in Portugal rose from a low plateau to the euro-area average due to a combination of weak demand and positive transitory wage markup shocks.

The unemployment hump of the Global Financial Crisis in the southern economies is explained by a combination of negative euro-area productivity shocks, that spillover and raise unemployment, and adversarial demand shocks. The unemployment spike of the Sovereign Debt Crisis was predominantly explained by demand factors including high risk premia and investment costs. The subsequent unemployment decline was enabled by weak demand conditions and heterogeneous factors across countries. The former likely reflects the weak credit conditions of the post-crisis economic slump found by Kollmann et al. (2016).

Section 2 displays empirical regularities. Section 3 outlines the model. Section 4 discusses the estimation. Section 5 presents the results[11]. Section 6 concludes.

II. Empirical Regularities of the Unemployment Rate

According to the top-left panel of Fig.(1), the unemployment rates of the peripheral economies exhibit considerable differences at the beginning of the common currency era. Thereafter, they gradually converge to about 6-8%. Their convergence is followed by spikes during the Great Recession and the Sovereign Debt Crisis. After the latter, the rates steeply fall. Their overall path is mirrored in the evolution of per capita employment (bottom-left panel). Such protracted swings raise the question of a unit root, and suggest that modeling the unemployment rate as a stationary variable fluctuating around its steady state following the approach of Galí et al. (2012b) would lead to prolonged periods of undershooting (late 1990s to Great Recession) and overshooting (Great Recession to 2018).

Table (1) presents the results of a battery of unit root tests. The unit root hypothesis in the unemployment rate cannot be rejected in all the economies. When first differences are applied, the hypothesis is rejected in all economies but Greece. Greece's case is not altered even after augmenting the test equation with intercept and trend. The finding of a unit root in the 1999-2018 euro-area unemployment rate is consistent with that of Galí (2015) for the 1970-2014 period.

Table 1—Unit Root Tests, Full Sample: 1999Q1-2018Q4

UR in levels	GR	IT	PT	SP	EA
plain	29%	51%	49%	48%	46%
w/ intercept	21%	67%	35%	61%	13%
w/ intercept and trend	16%	57%	92%	87%	34%
UR in first differences					
plain	10%	0%	1%	0%	1%
w/ intercept	51%	0%	9%	1%	9%
w/ intercept and trend	81%	0%	14%	4%	26%
Employment in levels					
w/ intercept	22%	30%	40%	23%	15%

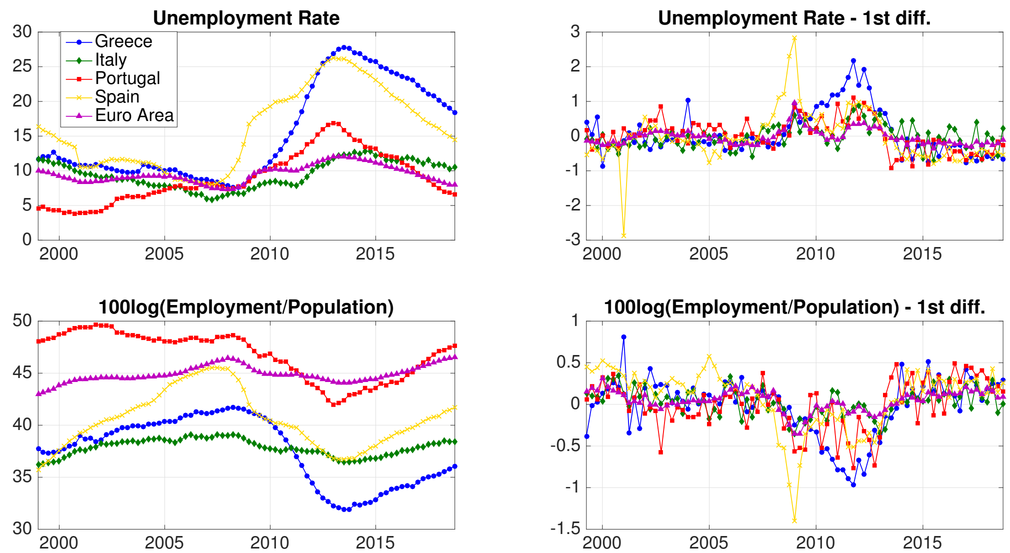
Note: One-sided p-values from augmented Dickey-Fuller tests for the unemployment rate ("UR") and p.c. log-employment. Null hypothesis: unit root. Lag selection based on the Schwarz information criterion.

The above findings, however, are influenced by the unprecedented unemployment rise triggered by the Great Recession. To remove this effect, I repeat the tests for a subsample of the data, namely 1999-2008[12] (Table 2). Interestingly, the tests

[11] The results are based on a linear solution. Downward nominal wage rigidities (DNWR) are outside of this paper's scope. However, recent studies using high-quality administrative data find no DNWR before and during the Great Recession in several Eurozone economies [Verdugo, 2016; Doris et al., 2015].

[12] The power of unit root tests, however, weakens in short samples [e.g. Cochrane, 1991].

Figure 1. Unemployment Rates and Employment, 1999-2018



Note: Unemployment Rates and Employment Per Capita (levels and first differences). *Source:* OECD.

reject the unit root hypothesis for the euro-area unemployment rate at conventional levels of statistical significance once an intercept is included. This result could imply that the euro-area rate is a stationary, albeit low frequency, process that might look non-stationary over some periods. In contrast[13], the hypothesis cannot be rejected in the cases of the southern economies. Taking first differences leads to a rejection of the hypothesis and, hence, corroborates the latter finding.

Table 2—Unit Root Tests, Before Great Recession: 1999Q1-2008Q4

UR in levels	GR	IT	PT	SP	EA
plain	5%	0%	92%	63%	81%
w/ intercept	90%	26%	89%	45%	0%
w/ intercept and trend	42%	8%	82%	100%	1%
UR in first differences					
plain	0%	5%	0%	1%	36%
w/ intercept	0%	0%	0%	75%	89%
w/ intercept and trend	0%	0%	9%	89%	42%

Note: One-sided p-values from augmented Dickey-Fuller tests for the unemployment rate (in levels and first differences). Null hypothesis: unit root. Lag selection based on the Schwarz information criterion.

[13]Few exceptions: Italy (with constant and trend) and Greece at 10% level of significance.

Altogether, the findings point to a unit root. Neglecting it could lead to spurious results for the determinants of the unemployment rate. Taking it into account, however, implies the need to work with the stationary changes of that rate depicted in Fig.(1). The figure plots employment growth as well since a thorough analysis of labor market dynamics requires the joint study of unemployment and employment, while the existence of unit root in employment has been controversial (e.g. Galí, 1999; Christiano et al., 2003). Table (1) suggests such a root.

III. Small Open Economy Model

I study the southern peripheral economies by augmenting the medium scale small open economy (SOE) DSGE model of Adolfson et al. (2005, 2007, 2008) with unemployment stemming from nominal wage rigidities along the lines of Galí (2011), non-stationary wage markup and labor disutility shocks to capture unit root dynamics in the labor market, and few twists[14]. The model is outlined below.

Households choose consumption, investment, domestic and foreign bonds. Their members supply labor along the extensive margin and derive heterogeneous labor disutility. Monopolistically competitive labor agencies set wages in a staggered fashion. Packers bundle the differentiated labor and sell it to monopolistically competitive firms. The latter combine labor and capital to produce intermediate goods. Those goods are aggregated to a final good allocated to domestic as well as to exported consumption and investment. Nominal rigidities and staggered price setting determine exports. Monopolistically competitive importers of consumption and investment goods differentiate the foreign good, and set prices in a staggered way. The external sector (Euro Area) is modeled as in Galí et al. (2012b) and includes random walk wage markup and labor disutility shocks.

A. Households and the Labor Market

A continuum of identical households populates the economy. The household is a large family of members uniformly situated in the unit square indexed by $(i, j) \in [0, 1] \times [0, 1]$. The members differ in terms of their labor type ("i") and disutility of work ("j"). The latter is given by j^{χ} if the individual is employed and by zero otherwise. χ governs the curvature of labor disutility. Labor is indivisible. The individual felicity is: $log(C_t(i, j) - \eta C_{t-1}) - \mathbf{1}\Omega_t X_t^{1+\chi} j^{\chi}$. η reflects external habit formation. The indicator $\mathbf{1}$ equals to unity for employed members.

$X_t \equiv \overline{X}_t \widetilde{X}_t$ is the labor disutility shock composed of two parts: the stylized stationary part $(\overline{X}_t)$ capturing recurrent fluctuations in labor supply, and the

[14]First, I match the unemployment rate and multiple wage measures in the estimation to strengthen identification. Second, I explicitly model the foreign economy and estimate it over nine series instead of using a three-variable VAR. Third, I include shocks in the transformation of output to investment and in export demands to proxy for financial and global conditions, respectively, but not in the inflation target.

unit-root part ($\widetilde{X}_t$) capturing non-stationary shifts in labor supply. $\overline{X}_t$ follows an autoregressive process of degree one with slope coefficient $\rho_{\overline{x}}$ and standard deviation $\sigma_{\overline{x}}$, denoted as $AR(1;\rho_{\overline{\chi}},\sigma_{\overline{\chi}})$ hereafter. As explained later, for a balanced growth path to exist, a SOE and the Euro Area need to grow with the same rate in the long run. $\widetilde{X}_t$ is, therefore, defined as $\widetilde{X}^*_t\epsilon^{\chi}_t$, where $\widetilde{X}^*_t$ stands for the euro-area-wide random walk process for labor disutility shocks, to wit:

$$ln\widetilde{X}^*_t = \gamma^*_x + ln\widetilde{X}^*_{t-1} + \epsilon^{\chi,*}_t \tag{1}$$

ϵ^{χ}_t captures country-specific trend features of employment and allows for temporary deviations between the trends in the Euro Area and the SOE. $\epsilon^{\chi,*}_t$ captures ephemeral trend changes in the whole Euro Area,. $ln\epsilon^{\chi}_t$ and $\epsilon^{\chi,*}_t$ evolve according to an $AR(1;\rho_{\chi},\sigma_{\chi})$ process each. Postulating perfect insurance ($C_t(i,j) = C_t$) and a common discount factor (β), and aggregating the felicity functions across household members leads to inter-temporal preferences:

$$E_0\sum_{t=0}^{\infty}\beta^t\left[log\big(C_t-\eta C_{t-1}\big) - \ \Omega_t X_t^{1+\chi}\int_0^1 \frac{{N_{it}}^{1+\chi}}{(1+\chi)}di\right] \tag{2}$$

N_{it} denotes the period-t employment rate among workers of type "i". χ is interpreted as a Frisch elasticity along the extensive margin. Ω_t is an endogenous shifter parameterizing the strength of wealth effects on labor supply, and helping the model match the response of labor force to monetary policy shocks [Galí et al. 2012b, 2012a]. It preserves additive separability in preferences while reconciling balanced growth with an arbitrarily small wealth effect. It is defined as

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

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

The household chooses consumption (C_t) at price P_t, investment (I_t) at price P^I_t, and one-period domestic (B_t) and euro-area (D_t) bonds denominated in the same currency and yielding gross interest rates R_t and R^*_t, respectively. Trading on D_t is subject to a debt elastic premium that guarantees stationarity in the external debt position [Schmitt-Grohé and Uribe, 2003; Kollmann, 2004; Benigno, 2009] and constitutes a reduced-form representation of financial intermediation costs. The premium depends on the (stationary) real debt-to-income ratio (d_t), and is given by $\Xi_t \equiv exp(-\xi d_t + \upsilon^{\xi}_t)$, where ξ is the debt premium elasticity and υ^{ξ}_t is an AR(1; ρ_{ξ},σ_{ξ}) debt premium shock. The flow budget constraint reads as

$$\begin{aligned} P_tC_t + P^I_tI_t + B_t + D_t &= B_{t-1}R_{t-1}\upsilon^d_{t-1} + D_{t-1}R^*_{t-1}\Xi_{t-1}\upsilon^d_{t-1} + \textstyle\int W_{it}N_{it}di \\ &+R^k_t(P^I_t/P_t)K^s_t - P_t a(\Psi_t)(P^I_t/P_t)K_{t-1} + \Pi_{H,t} + \Pi_{M,t} + \Pi^I_{M,t} + \Pi_{X,t} - T_t \end{aligned} \tag{4}$$

υ_t^d is a domestic AR(1; ρ_d, σ_d) risk premium shock. By affecting both R_t and R_t^*, this shock does not enter in the uncovered interest rate parity condition ($R_t = R_t^* \Xi_t$) and, thus, it is not convoluted with υ_t^ξ. T_t stands for taxes. $\{\Pi_{H,t}, \Pi_{M,t}, \Pi_{M,t}^I, \Pi_{X,t}\}$ denote profits for intermediate good producers, consumption and investment importers, and exporters. R_t^k is the nominal rental rate of effective capital, K_t^s. The latter is determined by the utilization rate Ψ_t of raw capital (K_t): $K_t^s = \Psi_t K_{t-1}$. Raw capital evolves according to $K_t = (1-\delta)K_{t-1} + e^{\upsilon_t^i}[1 - S(I_t/I_{t-1})]I_t$. υ_t^i is an AR(1; ρ_i, σ_i) investment shock. δ mirrors capital depreciation. $S(I_t/I_{t-1})$ stands for adjustment costs as in Smets and Wouters (2007). $a(\Psi_t)K_{t-1}$ are utilization costs in units of the capital good.

Household members participate in the labor market[15] when the wage exceeds their labor disutility expressed in terms of the consumption good:

$$W_{it}/P_t \geq \Omega_t X_t^{1+\chi} j^\chi (C_t - \eta C_{t-1}) \tag{5}$$

Eq.(5) in equilibrium becomes $W_{it}/P_t = \Omega_t X_t^{1+\chi} L_{it}^\chi (C_t - \eta C_{t-1})$ where L_{it} denotes the marginal worker who is indifferent between participating in and staying out of the market. Hence, L_{it} denotes the mass of workers participating in the market.

Type "i" workers form a monopolistically competitive coalition, and set wages with probability $1 - \theta_w$ when seeking to maximize household utility (2) subject to a downward-slopping labor demand curve, $N_{it} = (W_{it}/W_t)^{-\epsilon_{w,t}} N_t$, emanating from the aggregation of a perfectly competitive labor packer: $N_t = [\int N_{it}^{(\epsilon_{w,t}-1)/\epsilon_{w,t}} di]^{\epsilon_{w,t}/(\epsilon_{w,t}-1)}$. The wage index is $W_t = (\int W_{it}^{1-\epsilon_{w,t}} di)^{1/(1-\epsilon_{w,t})}$. In periods in which wages are not reset, they are partially indexed to inflation based on the parameter γ_w: for a wage lastly reset in t at W_{it}°, the period-T wage is given by $W_{iT|t} = W_{it}^\circ (P_{T-1}/P_{t-1})^{\gamma_w} (\widetilde{A}_T/\widetilde{A}_t)$. The last term accounts for productivity growth explained below. $\epsilon_{w,t}$ is the time-varying elasticity of substitution across labor types, and the source of wage markup shocks: $\Upsilon_t \equiv \epsilon_{w,t}/(\epsilon_{w,t} - 1)$.

Such shocks encapsulate variations in workers' market power and, thereby, in labor market competitiveness. As in the case of labor disutility shocks, the wage markup is defined as $\Upsilon_t \equiv \overline{\Upsilon}_t \widetilde{\Upsilon}_t$. $\overline{\Upsilon}_t$ is a stylized recurrent $AR(1; \rho_{\overline{w}}, \sigma_{\overline{w}})$ disturbance. To capture the unit root behavior of the unemployment rate, I postulate that $\widetilde{\Upsilon}_t \equiv \widetilde{\Upsilon}_t^* \epsilon_t^w$, where $ln\widetilde{\Upsilon}_t^*$ is the non-stationary euro-area-wide component:

$$ln\widetilde{\Upsilon}_t^* = \gamma_w^* + ln\widetilde{\Upsilon}_{t-1}^* + \epsilon_t^{w,*} \tag{6}$$

$ln\epsilon_t^w$ and $\epsilon_t^{w,*}$ capture country-specific and euro-area-wide trend changes, respectively. They follow an $AR(1; \rho_w, \sigma_w)$ process each.

The equilibrium wage exceeds the wage in the absence of nominal rigidities and,

[15] As is often assumed in open economy models, emigrants are a negligible fraction of the labor force.

thereby, the marginal labor disutility in (5). As a result, equilibrium labor supply exceeds employment, $L_{it} > N_{it}$, and causes unemployment.

B. Domestic Production

A perfectly competitive packer aggregates domestic intermediate goods to a final good according to: $Y_{H,t} = (\int Y_{H,t}(j)^{(\zeta_{h,t}-1)/\zeta_{h,t}} dj)^{\zeta_{h,t}/(\zeta_{h,t}-1)}$. $\zeta_{h,t}$ is the elasticity of substitution. The good's price is $P_{H,t} = (\int P_{H,t}(j)^{(1-\zeta_{h,t})} dj)^{1/(1-\zeta_{h,t})}$, where $\Upsilon_t^h \equiv \zeta_{h,t}/(\zeta_{h,t}-1)$ is the $AR(1;\rho_h,\sigma_h)$ price markup shock.

Monopolistically competitive intermediate good producers are indexed by $i \in [0,1]$. Each of them hires $N_t(i)$ units of labor at the wage W_t and $K_t^s(i)$ units of effective capital at the rental rate R_t^k to produce $Y_{H,t}(i)$ according to:

$$Y_{H,t}(i) = \overline{A}_t(K_t^s(i))^\alpha(\widetilde{A}_t N_t(i))^{1-\alpha} \tag{7}$$

$ln\overline{A}_t$ is a stationary $AR(1;\rho_{\overline{a}},\sigma_{\overline{a}})$ technology process, while $\widetilde{A}_t \equiv \widetilde{A}_t^* \epsilon_t^a$. $\widetilde{A}_t^*$ is the euro-area-wide permanent labor productivity shock following a random walk:

$$ln\widetilde{A}_t^* = \gamma_a^* + ln\widetilde{A}_{t-1}^* + \epsilon_t^{a,*} \tag{8}$$

$\epsilon_t^{a,*}$ and ϵ_t^a are the euro-area and country-specific components, respectively, following $AR(1;\rho_a^*,\sigma_a^*)$ and $AR(1;\rho_a,\sigma_a)$ processes.

Profits read as $\Pi_{H,t} = P_{H,t}(i)Y_{H,t}(i) - W_t N_t(i) - R_t^k K_t^s(P_t^I/P_t)$. Cost minimization yields the capital-to-labor ratio: $K_t^s(i)/N_t(i) = (\alpha/(1-\alpha))(W_t/R_t^k(P_t^I/P_t))$, and marginal cost: $MC_{H,t} = (1-\alpha)^{-(1-\alpha)}\alpha^{-\alpha}(R_t^k P_t^I/P_t)^\alpha (W_t/\widetilde{A}_t)^{1-\alpha}/\overline{A_t}$.

Each firm chooses price $P_t^\circ(i)$ with probability $1-\theta_h$ to maximize the present value of profits, $E_t \sum_{T=t}^\infty (\beta\theta_h)^{T-t}\Lambda_{t,T}\Pi_{H,T|t}$, subject to a downward-slopping demand. In periods in which the price is not updated, it is partially indexed to one-period lagged inflation. Thus, the period-T price of firm "i" that has not reset prices since period t is: $P_{H,T|t}(i) = P_{H,t}^\circ(i)\,(P_{H,T-1}/P_{H,t-1})^{\gamma_h}$, where γ_h governs the strength of indexation. $\Lambda_{t,T}$ stands for the ratio of period-T to period-t marginal utility of consumption. Inflation is determined by the resulting Phillips curve.

C. Consumption and Investment Imports

The consumption basket consists of domestic ($C_{H,t}$) and imported ($C_{M,t}$) goods:

$$C_t = \left[(1-\tau)^{\frac{1}{\nu}} C_{H,t}{}^{\frac{\nu-1}{\nu}} + \tau^{\frac{1}{\nu}} C_{M,t}{}^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}} \tag{9}$$

Its price is: $P_t = [(1-\tau)P_{H,t}^{1-\nu} + \tau P_{M,t}^{1-\nu}]^{1/(1-\nu)}$. τ is the share of foreign goods. ν is the consumption trade elasticity. The CES aggregator of imported goods is:

$C_{M,t} = (\int C_{M,t}(j)^{(\zeta^c_{m,t}-1)/\zeta^c_{m,t}} dj)^{\zeta^c_{m,t}/(\zeta^c_{m,t}-1)}$, with $\zeta^c_{m,t}$ denoting the substitution elasticity, and $\zeta^c_{m,t}/(\zeta^c_{m,t}-1)$ the $AR(1;\rho^c_m,\sigma^c_m)$ import price markup shock.

The investment basket below (10) consists of domestic ($I_{H,t}$) and imported ($I_{M,t}$) investment goods. $I_{H,t}$ units of the final domestic good are transformed to $\Phi_t I_{H,t}$ units of domestic investment. $ln\Phi_t$ captures deviations in the relative price of the two goods, and follows an $AR(1;\rho_\phi,\sigma_\phi)$ scheme.

$$I_t = \left[(1-\lambda)^{\frac{1}{\zeta}}(I_{H,t}\Phi_t)^{\frac{\zeta-1}{\zeta}} + \lambda^{\frac{1}{\zeta}} I_{M,t}{}^{\frac{\zeta-1}{\zeta}}\right]^{\frac{\zeta}{\zeta-1}} \tag{10}$$

The basket price is $P^I_t = [(1-\lambda)(P_{H,t}/\Phi_t)^{1-\zeta} + \lambda P^I_{M,t}{}^{1-\zeta}]^{1/(1-\zeta)}$. λ is the share of foreign goods. ζ is the investment trade elasticity. The imported good is defined as: $I_{M,t} = (\int I_{M,t}(j)^{(\zeta^i_{m,t}-1)/\zeta^i_{m,t}} dj)^{\zeta^i_{m,t}/(\zeta^i_{m,t}-1)}$. $\zeta^i_{m,t}$ denotes the substitution elasticity, and $\zeta^i_{m,t}/(\zeta^i_{m,t}-1)$ an $AR(1;\rho^i_m,\sigma^i_m)$ import price markup shock.

The price pass-through is imperfect as in Monacelli (2005). Monopolistically competitive importers purchase the foreign good at price P^*_t, differentiate it based on a brand naming technology, and sell it domestically by setting prices in a staggered fashion subject to downward slopping demand curves. The marginal costs of consumption and investment importers are given by $MC^c_{M,t} = (1-\iota^c_M)P^*_t$ and $MC^i_{M,t} = (1-\iota^i_M)P^*_t$, respectively. Price stickiness and indexation in the two markets are captured by θ^c_m, θ^i_m and γ^c_M, γ^i_M, respectively. Inflation rates are pinned down by the two resulting Phillips curves featuring the above mentioned import price markup shocks. Subsidies ι^c_M, ι^i_M ensure zero steady state profits.

Monopolistically competitive exporters buy the domestic good at $P_{H,t}$, differentiate it, and sell it to euro-area markets for consumption and investment purposes by setting prices à la Calvo. Each j variety faces a downward-slopping demand given by $X_t(j) = (P^x_t(j)/P^x_t)^{-\zeta_{x,t}} X_t$, where $P^x_t(i)$ is the export price, $\zeta_{x,t}/(\zeta_{x,t}-1)$ is an $AR(1;\rho_x,\sigma_x)$ export price markup shock, and X_t is total exports. A Phillips Curve for P^x_t is obtained. θ_x denotes the degree of price stickiness, and γ_x the degree of price indexation. Per unit subsidy ι_X ensures zero steady state profits.

Following the literature, the demands for consumption and investment exports are $C^*_{H,t} = (P^x_t/P^*_t)^{-f} C^*_t$ and $I^*_{H,t} = (P^x_t/P^*_t)^{-f} I^*_t$, respectively. f is the elasticity of substitution. To these demands, I attach a multiplicative $AR(1;\rho_o,\sigma_o)$ shock O_t. This shock shifts the demand for SOE's exports, and generates a simultaneous decline in output and the trade balance. It helps match the data since the downward slopping export demands have troubles matching the simultaneous decrease in the price and quantity of exports observed during the Global Financial Crisis[16].

[16] To illustrate this point, in 2009Q1 the inflation differential between Spanish export prices and euro-area prices was -2.9%. The combined decrease in euro-area consumption and investment ($C^*_t + I^*_t$) was about -2.7%. Combining these figures with a conventional value of 1.5 for f would imply that Spanish exports rose by 1.7%. The latter is at odds with the observed decline of Spanish exports by 7.1%, and

O_t can be viewed as a stand-in shock for factors left outside of the model such as global economic conditions, financial distress, and international competitiveness.

D. Government and Market Clearing

The government levies lump sump taxes, subsidizes importers of consumption and investment goods as well as exporters, and spends G_t while keeping a balanced budget: $T_t = \iota^c_M P^*_t \int C_{M,t}(j)dj + \iota^i_M P^*_t \int I_{M,t}(j)dj + \iota_X P_{H,t} \int X_t(j)dj + P_{H,t}G_t$. G_t, after rendered stationary, follows an $AR(1;\rho_g,\sigma_g)$ process.

In equilibrium, domestic production equals the sum of domestic consumption and investment, exported consumption and investment, and government spending:

$$Y_{H,t} = C_{H,t} + I_{H,t} + C^*_{H,t} + I^*_{H,t} + G_t \tag{11}$$

Combining profits, the household budget constraint, and the economy's resource constraint (11) yields the evolution of external debt that depends on past debt, the trade balance (TB_t) shown in the Appendix, and capital adjustment costs:

$$D_t = D_{t-1}R^*_{t-1}\Xi_{t-1}\upsilon^d_{t-1} + TB_t - P^I_t a(\Psi_t)K_{t-1} \tag{12}$$

E. International Prices, the Euro Area, and Channels of Transmission

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

The equations for the euro-area block are obtained by imposing zero trade shares (τ,λ) in the consumption (9) and investment (10) aggregators, and by adding an interest rate rule: $R^*_t/R^* = (R^*_{t-1}/R^*)^{\rho_r}[\Pi_t^{\psi_\pi}(Y^*_t/Y^*_{t-1})^{\psi_y}]^{1-\rho_r}\upsilon^{mp}_t$ that involves euro-area inflation, Π^*_t, output, Y^*_t, and the white noise disturbance $ln(\upsilon^{mp}_t)$[17].

It is worth summarizing the four channels of international spillovers: (i) variations in euro-area lending conditions influence SOE's external debt (12) and, thereby, SOE's domestic conditions; (ii) euro-area conditions pin down the demand for exports which, in turn, affect domestic production (11) and the trade balance in (12); (iii) shifts in import price markups affect the relative prices, consumption and investment imports and thus the trade balance in (12), as well as the consumption and investment bundles (9, 10); (iv) shocks in the euro-area productivity, wage markup and labor disutility trends alter SOE's trend dynamics.

induces counterfactual dynamics in (11) and (12). Similar examples hold for the other sample economies. For that reason, I also allow for price inelastic exports ($f \in (0,+\infty)$) which differs from Adolfson et al. (2005, 2007, 2008) and Christiano et al. (2011) who assume that f's distribution is truncated at 1.

[17]The rule does not account for the zero lower bound which starts binding from 2014Q4 and, thus, affects only a small part of the sample since the euro-area short-term rate became negative after 2015Q2. Kollmann et al. (2016) omit applying the ZLB in their estimated model too.

F. Stationary Equilibrium and Stochastic Structure

With random walk shocks, variable transformations are required to render the model stationary. Long-run growth in the Euro Area is given by: $\gamma_y^* = \gamma_a^* - \gamma_x^* - \gamma_w^*/(1+\chi^*)$. For a balanced growth path to exist, long-run growth in the Euro Area and the SOE need to be the same. Thus, the model imposes a parameter restriction: $\chi = \chi^*$, that is, the inverse Frisch elasticity in the SOE and the Euro Area need to be the same. Then, stationary outputs in the SOE and the Euro Area are defined as Y_t/V_t and Y_t^*/V_t^*, respectively, where the associated trends are given by $V_t \equiv \widetilde{A}_t/[\widetilde{X}_t\widetilde{\Upsilon}_t^{1/(1+\chi)}]$ and $V_t^* \equiv A_t^*/[X_t^*\Upsilon_t^{*1/(1+\chi)}]$.

More specifically, productivity induces non-stationarity in real aggregates (output, consumption, investment, government spending) and wages. The labor disutility shock introduces unit root changes in real aggregates, employment, and labor supply; all are scaled up by $\widetilde{X}_t$. This shock, though, does not render the unemployment rate non-stationary since changes in employment and labor supply cancel each other out. The wage markup shock introduces non-stationarity in the unemployment rate (needs to be scaled down by $\widetilde{\Upsilon}_t^{1/\chi}$), the marginal disutility of work in consumption terms (scaled up by $\widetilde{\Upsilon}_t$), in real aggregates and employment (scaled up by $\widetilde{\Upsilon}_t^{1/(1+\chi)}$), and in labor supply (scaled down by $\widetilde{\Upsilon}_t^{1/(\chi(1+\chi))}$). The derivation of the required scaling associated with $\widetilde{A}_t$ and $\widetilde{X}_t$ is straightforward, whereas that associated with $\widetilde{\Upsilon}_t$ is relegated to the Appendix.

After rendered stationary, the model is log-linearized around the steady state. Following Galí (2011), the unemployment rate reads as: $\widehat{u}_t = \widehat{l}_t - \widehat{n}_t$, where $\widehat{l}_t$ and $\widehat{n}_t$ stand for labor supply and employment log-deviations from steady state.

The SOE model features twenty seven sources of business cycles. Shocks in the risk premium, investment, government spending, the price markup, the transitory as well as the trend component of technology, the wage markup, and labor disutility appear in both the SOE and the Euro Area. The SOE features additional shocks in the consumption and investment import price markups, the export price markup, the debt premium, the relative price of investment, and the demand for exports. A monetary policy disturbance appears in the Euro Area.

IV. Estimation

A. Observables

I conduct Bayesian estimation for the period 1999Q1-2018Q4. The inclusion of the Great Recession and of the years after it in the sample is motivated by the fact that the 2009Q1-2018Q4 period constitutes about half of Eurozone's history.

Twenty three series are used in each estimation run. Eight series appear in both the Euro Area and each peripheral economy: real per capita (p.c.) growth in (i) GDP (Y_t^o), (ii) private consumption (C_t^o), (iii) gross fixed capital formation (I_t^o), and (iv) wages and salaries ($W_t^{w,o}$); (v) the unemployment rate (UR_t^o) in first differences; (vi) p.c. employment (N_t^o) growth; (vii) CPI inflation ($\Pi_t^{cpi,o}$); and (viii) real growth in hourly private earnings ($W_t^{e,o}$)[18]. In addition, for each southern economy, (i) real p.c. growth in government spending (G_t^o), and the inflation rates of the deflators of (ii) exports ($\Pi_t^{x,o}$), (iii) imports ($\Pi_t^{im,o}$), (iv) investment ($\Pi_t^{i,o}$), and (v) GDP ($\Pi_t^{h,o}$). For borrowing costs (R_t^o), I match the three-month money market rate in the Euro Area and short-term sovereign debt yields in the periphery[19]. The data are obtained from the OECD, ECB, and IMF.

B. *Trends, Cycles, and Observation Equations*

As a result of the random walks, the measurement equations for SOE's output (Y_t^o), employment (N_t^o), and the unemployment rate (UR_t^o) read as:

$$(13)\quad \Delta lnY_t^o = \gamma_y^* + (\epsilon_t^{a,*} + \Delta\epsilon_t^a) - (\epsilon_t^{\chi,*} + \Delta\epsilon_t^{\chi}) - (\epsilon_t^{w,*} + \Delta\epsilon_t^w)/(1+\chi) + \Delta\widehat{y}_t$$

$$(14)\quad \Delta lnN_t^o = -\gamma_x^* - \gamma_w^*/(1+\chi) - (\epsilon_t^{\chi,*} + \Delta\epsilon_t^{\chi}) - (\epsilon_t^{w,*} + \Delta\epsilon_t^w)/(1+\chi) + \Delta\widehat{n}_t$$

$$(15)\quad \Delta UR_t^o = \gamma_w^* + (\epsilon_t^{w,*} + \Delta\epsilon_t^w)/\chi + \Delta\widehat{u}_t$$

$\{\epsilon_t^{a,*}, \epsilon_t^{x,*}, \epsilon_t^{w,*}\}$ are identified at the euro-area level, whereas the country-specific components $\{\epsilon_t^a, \epsilon_t^x, \epsilon_t^w\}$ are identified from the data of each southern economy. The construction of all observation equations is displayed in the Appendix.

Furthermore, instead of only considering the same three trends ($\gamma_a^*, \gamma_x^*, \gamma_w^*$) for all SOEs, I opt into an empirically oriented approach and allow for different deterministic trends across variables. This is motivated by the short sample size and Table (3) showing different means across variables – like output, consumption, investment, etc – that should grow at the same rate along the balanced growth path, and across inflation rates. Christiano et al. (2011) adopt this approach too. I remove all trends prior to estimation because, first, sampling heterogeneous trends would raise considerably the dimension of the already large parameter space and, second, deterministic trends would be identified as the sample averages.

It is worth mentioning that the multiple wage measures are incorporated through a factor specification building on Boivin and Giannoni (2006) who first introduce it in a DSGE model, and on Justiniano et al. (2013), Galí et al. (2012a, 2012a)

[18]Wages and salaries equal compensation minus social and pension contributions obtained from national accounts. The survey-based private earnings index is not available for Greece. I approximate it by dividing total compensation by total hours of work. Real variables are defined over their respective deflator. Consumption, wages, and survey-based earnings are defined over the CPI.

[19]Those are obtained from IMF. They are constructed as the weighted averages of the rates on sovereign bonds with maturities ranging from three to twenty four months. Although, the frequency of the model is quarterly, using those rates helps approximate the financial conditions in the southern economies.

Table 3—Descriptive Statistics

$\Delta ln[Y_t^o$		C_t^o	I_t^o	G_t^o	$W_t^{w,o}$	$W_t^{e,o}]$	$\Pi_t^{x,o}$	$\Pi_t^{im,o}$	$\Pi_t^{cpi,o}$	$\Pi_t^{h,o}$	$\Pi_t^{i,o}$	$\Delta[UR_t^o$	$lnN_t^o]$	R_t^o
GR	.09	-.02	-.80	.10	.05	.04	.44	.44	.49	.37	.07	.09	-.05	.56
IT	.04	.04	-.04	.05	.15	.11	.34	.45	.44	.42	.41	-.02	.08	.50
PT	.19	.28	-.31	.17	.14	-.01	.29	.24	.48	.52	.41	.02	-.01	.82
SP	.29	.18	.17	.47	.20	.11	.40	.46	.53	.48	.44	-.02	.19	.52
EA	.27	.15	.24		.23	.17				.38		-.03	.10	.46

Note: Sample averages. For variable definitions see text. *Sources:* OECD, ECB, IMF.

and Lindé et al. (2016) who use multiple wage indicators in order to strengthen the identification of wage markup shocks. The loading of wages and salaries is unity, while that of earnings is Ψ_e. Each wage series enters with a white noise measurement error $\{\mu_t^w, \mu_t^e\}$ with standard deviation denoted by $\{\mu^w, \mu^e\}$.

C. State Space

The rational expectations solution of the DSGE model is casted in state space form and estimated with state-of-the-art Bayesian methods. Since the model's state space is large, the present paper operationalizes the approach of Chan and Jeliazkov (2009) in a DSGE context along the lines of Charalampidis (2019). The approach provides an alternative to Kalman filtering [Durbin and Koopman, 2001] and is suited for large state spaces since it helps achieve computational gains by exploiting the insights of Fahrmeir and Kaufmann (1991) on the nature of sparse and block-banded precision matrices. Details are relegated to the Appendix.

D. Priors

A conventional prior is considered and reported in Table (4). Few non-identified parameters are calibrated as it is often done in the literature. The capital share α is set to 30%, the depreciation rate to 2.5%, and the discount factor to 0.998. The steady state real per capita government-to-output ratio is based on the sample average (0.20 for GR and the EA, 0.19 for IT and PT, 0.18 for SP). Similarly, the shares of imported consumption and investment in their respective baskets are assumed to be the same and fixed at the sample average of the imports-to-GDP-ratio over the sum of the consumption-to-GDP-ratio and investment-to-GDP-ratio[20]. Thus, τ is 0.37 for GR, 0.32 for IT, 0.45 for PT, 0.36 for SP.

I partition the parameters into two sets: one for those that pertain to the Euro Area and another one for those that pertain to the SOE. I estimate the former in a separate run. I then fix it at its posterior mean in the SOE runs to guarantee that it stays unchanged since there is no feedback from the SOE to the Euro Area. The priors for parameters appearing in both blocks are rather the same.

[20]The rationale for this choice is that the observed imports-to-GDP ratio, $(C_M + I_M)/Y$, equals to $\tau(C/Y) + \lambda(I/Y)$ in the model. For $\tau = \lambda$, the latter yields $\tau = [(C_M + I_M)/Y]/[(C/Y) + (I/Y)]$.

Moreover, the disturbances in the random walks are assumed to be less persistent (0.5 vs 0.85) and volatile (0.15 vs 0.4) than their stationary analogues, whose priors follow Adolfson et al. (2005) and Christiano et al. (2011), since the former shocks already include a unit root. The prior volatility of stationary supply side shocks is assumed a tad higher (0.5 vs 0.15) than that of demand side shocks[21].

Table 4—Prior Distributions

parameter		mean	std	dist.	parameter		mean	std	dist.
Labor Market					export indexation	γ_x	0.5	0.15	B
wealth effect	ω	0.2	0.1	B	AR export demand	ρ_o	0.5	0.2	B
inverse Frisch elasticity	χ	2	1	N	std export demand	σ_o	0.15	1	IG
wage stickiness	θ_w	0.75	0.075	B	consumption elasticity	ν	1.5	0.5	G
wage indexation	γ_w	0.5	0.15	B	investment elasticity	ζ	1.5	0.5	G
steady state wage mkp	Υ	0.15	0.03	B^{*1}	foreign good elasticity	f	1.5	0.5	G
unit root, AR wage mkp	ρ_w	0.5	0.2	B	**Domestic Dimension**				
unit root, std wage mkp	σ_w	0.15	1	IG	habit	η	0.7	0.1	B
stationary,AR wage mkp	$\rho_{\overline{w}}$	0.85	0.1	B	inv. adj. cost elast.	S	4	1	N
stationary, std wage mkp	$\sigma_{\overline{w}}$	0.4	1	IG	capital adj. cost elast.	ψ	0.5	0.1	B
unit root, AR labor dis.	ρ_χ	0.5	0.2	B	domestic stickiness	θ_h	0.75	0.075	B
unit root, std labor dis.	σ_χ	0.15	1	IG	domestic indexation	γ_h	0.5	0.15	B
stationary, AR labor dis.	$\rho_{\overline{\chi}}$	0.85	0.1	B	steady state price mkp	Υ^h	0.15	0.03	B^{*1}
stationary, std labor dis.	$\sigma_{\overline{\chi}}$	0.4	1	IG	AR investment	ρ_i	0.85	0.1	B
loading earnings	Ψ_e	1	0.5	N	std investment	σ_i	0.15	1	IG
std meas. error wages	μ_w	0.15^{*2}	1	IG	AR risk premium	ρ_d	0.85	0.1	B
std meas. error earnings	μ_e	0.15^{*2}	1	IG	std risk premium	σ_d	0.15	1	IG
International Dimension					AR gov't spending	ρ_g	0.85	0.1	B
AR debt premium	ρ_ξ	0.85	0.1	B	std gov't spending	σ_g	0.15	1	IG
std debt premium	σ_ξ	0.15	1	IG	stationary, AR tech.	$\rho_{\overline{a}}$	0.85	0.1	B
debt elasticity	ξ	0.03	0.01	B	stationary, std tech.	$\sigma_{\overline{a}}$	0.4	1	IG
import cons. stickiness	θ_m^c	0.75	0.075	B	unit root, AR tech.	ρ_a	0.5	0.2	B
import cons.indexation	γ_m^c	0.5	0.15	B	unit root, std tech.	σ_a	0.15	1	IG
import inv. stickiness	θ_m^i	0.75	0.075	B	AR relative price	ρ_ϕ	0.85	0.1	B
import inv. indexation	γ_m^i	0.5	0.15	B	std relative price	σ_ϕ	0.5	1	IG
AR import cons. mkp	ρ_m^c	0.85	0.1	B	AR price mkp	ρ_h	0.85	0.1	B
std import cons. mkp	σ_m^c	0.5	1	IG	std price mkp	σ_h	0.5	1	IG
AR import inv. mkp	ρ_m^i	0.85	0.1	B	MP int. rate resp.	ρ_r	0.75	0.1	B
std import inv. mkp	σ_m^i	0.5	1	IG	MP inflation resp.	ψ_π	1.7	0.25	N
AR export mkp	ρ_x	0.85	0.1	B	MP output resp.	ψ_y	0.12	0.05	N
std export mkp	σ_x	0.5	1	IG	std MP shock	σ_{mp}	0.15	1	IG
export stickiness	θ_x	0.75	0.075	B	std meas. error j series	μ_j	0.01	0.001	IG

Note: "std" denotes standard deviation, "AR" the autoregressive coefficient, "B" the Beta distribution, "N" the Normal, "G" the Gamma, and "IG" the inverse Gamma. μ_j pertains to the 19 series other than wages and earnings. ^{*1} and ^{*2}: G and 0.5 for the Euro Area, respectively.

[21] I include a white noise measurement error to each series; the error is tightly estimated to be negligible for all series except for wages and earnings.

V. Findings

A. Posterior Parameter Estimates

I discuss below some key parameter estimates reported in Tables (5, 6). Starting from labor market parameters and, in particular, the characteristics of labor market shocks, I find that stochastic changes in the euro-area-wide trends of labor market competitiveness and labor supply are neither persistent (ρ_w, ρ_x) nor volatile (σ_w, σ_x). The country-specific trend developments that differentiate the labor markets of the southern economies from that of the Euro Area are not protracted either, but they are a tad more volatile than the euro-area-wide trend shifts. Transitory wage markup shocks are persistent $(\rho_{\overline{w}})$ and volatile $(\sigma_{\overline{w}})$, especially in Portugal. Transitory labor disutility shocks are protracted too, but less volatile than wage markup shocks. Smets and Wouters (2003) find a tad more volatile transitory shocks for the Euro Area than the ones obtained here.

Consistently with the evidence of Galí et al. (2012b), weak wealth effects on labor supply are favored according to the low value of ω, and the inverse Frisch elasticity (χ) is 4.2. Wage stickiness is moderate in all economies. The euro-area estimate (0.55) is a tad lower than that of Smets and Wouters (2003), 0.74, and that of Adolfson et al. (2007), 0.72. The lower θ_w is consistent with Galí et al. (2012b) who find that the U.S. estimate of θ_w is lower when unemployment is observed than when it is not (0.47 vs 0.61). The data suggest small wage indexation $(\gamma_w \approx 0.1\text{-}0.3)$ in all regions. The loadings of the survey-based earnings series (Ψ_e) move far from unity, suggesting that earnings encapsulate information that is not highly correlated with that of wages and salaries. The standard deviation of measurement errors associated with wage series (μ_w, μ_e) implies sizable errors.

Turning to the parameters associated with the international dimension of the model, I find that the data favor price-inelastic exports (f) that are influenced by the simultaneous decrease of export prices and quantities during the Global Financial Crisis. The estimated price elasticities of consumption and investment imports (ν, ζ) are aligned with the estimates of Adolfson et al. (2007) and Christiano et al. (2011). The characteristic of export and (consumption and investment) import price markup shocks is that they are highly volatile $(\sigma_x, \sigma_m^c, \sigma_m^i)$ in all the southern economies. Their volatility, in some cases, is orders of magnitude higher than that of other disturbances. The shock to export demand is protracted (ρ_o) and of moderate volatility (σ_o). Shocks to export demand and to price markups, therefore, are likely to be influential in SOE's business cycles. In contrast, the debt premium shock, although persistent (ρ_ξ), has a small volatility (σ_ξ) compared to that of the other international shocks.

As for the domestic parameters, the habit parameter is higher in the southern economies than in the Euro Area mirroring persistent consumption dynamics in

Table 5—Labor Market Parameters

	Greece	Italy	Portugal	Spain	Euro Area
χ					4.20 [3.26, 5.37]
ω	0.04 [0.01, 0.07]	0.15 [0.05, 0.29]	0.04 [0.01, 0.07]	0.03 [0.01, 0.06]	0.17 [0.08, 0.26]
θ_w	0.44 [0.37, 0.52]	0.75 [0.65, 0.82]	0.31 [0.24, 0.40]	0.79 [0.73, 0.83]	0.55 [0.47, 0.63]
γ_w	0.12 [0.05, 0.22]	0.31 [0.14, 0.51]	0.16 [0.07, 0.27]	0.16 [0.07, 0.26]	0.17 [0.07, 0.30]
Υ	0.18 [0.13, 0.22]	0.15 [0.11, 0.20]	0.20 [0.15, 0.25]	0.15 [0.10, 0.20]	0.17 [0.12, 0.22]
ρ_χ	0.50 [0.15, 0.83]	0.52 [0.18, 0.86]	0.53 [0.21, 0.85]	0.71 [0.42, 0.93]	0.76 [0.56, 0.90]
σ_χ	0.12 [0.03, 0.25]	0.08 [0.03, 0.16]	0.07 [0.03, 0.14]	0.07 [0.03, 0.16]	0.04 [0.03, 0.07]
ρ_w	0.54 [0.23, 0.83]	0.52 [0.18, 0.86]	0.51 [0.18, 0.84]	0.54 [0.20, 0.85]	0.54 [0.22, 0.85]
σ_w	0.14 [0.03, 0.41]	0.13 [0.03, 0.34]	0.13 [0.03, 0.38]	0.15 [0.03, 0.46]	0.16 [0.04, 0.39]
$\rho_{\overline{\chi}}$	0.90 [0.82, 0.98]	0.96 [0.92, 0.99]	0.85 [0.71, 0.96]	0.98 [0.97, 1.00]	0.84 [0.67, 0.98]
$\sigma_{\overline{\chi}}$	0.36 [0.28, 0.44]	0.34 [0.29, 0.39]	0.27 [0.22, 0.33]	0.39 [0.34, 0.45]	0.08 [0.07, 0.10]
$\rho_{\overline{w}}$	0.89 [0.74, 0.99]	0.88 [0.70, 0.99]	0.97 [0.94, 0.99]	0.83 [0.58, 0.98]	0.85 [0.64, 0.98]
$\sigma_{\overline{w}}$	0.50 [0.10, 1.72]	0.62 [0.10, 2.24]	3.13 [2.07, 4.45]	0.56 [0.10, 1.99]	0.46 [0.10, 1.39]
Ψ_e	0.35 [0.16, 0.57]	0.37 [0.14, 0.67]	0.58 [0.37, 0.83]	0.28 [0.16, 0.40]	0.15 [-0.05, 0.37]
μ_w	3.14 [2.75, 3.57]	0.78 [0.68, 0.88]	0.98 [0.82, 1.17]	1.32 [1.17, 1.51]	0.35 [0.31, 0.41]
μ_e	3.17 [2.78, 3.63]	0.75 [0.66, 0.86]	1.25 [1.10, 1.42]	0.58 [0.51, 0.67]	0.30 [0.26, 0.34]

Note: Posterior Mean [5-95% CI].

the south. Risk premium shocks are more volatile (σ_d) in Greece, Portugal, and Spain than in Italy and the Euro Area reflecting the volatility of the sovereign debt yields during the Sovereign Debt crisis. Investment shocks are less volatile (σ_i) than risk premium shocks in all southern economies. Similarly to import and export price markup shocks, domestic price markup shocks are volatile (σ_h) but not persistent. As often found in the literature [Adolfson et al., 2005; Christiano et al., 2011], price stickiness in domestic goods (θ_h) is a tad higher than that of imported and exported goods ($\theta^c_m, \theta^i_m, \theta_x$). Shocks in the productivity trend demonstrate low-frequency characteristics. In contrast, stationary technology shocks are high-frequency and persistent disturbances that will be influential in business cycle dynamics. Shocks to the relative investment price exhibit elevated persistence (ρ_ϕ) but small volatility (σ_ϕ).

B. The Propagation of Disturbances

Fig.(2) sets the stage by displaying the transmission of transitory labor market and productivity shocks. Both labor market shocks generate a negative correlation of inflation and the real wage with output. The productivity shock spurs the counter-cyclical inflation response and the pro-cyclical real wage response[22] usually obtained in the literature. Consistently with the evidence of Galí et al. (2012b), wage markup shocks generate a negative correlation between output and the unemployment rate, whereas labor disutility shocks trigger a positive one. Thus, this characteristic disentangles the two disturbances. That correlation is positive in response to productivity shocks. The finding that the unemployment rate rises in response to positive productivity shocks in all the euro-area economies

[22]In some countries, since in Greece and Portugal the evidence suggests a counter-cyclical real wage.

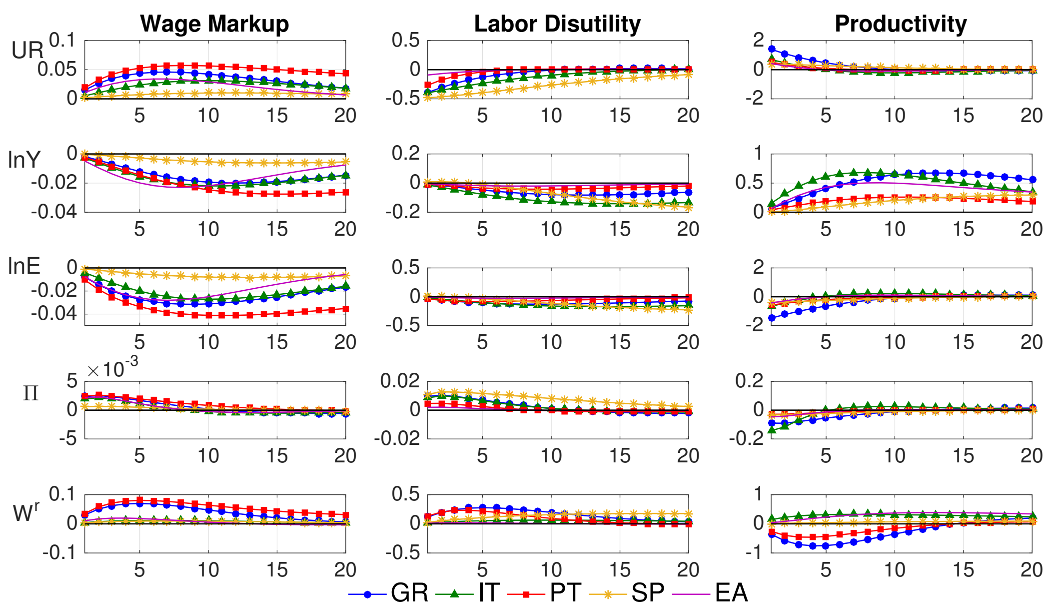
Table 6—Domestic and Openness Parameters

	Greece	**Italy**	**Portugal**	**Spain**	**Euro Area**
International Parameters					
ρ_ξ	0.98 [0.94, 1.00]	0.89 [0.78, 0.96]	0.97 [0.93, 0.99]	0.91 [0.84, 0.96]	
σ_ξ	0.12 [0.10, 0.14]	0.11 [0.10, 0.13]	0.28 [0.24, 0.32]	0.10 [0.09, 0.12]	
ξ	0.01 [0.00, 0.01]	0.01 [0.00, 0.01]	0.02 [0.02, 0.03]	0.01 [0.00, 0.01]	
θ_m^c	0.71 [0.57, 0.84]	0.68 [0.55, 0.80]	0.73 [0.62, 0.83]	0.70 [0.55, 0.81]	
γ_m^c	0.18 [0.08, 0.31]	0.25 [0.11, 0.42]	0.33 [0.16, 0.53]	0.23 [0.11, 0.40]	
θ_m^i	0.48 [0.37, 0.60]	0.67 [0.53, 0.78]	0.69 [0.51, 0.82]	0.50 [0.39, 0.62]	
γ_m^i	0.14 [0.05, 0.26]	0.28 [0.12, 0.45]	0.21 [0.08, 0.39]	0.16 [0.06, 0.30]	
ρ_m^c	0.72 [0.46, 0.88]	0.65 [0.47, 0.81]	0.75 [0.58, 0.88]	0.68 [0.52, 0.82]	
σ_m^c	3.50 [2.60, 4.70]	1.07 [0.81, 1.40]	1.18 [0.85, 1.54]	1.48 [1.10, 1.96]	
ρ_m^i	0.22 [0.13, 0.34]	0.62 [0.43, 0.79]	0.64 [0.43, 0.83]	0.97 [0.94, 0.99]	
σ_m^i	19.0 [15.3, 23.8]	1.39 [1.09, 1.80]	1.00 [0.74, 1.44]	2.11 [1.35, 2.97]	
θ_x	0.56 [0.40, 0.68]	0.81 [0.75, 0.88]	0.64 [0.51, 0.75]	0.53 [0.40, 0.68]	
γ_x	0.18 [0.08, 0.33]	0.21 [0.10, 0.36]	0.20 [0.08, 0.36]	0.20 [0.08, 0.37]	
ρ_x	0.55 [0.37, 0.76]	0.76 [0.59, 0.89]	0.68 [0.50, 0.83]	0.81 [0.66, 0.91]	
σ_x	8.61 [3.96, 13.9]	7.64 [3.76, 15.9]	5.52 [2.82, 9.99]	3.18 [1.86, 5.83]	
ρ_o	0.92 [0.85, 0.96]	0.93 [0.90, 0.95]	0.93 [0.89, 0.96]	0.85 [0.79, 0.90]	
σ_o	1.47 [1.27, 1.73]	0.69 [0.59, 0.82]	0.68 [0.59, 0.79]	0.75 [0.64, 0.86]	
ν	1.83 [1.39, 2.28]	1.25 [0.78, 1.76]	1.41 [1.04, 1.82]	1.24 [0.92, 1.58]	
ζ	2.16 [1.68, 2.67]	1.40 [0.87, 2.02]	1.12 [0.61, 1.73]	0.96 [0.49, 1.50]	
f	0.42 [0.31, 0.55]	1.15 [0.86, 1.46]	0.54 [0.39, 0.72]	0.64 [0.53, 0.76]	
Domestic Parameters					
η	0.86 [0.82, 0.90]	0.78 [0.73, 0.82]	0.87 [0.83, 0.90]	0.80 [0.75, 0.85]	0.71 [0.62, 0.78]
S	5.55 [4.43, 6.71]	6.80 [5.64, 7.99]	5.91 [4.58, 7.24]	6.90 [5.60, 8.33]	4.77 [3.42, 6.14]
ψ	0.45 [0.33, 0.57]	0.59 [0.45, 0.72]	0.35 [0.24, 0.48]	0.47 [0.34, 0.59]	0.45 [0.31, 0.60]
θ_h	0.91 [0.87, 0.94]	0.68 [0.58, 0.78]	0.91 [0.88, 0.94]	0.88 [0.81, 0.92]	0.85 [0.77, 0.90]
γ_h	0.13 [0.05, 0.23]	0.25 [0.11, 0.44]	0.11 [0.05, 0.20]	0.16 [0.06, 0.29]	0.16 [0.07, 0.28]
Υ^h	0.49 [0.43, 0.55]	0.12 [0.08, 0.16]	0.18 [0.13, 0.24]	0.23 [0.18, 0.29]	0.20 [0.14, 0.26]
ρ_i	0.44 [0.26, 0.65]	0.93 [0.88, 0.98]	0.62 [0.45, 0.80]	0.95 [0.91, 0.98]	0.34 [0.20, 0.51]
σ_i	3.75 [2.89, 4.62]	0.05 [0.03, 0.08]	0.88 [0.67, 1.09]	0.22 [0.16, 0.28]	0.61 [0.50, 0.72]
ρ_d	0.54 [0.40, 0.67]	0.89 [0.84, 0.95]	0.66 [0.49, 0.81]	0.31 [0.19, 0.43]	0.85 [0.79, 0.91]
σ_d	8.34 [4.94, 14.4]	0.36 [0.22, 0.54]	3.22 [1.72, 5.26]	3.05 [2.22, 4.07]	0.27 [0.16, 0.41]
ρ_h	0.25 [0.14, 0.38]	0.42 [0.26, 0.60]	0.26 [0.15, 0.39]	0.37 [0.21, 0.57]	0.51 [0.30, 0.74]
σ_h	0.69 [0.58, 0.80]	0.47 [0.37, 0.58]	0.42 [0.35, 0.48]	0.20 [0.16, 0.24]	0.11 [0.09, 0.13]
ρ_a	0.51 [0.17, 0.81]	0.54 [0.20, 0.86]	0.55 [0.20, 0.88]	0.62 [0.28, 0.90]	0.55 [0.21, 0.84]
σ_a	0.14 [0.03, 0.33]	0.08 [0.03, 0.17]	0.06 [0.03, 0.12]	0.07 [0.03, 0.13]	0.06 [0.03, 0.12]
$\rho_{\overline{a}}$	0.94 [0.90, 0.97]	0.94 [0.89, 0.98]	0.93 [0.87, 0.97]	0.99 [0.97, 1.00]	0.97 [0.91, 0.99]
$\sigma_{\overline{a}}$	1.40 [1.21, 1.60]	0.68 [0.59, 0.78]	0.60 [0.53, 0.69]	0.33 [0.28, 0.38]	0.43 [0.37, 0.50]
ρ_ϕ	0.86 [0.67, 0.98]	0.55 [0.38, 0.73]	0.85 [0.67, 0.97]	0.84 [0.64, 0.98]	
σ_ϕ	0.11 [0.03, 0.27]	2.14 [1.76, 2.55]	0.11 [0.03, 0.28]	0.24 [0.03, 1.18]	
ρ_g	0.98 [0.96, 1.00]	0.97 [0.94, 0.99]	0.98 [0.97, 1.00]	0.99 [0.98, 1.00]	0.96 [0.93, 0.99]
σ_g	2.40 [2.10, 2.74]	0.79 [0.69, 0.91]	0.54 [0.46, 0.63]	0.64 [0.56, 0.73]	1.79 [1.58, 2.05]
ρ_r					0.86 [0.83, 0.89]
ψ_π					2.03 [1.73, 2.39]
ψ_y					0.20 [0.12, 0.28]
σ_{mp}					0.09 [0.08, 0.11]

Note: Posterior Mean [5-95% CI].

of the sample corroborates the results of Galí et al. (2012b) for U.S. and of Christiano et al. (2011) for Sweden. What is different compared to Galí et al. (2012b) is that the effects of wage markup shocks, both in the peripheral economies and the Euro Area, are small in magnitude. Matching the first differences instead of the level of the unemployment rate in the estimation, therefore, attenuates the impact of labor market shocks.

Figure 2. Transitory Labor Market and Productivity Shocks

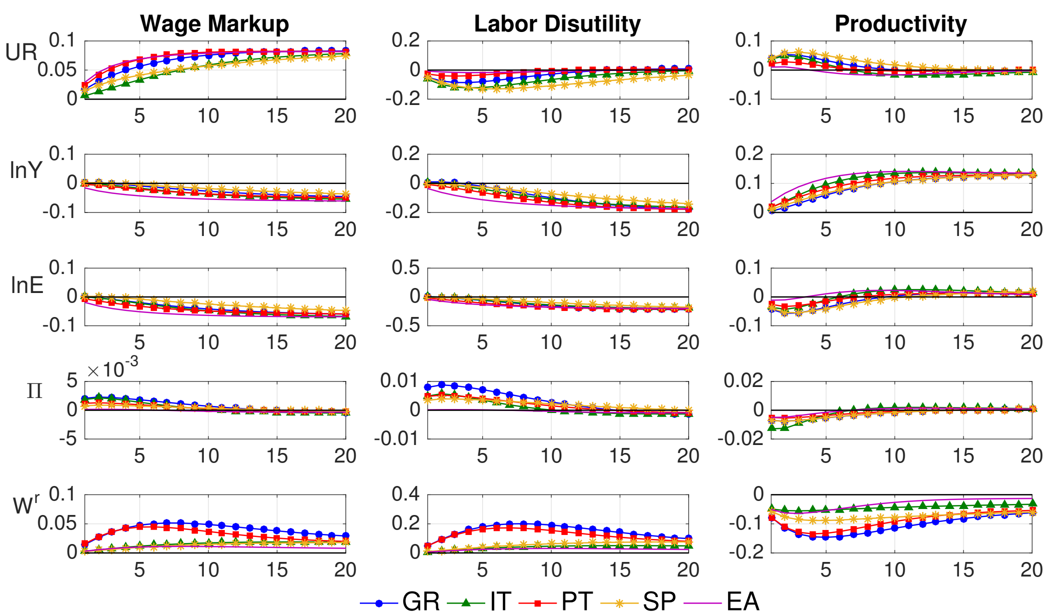


Note: Impulse responses to one standard deviation shocks. Computations at the posterior parameter mean. Rows: responding variables, Columns: disturbances. *Mnemonics:* UR: unemployment rate, lnY: real per capita output, lnE: per capita employment, Π: inflation, W^r: real wage. The response of Portugal's variables to the wage markup shock are scaled down by a factor of ten to ease the exposition.

Fig.(3) turns to the novel shocks of this work, and pins down the propagation of euro-area-wide trend shocks that induce permanent changes in the euro-area-wide labor market characteristics and productivity. The figure suggests that these shocks influence the Euro Area and spillover to the southern economies in a homogeneous way. Positive trend shocks in wage markups gradually and permanently raise the unemployment rate to a higher plateau, and suppress employment and output to a lower level. Consistently with the findings of Galí (2015) from a calibrated model, the effect of these shocks on price and wage inflation is of negligible magnitude. Positive trend shocks in labor disutility permanently decrease employment and output too, both in the periphery and the Euro Area. Nevertheless, they only temporarily reduce unemployment since they (permanently) contract the labor force. These shocks raise price and wage inflation to a small extent. Therefore, the findings suggest that in response to both transitory and permanent shocks in either wage markups or labor disutility, all variables respond in the same qualitative way and the sign of the output-unemployment correlation still disentangles wage markup from labor disutility shocks. The only differences between permanent and transitory shocks of either type are the persistence of their effect across time and the fact that the former originate in the Euro Area whereas the latter in each SOE.

Positive trend shocks in productivity permanently increase output in all regions. In the short run, they decrease employment and inflation, and raise unemployment. Interestingly, although the effects of euro-area-wide permanent technology shocks are qualitatively similar to the effects of their transitory analogues in each SOE, these shocks generate a negative short-run correlation between output and the real wage that differs from the positive correlation generated by their transitory analogues.

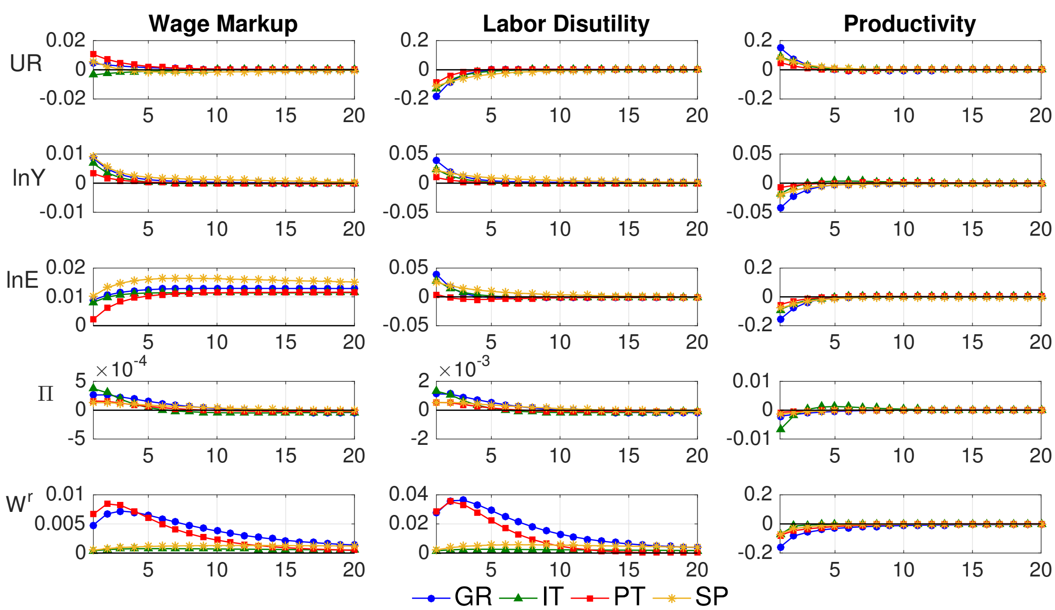
Figure 3. Permanent Shocks in Euro-Area-Wide Labor Market and Productivity Trends



Note: Impulse responses to one standard deviation shocks. Computations at the posterior parameter mean. Rows: responding variables, Columns: disturbances. *Mnemonics:* UR: unemployment rate, lnY: real per capita output, lnE: per capita employment, Π: inflation, W^r: real wage.

Fig.(4) reports the effects of country-specific trend developments in the labor markets and the productivity of the southern economies. The responses of the unemployment rate, price inflation, and wage inflation are small, short-lived, and similar to those observed in response to permanent and transitory labor market and productivity shocks. Nevertheless, the figure reveals a difference: in response to positive country-specific wage markup and labor disutility shocks, output and employment expand. As a result, the output-unemployment correlation becomes positive in response to wage markup shocks and negative in response to labor disutility shocks. There are direct and indirect effects at play. The direct effect pertains to downward pressures in the output trend. The indirect effect works through a general equilibrium channel: the downward trend pressures raise the value of exports (above the trend) and, hence, trigger an expansionary effect via the resource constraint (11) and the trade balance in the equation for foreign assets (12)[23]. On impact, the general equilibrium effect is stronger than the direct effect. The two effects, however, quickly cancel each other out. The output decline in response to a positive country-specific trend development in productivity can be explained based on the above reasoning too.

FIGURE 4. COUNTRY-SPECIFIC TRANSITORY TREND DEVELOPMENTS IN THE SOUTHERN ECONOMIES



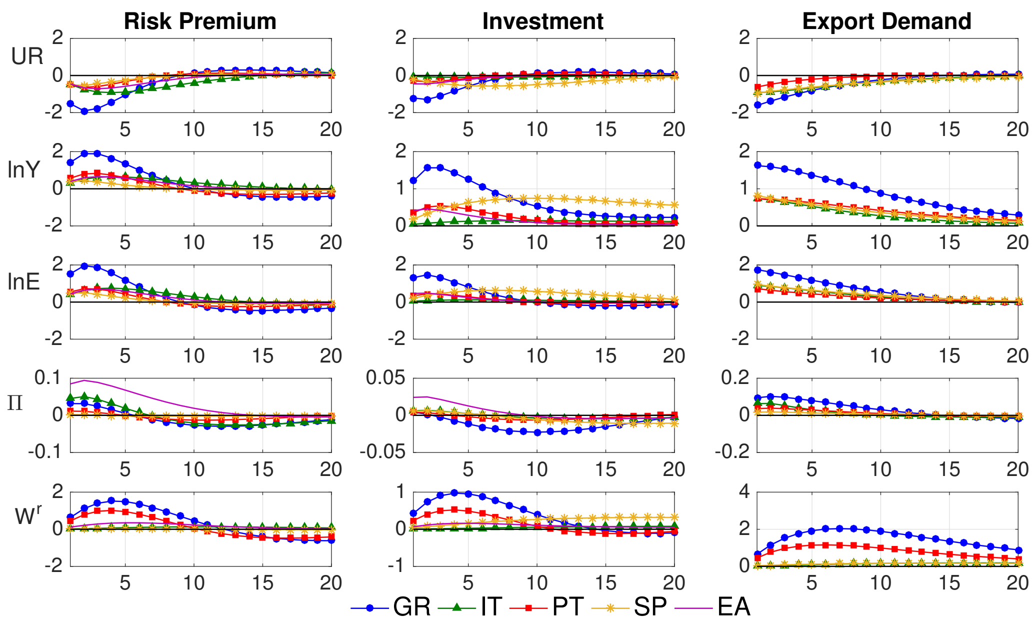
Note: Impulse responses to one standard deviation shocks. Computations at the posterior parameter mean. Rows: responding variables, Columns: disturbances. *Mnemonics:* UR: unemployment rate, lnY: real per capita output, lnE: per capita employment, Π: inflation, W^r: real wage.

Fig.(5) tackles the responses to demand shocks and, in particular, to a reduction in the risk premium, a decrease in investment costs, and a stimulus in export demand. All three shocks shift output, inflation, and the real wage to the same

[23]In those equations, exports $C^*_{H,t} + I^*_{H,t}$ are scaled according to the euro-area trend whereas the rest of the variables according to SOE's trend, thus the following factor appears: $[(C^*_{H,t} + I^*_{H,t})/V^*_t][V^*_t/V_t]$.

direction in all the economies. They create an economic expansion, raise employment, and decrease unemployment. Unemployment is, thus, pro-cyclical in response to demand shocks whose impact is sizable – significantly higher than that observed in response to labor market shocks – and persistent over time.

FIGURE 5. TRANSITORY DEMAND SIDE SHOCKS

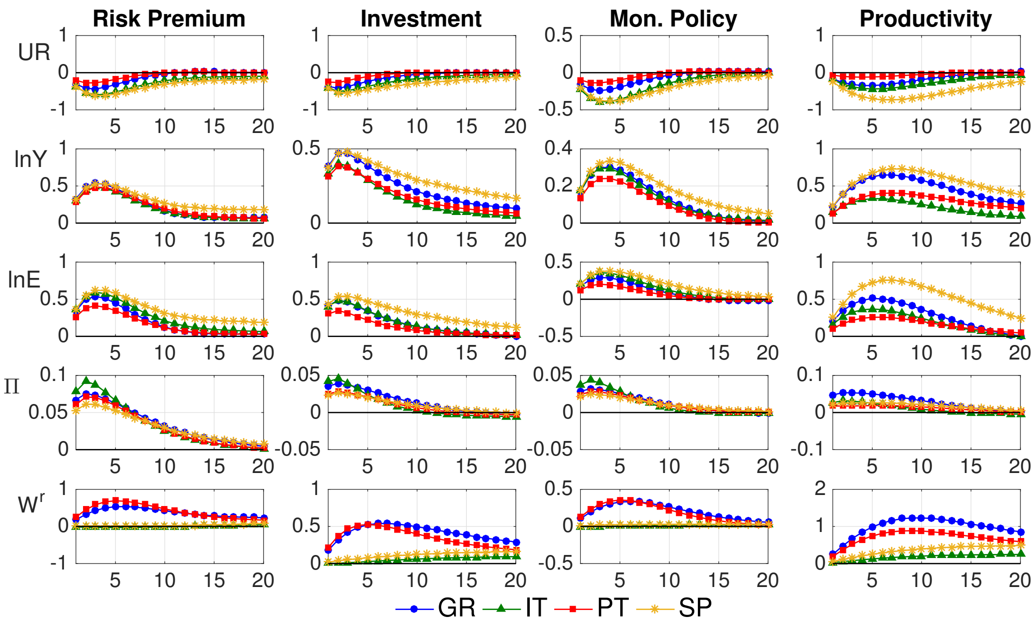


Note: Impulse responses to one standard deviation shocks. Computations at the posterior parameter mean. Rows: responding variables, Columns: disturbances. *Mnemonics:* UR: unemployment rate, lnY: real per capita output, lnE: per capita employment, Π: inflation, W^r: real wage.

Fig.(6) quantifies the spillover effects from the euro-area demand and supply conditions to the southern economies. The effects of euro-area expansionary demand and productivity shocks on the set of SOE's variables shown in the figure are similar, though a tad smaller in size, to the effects of domestic demand shocks shown in Fig.(5). Thus, an euro-area expansion transmits to the southern economies, and triggers an output expansion as well as an unemployment reduction. It is important to point out that, according to the responses shown in figures (2) and (6), a transitory euro-area-wide productivity advancement would raise unemployment in the Euro Area but decrease unemployment in the southern periphery.

Finally, Fig.(7) addresses how labor market variables and output behave after various relative price distortions generated by price markup shocks and, in particular, domestic, import, and export price markup shocks. The effect of all price markup shocks on the unemployment rate and the economy is more temporary than that

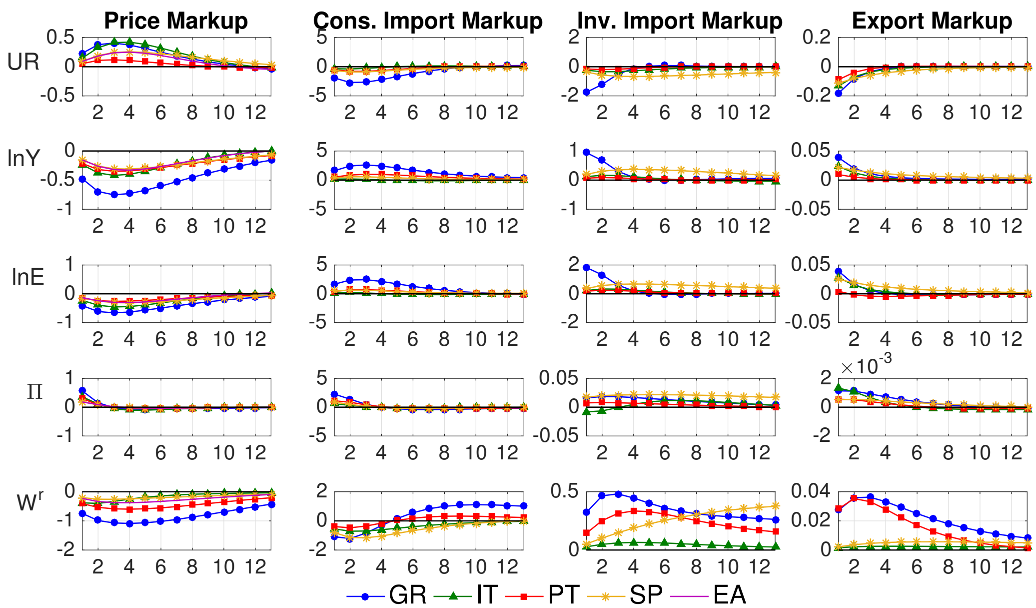
Figure 6. Spillover Effects of Euro Area Demand and Supply Conditions



Note: Impulse responses to one standard deviation shocks. Computations at the posterior parameter mean. Rows: responding variables, Columns: disturbances. *Mnemonics:* UR: unemployment rate, lnY: real per capita output, lnE: per capita employment, Π: inflation, W^r: real wage.

of demand and supply shocks – it lasts about two years. Similarly, to productivity shocks, domestic price markup shocks generate a negative correlation between inflation and output. Contrary to the former shocks, however, domestic price markup shocks generate a counter-cyclical unemployment response that is consistent with the impulse responses of Galí et al. (2012b) after a few periods. Both import, in consumption and in investment, and export price markup shocks result in pro-cyclical inflation and counter-cyclical unemployment responses. More specifically, high relative import prices make the consumers substitute foreign goods for domestic and, thus, stimulate domestic production and decrease unemployment. Higher relative export prices decrease export demand but raise the value of a given amount of exports. Since the model suggests rather price-inelastic exports (f is low), the latter effect dominates the former leading to an improvement of the trade balance, an increase of foreign assets and a subsequent decrease of the domestic interest rate. The latter, in turn, triggers an increase in domestic consumption and production that result in an unemployment reduction.

Figure 7. Relative Price Distortions



Note: Impulse responses to one standard deviation shocks. Computations at the posterior parameter mean. Rows: responding variables, Columns: disturbances. *Mnemonics:* UR: unemployment rate, lnY: real per capita output, lnE: per capita employment, Π: inflation, W^r: real wage.

C. Business Cycles

This section pins down the drivers of unemployment. Table (7) displays the forecast error variance decomposition (FEVD) of the growth rate of output, unemployment, employment, real wages, and prices eight quarters ahead. A finding that stands out across all sample economies is that neither trend nor transitory shocks in wage markups and labor disutility have a sizable influence on unemployment, output, and any other variable. The effect of trend shocks is at 0-1%, that of stationary wage markup shocks is at 0-1% for unemployment and at 0-3% for output, and that of labor disutility shocks is negligible for unemployment and at about 1-7% for output. The negligible influence of wage markup shocks on output is consistent with the zero influence found by Smets and Wouters (2003) for the Euro Area, and the small influence (4.8%) found by in 't Veld et al. (2014) for Spain. It differs from the U.S. evidence of Galí et al. (2012b), where shifts in labor market competitiveness account for about 40% and 80% of short-run and long-run unemployment cycles. The small influence of labor disutility shocks on output is compatible with the 7.9% impact found by Christiano et al. (2011) for Sweden, but differs from the 32% influence found by Smets and Wouters (2003).

In contrast, a large fraction (about 42-57%) of unemployment fluctuations is driven by demand factors – a combination of domestic, euro-area, and global demand factors that incorporates the effect of financial conditions. The southern economies are no different from the Euro Area in this respect. More specifically, domestic risk premium, debt premium, and investment shocks[24] account for 8-25% of unemployment fluctuations in the southern economies and for 55% of the euro-area fluctuations. Demand shocks in the Euro Area spillover to the periphery and explain 2-15% of its unemployment cycles, while export demand shocks account for 15-29% of the above fluctuations. In contrast, in Galí et al. (2012b), demand shocks explain only 7-20% of unemployment cycles across different horizons. Moreover, the impact of demand factors on output is sizable as well (38-57%). The latter result is compatible with the 56% influence of all demand side shocks on output ten quarters ahead found by Smets and Wouters (2003) for the Euro Area, and the influence of financial factors in the euro-area post-crisis slump and in Spain found by Kollmann et al. (2016) and in 't Veld et al. (2014), respectively.

The effect of supply shocks – a combination of shocks in productivity, the price markup, and the relative price of investment – on output and the unemployment rate varies from a quarter in the Euro Area to 5-25% in the southern economies, with the Spanish unemployment being the least affected by supply factors. The influence of supply factors on the unemployment swings is thus sizable and similar to what Christiano et al. (2011) obtain for the Swedish economy (about 30%), but it is above what Galí et al. (2012b) find for the U.S. economy (1-4%).

Furthermore, the findings reveal a sizable influence of import and export price markup shocks on unemployment and the other variables, especially inflation. As shown in Table (6) and Fig.(7), these shocks are volatile and have a sizable ephemeral impact, characteristics that reflect the volatility of the underlying import, export, and investment price indices that are used in the estimation. These shocks explain about 25-50% of unemployment and output fluctuations, and their influence is more pronounced in Greece than in the other southern economies.

It is important to point out that the decomposition of the forces driving employment growth is similar to that obtained for the unemployment rate in all the sample economies. This result suggests that the responses of the unemployment rate and employment to business cycle shocks are of about the same magnitude. The corollary of the latter is that the responses of the labor force are small in magnitude. This finding is consistent with the evidence of Galí et al. (2012b).

Interestingly, purely euro-area shocks account for 2-17% of output cycles in the southern economies. This influence is a tad above the 5% influence found in Justiniano and Preston (2010) that has been the benchmark in the literature.

[24]One could add the government spending shocks in that category, but the influence of those shocks in the peripheral economies is negligible.

Furthermore, combining euro-area and international price markup shocks yields an influence of foreign shocks on SOE's output in the range of 36-51%. The latter is a tad above the influence of foreign shocks on Swedish output (32%) found in Christiano et al. (2011). Thus, a considerable degree of connectedness between the Euro Area and the southern economies exists. The FEVD of inflation suggests that it is mainly driven by domestic, import, and export price markup shocks. Although about 40% of fluctuations in wage inflation stems from import and export price markup shocks in all economies, the FEVD shows a degree of country heterogeneity. In particular, wage growth depends more on euro-area than on domestic conditions in Italy and Spain than in Greece and Portugal.

Table 7—Business Cycle Fluctuations

	Trends		**Euro Area**		**Int'l**		**Domestic**				
	Perm.	Country	All	Demand	Price Mkp	Export Dem.	All	Demand	Supply	Wage Mkp	Labor Dis.
GR: ΔlnY_t^o	0	0	2	2	48	13	36	23	11	0	1
GR: ΔUR_t^o	0	0	2	2	43	15	39	25	13	0	0
GR: ΔlnE_t^o	0	0	4	3	40	19	37	33	3	0	0
GR: $\widehat{\pi}_t$	0	0	1	1	94	1	5	0	5	0	0
GR: $\Delta\widehat{w}_t$	0	0	9	4	50	15	25	19	5	0	0
IT: ΔlnY_t^o	0	1	14	12	23	22	39	10	23	0	4
IT: ΔUR_t^o	0	0	15	13	24	25	36	8	27	0	0
IT: ΔlnE_t^o	0	0	19	16	28	30	23	10	12	0	0
IT: $\widehat{\pi}_t$	0	0	8	7	64	2	27	1	26	0	0
IT: $\Delta\widehat{w}_t$	1	0	37	25	32	12	17	8	8	0	1
PT: ΔlnY_t^o	0	1	7	7	29	19	43	22	15	3	4
PT: ΔUR_t^o	0	0	10	9	23	22	44	26	17	1	0
PT: ΔlnE_t^o	0	0	13	11	29	23	35	32	3	0	0
PT: $\widehat{\pi}_t$	0	0	2	1	94	0	4	0	4	0	0
PT: $\Delta\widehat{w}_t$	0	0	15	10	42	11	32	22	4	6	1
SP: ΔlnY_t^o	0	1	17	12	34	25	23	11	5	0	7
SP: ΔUR_t^o	0	0	21	15	30	29	19	12	6	0	0
SP: ΔlnE_t^o	0	0	23	15	29	31	17	14	2	0	0
SP: $\widehat{\pi}_t$	0	0	3	2	92	0	4	0	4	0	0
SP: $\Delta\widehat{w}_t$	1	0	46	20	38	5	10	5	2	0	4
EA: ΔlnY_t^o	0	0	0	0	0	0	100	57	26	0	1
EA: ΔUR_t^o	1	0	0	0	0	0	99	55	27	0	0
EA: ΔlnE_t^o	1	0	0	0	0	0	99	66	13	0	0
EA: $\widehat{\pi}_t$	0	0	0	0	0	0	100	49	50	0	0
EA: $\Delta\widehat{w}_t$	1	0	0	0	0	0	99	90	6	0	0

Note: Forecast Error Variance Decomposition in %, 8 quarters ahead, at the posterior mean of the parameters. // "***Trends***": *"Perm.":* permanent euro-area-wide trend shocks in wage markup, labor disutility, productivity. *"Country:* country-specific trend shocks in wage markup, labor disutility, productivity. // "***Euro Area***": *"All":* shocks in risk premium, investment, government spending, monetary policy, productivity, price markup, wage markup, labor disutility. *"Demand":* shocks in risk premium, investment. // "***Int'l***": *"Price Mkp":* shocks in consumption and investment import price markups, export price markup. // "***Domestic***": *"All":* shocks in risk premium, investment, government spending, debt premium, productivity, price markup, wage markup, labor disutility, relative price of investment. *"Demand":* shocks in risk premium, investment, debt premium. *"Supply":* shocks in productivity, price markup, relative price of investment.

Furthermore, although the level of the unemployment rate has a unit root, and thus its long-run swings are explained by permanent euro-area-wide shifts in labor market competitiveness captured by wage markup shocks, it is important to understand its short-run drivers. To that end, Table (8) reports the FEVD of the levels of the unemployment rate and output over business cycle frequencies. The decomposition of the levels is similar[25] to that of the growth rates of those variables shown in Table (7). Put differently, permanent and country-specific trend shocks still explain a negligible share of the unemployment and output swings. Therefore, factors capturing the competitiveness of the labor market take time to be built in unemployment and output fluctuations.

Table 8—Business Cycle Fluctuations – Levels

	Trends		**Euro Area**		**Int'l**		**Domestic**				
	Perm.	Country	All	Demand	Price Mkp	Export Dem.	All	Demand	Supply	Wage Mkp	Labor Dis.
GR: lnY_t^o	0	0	4	2	48	12	36	27	8	0	1
GR: UR_t^o	0	0	7	3	38	17	39	28	10	0	0
IT: lnY_t^o	0	0	23	16	28	17	32	22	8	0	2
IT: UR_t^o	0	0	23	17	33	17	27	17	9	0	1
PT: lnY_t^o	1	0	8	6	29	9	53	21	6	25	1
PT: UR_t^o	1	0	17	12	22	16	44	26	9	8	0
SP: lnY_t^o	1	0	35	17	29	13	22	13	4	0	5
SP: UR_t^o	0	0	39	18	26	15	20	15	4	0	0
EA: lnY_t^o	1	0	0	0	0	0	99	78	14	0	0
EA: UR_t^o	4	0	0	0	0	0	96	72	16	0	0

Note: Forecast Error Variance Decomposition in %, 8 quarters ahead, at the posterior mean of the parameters. For Mnemonics see Notes on Table (7).

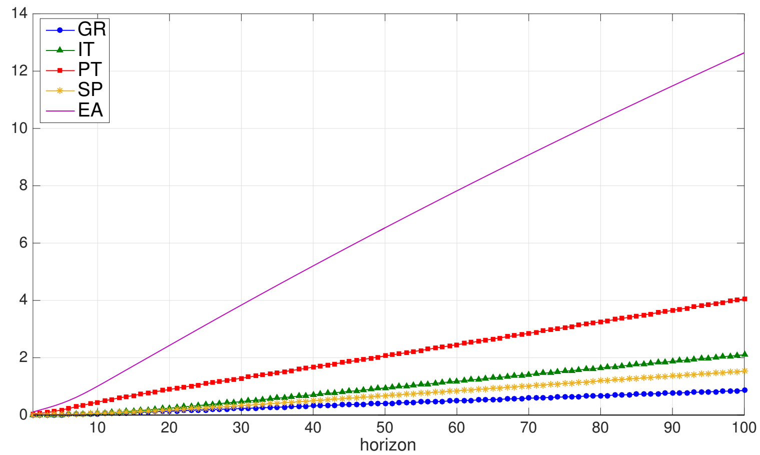
When do these factors kick in though? Fig.(8) delves into this question by plotting the share of fluctuations in the level of the unemployment rate explained by permanent euro-area-wide trend developments across different horizons and sample economies. The evidence suggests that shifts in labor market competitiveness take a lot of time to be built in the unemployment rate: even at 100 quarters ahead, the figure implies that only 1-13% of the fluctuations in the level of the unemployment rate are explained by wage markup shocks. Therefore, shifts in labor market competitiveness are outside of the spectrum of business cycle frequencies.

D. *The Drivers of Unemployment Fluctuations over Time*

What were the forces – the mix of demand, supply, and labor market disturbances – that shaped the unemployment evolution since the creation of the Euro Area and up to 2018? To address this question, Fig.(9) provides a trend–cycle decomposition of the annual change in the unemployment rate. The figure shows that the trend component of equation (15) exhibits small fluctuations across time

[25]Only in the case of Portugal, the influence of stationary wage markup shocks rises.

Figure 8. Unemployment and Wage Markup Shocks in Business Cycle Frequencies



Note: Vertical axis: share of fluctuations in the level of the unemployment rate that is explained by permanent euro-area-wide wage markup shocks. Horizontal axis: forecasting horizon in quarters.

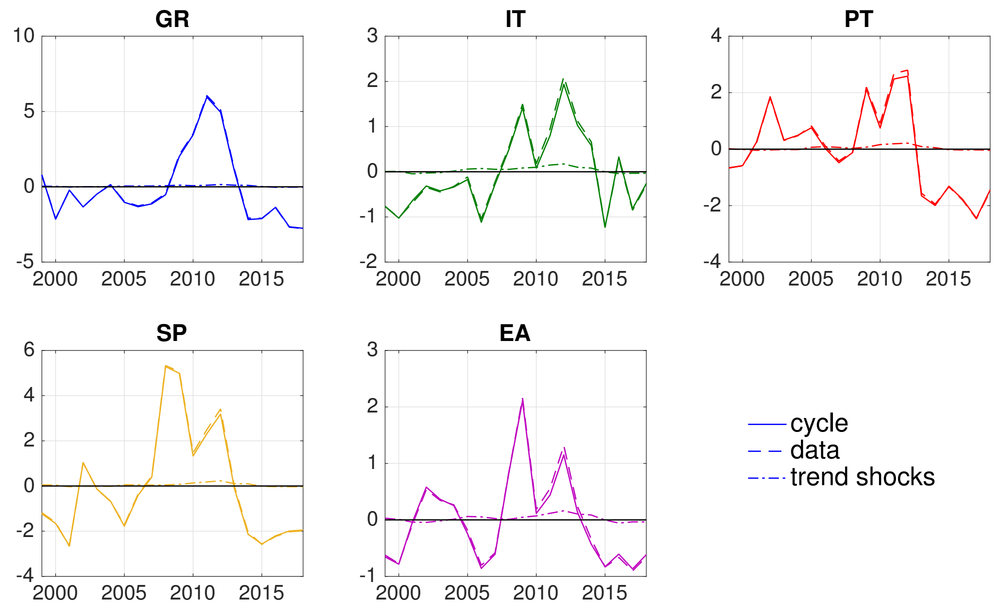
in both the southern economies and the Euro Area. The largest part of the period-to-period changes are attributed to cyclical variations.

Fig.(10) pins down the structural shocks behind the fluctuations in the annual change of the unemployment rate over time across all sample economies. During the pre-crisis period, the initially high unemployment rates in Greece, Italy and Spain converged to the lower plateau of the euro-area average. Favorable demand conditions that followed the creation of the Eurozone shaped that convergence. Positive export price markups played a role too (to a larger extent in Italy than in Greece and Spain). In contrast, the unemployment rate in Portugal rose from a low plateau to the euro-area average. Its evolution is explained by a combination of weak demand and positive transitory wage markup shocks. The appearance of the latter is consistent with the findings of Table (7) showing a small impact of those shocks on the swings of unemployment, and of Figures (2[26], 8) showing a larger response of Portuguese unemployment to wage markup shocks compared to the unemployment responses of the other economies. As for euro-area unemployment, temporary reductions in it were driven by positive demand shocks, whereas temporary increases in it were driven by positive productivity shocks.

During the first phase of the Global Financial Crisis, the unemployment hump in the southern economies is explained by a combination of negative euro-area productivity shocks that spillover and raise unemployment (fig.6) and adversarial demand shocks. The euro-area unemployment spike suggests a combination of euro-area productivity and demand shocks as well.

[26]Note that in that figure the responses of Portuguese variables are scaled down by a factor of ten.

Figure 9. Trends and Cycles in the Unemployment Rate

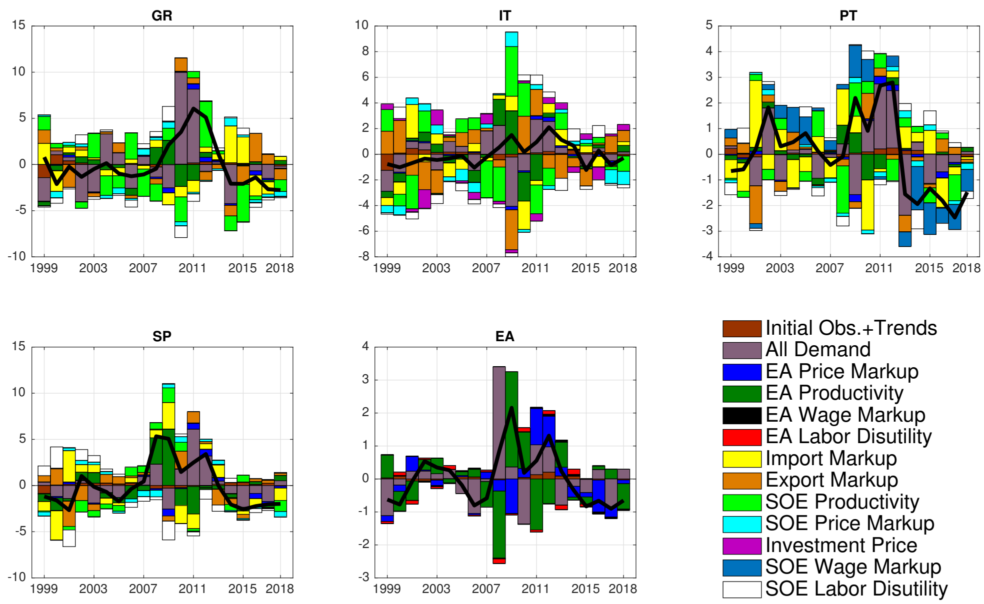


Note: The figure plots the observed (demeaned) annual change in the unemployment rate ("data"). "trend shocks" and "cycle" refer to the terms ϵ_t^w/χ and $\Delta\widehat{u}_t$ of equation (15), respectively.

The Sovereign Debt Crisis led to a second unemployment spike in all the economies (except in Greece were unemployment stayed persistently high after the first phase of the recession) that was predominantly explained by demand factors including high risk premia and investment costs both in the Euro Area and in the southern periphery. These shocks reflect the adversarial financial conditions that all the economies of the sample faced. Moreover, during that period, the model suggests positive euro-area price markup shocks that did transmit to the periphery and pushed towards an unemployment increase. Such price markups suggest that during the Sovereign Debt Crisis inflation fell less than what was implied by the underlying conditions in production.

The unemployment decline that followed the above crisis was helped by a strengthening in demand conditions only to a small extent. Weak demand conditions likely reflected the weak credit conditions of the euro-area markets that were found to be prominent in the post-crisis economic slump by Kollmann et al. (2016). In addition, Fig.(10) does not show homogeneity in the other factors that contributed to the unemployment decline across the sample economies. For instance, a reduction in the domestic price markups has played a role in the Euro Area and in Italy, a reduction in wage markups has been influential in Portugal, and a decrease in productivity has contributed in the unemployment decline in Greece.

FIGURE 10. THE DRIVERS OF UNEMPLOYMENT OVER TIME

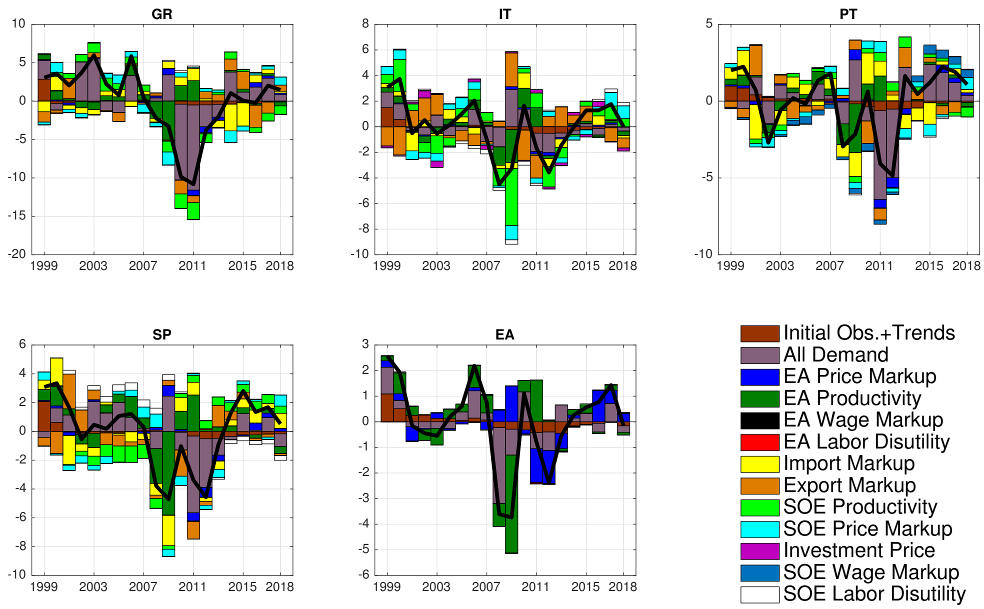


Note: Annual (demeaned) change in the unemployment rate. The columns show the contribution of each structural shock. "All Demand" includes the contributions of domestic demand shocks (risk premium, investment, debt premium, government spending), euro-area demand shocks (risk premium, investment, government spending, monetary policy), and export demand shocks.

Fig.(11) displays the decomposition of the annual real per capita output growth. The factors behind the fluctuations in output growth largely mirror those behind the unemployment fluctuations. More specifically, the sustained output growth during the pre-crisis period was largely influenced by positive demand shocks in all the economies but Portugal where demand was weak and the wage markup shocks were positive. The output trough during the first phase of the Global Financial Crisis was driven by a combination of demand and productivity shocks, while the trough of the sovereign debt crisis was driven by adversarial financial conditions, captured by risk premium and investment shocks, and positive price markup shocks to some extent. The post-crisis period is characterized by weak demand shocks likely reflecting the weak euro-area financial sector.

Before closing, it is worth justifying why I grouped together all the demand shocks (domestic demand, euro-area demand, and export demand shocks). The reason is that the innovations of both domestic and euro-area demand shocks are considerably correlated with the innovations of the export demand shock in a way

FIGURE 11. THE DRIVERS OF OUTPUT OVER TIME



Note: Annual (demeaned) growth in real per capita output. The columns show the contribution of each structural shock. "All Demand" includes the contributions of domestic demand shocks (risk premium, investment, debt premium, government spending), euro-area demand shocks (risk premium, investment, government spending, monetary policy), and export demand shocks.

that when either domestic or euro-area shocks push towards an expansion, the export demand innovations push towards an economic contraction. For instance, according to Table (9), export demand innovations are negatively correlated with domestic investment shocks in Greece as well as with euro-area investment shocks in Portugal and Spain. Additionally, they are positively correlated with domestic and euro-area risk premium shocks as well as with euro-area government spending shocks in Italy, Portugal, and Spain. Since all three types of demand shocks have the same implications for unemployment, output, employment, inflation, and real wage dynamics – as seen in Figures (5, 6) – the estimation better captures their *joint* effect. In this case, grouping together these shocks helps with the interpretation of the forces behind the historical decompositions.

VI. Conclusion

The present paper examined the cyclical drivers of unemployment in the Euro Area and in its southern periphery through the lens of an estimated structural model and by incorporating the empirically supported unit root of the unem-

Table 9—Export Demand Innovations and Demand Side Innovations

	GR	IT	PT	SP
domestic risk premium	0.28	0.36	0.28	0.52
domestic investment	-0.40	0.18	-0.13	0.02
domestic gov't spending	-0.29	-0.16	-0.32	-0.28
EA risk premium	0.06	0.41	0.27	0.34
EA investment	-0.19	-0.34	-0.47	-0.39
EA gov't spending	0.31	0.60	0.53	0.37

Note: Pairwise correlation of innovations in export demand with innovations in the shocks described in the first column. Computations at the posterior mean of the innovations.

ployment rate of those economies. In fact, the paper examined the unit root fluctuations of the unemployment rate jointly with the unit roots of employment and output. A rich stochastic structure featuring permanent, country specific, and transitory wage markup, labor disutility, and productivity shocks was modeled. Once a unit root is taken into account, the findings suggest a negligible role of wage markup and labor disutility shocks over business cycle frequencies despite the fact that the former shocks explain the long-run unemployment shifts. In contrast, demand side shocks, relative price distortions, and supply factors account for about 40%, 40%, and 20% of unemployment fluctuations, respectively. The demand factors were influential during the pre-crisis convergence of the unemployment rates of the southern economies, but became adversarial during the Global Financial Crisis and, especially, during the Sovereign Debt Crisis.

This paper sets the stage for several explorations. Understanding the sources of unemployment cycles can shape the desirable policy mix. The sizable influence of demand shocks on unemployment suggests that stabilization policies – demand management policies – would be more preferable than structural reforms in the short run. A welfare analysis of alternative policies in an estimated DSGE model featuring a unit root in the unemployment rate could shed light on the implications of those policies. Future work incorporating financial shocks could shed light on the importance of various financial channels for unemployment cycles.

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Appendices

State Space

The equilibrium conditions are casted in the form: $\Gamma_0(\Theta)\xi_t = \Gamma_1(\Theta)\xi_{t-1} + \Psi(\Theta)\epsilon_t + \Pi\eta_t$, where the matrices $\{\Gamma_0, \Gamma_1, \Psi\}$ are functions of the parameter vector Θ, ξ_t is the $(n_q \times 1)$ state vector, and η_t collects the expectational errors. The structural shocks are grouped in the $(n_\epsilon \times 1)$ vector ϵ_t. (A1) gives the VAR(1) representation of the rational expectations solution of Sims (2002).

$$\xi_t = \Phi_1(\Theta)\xi_{t-1} + \Phi_2(\Theta)\epsilon_t \ , \quad \epsilon_t \sim N(0_{n_\epsilon}, I_{n_\epsilon}), \quad \forall t \geq 2 \tag{A1}$$

$\{\Phi_1, \Phi_2\}$ are non-linear functions of Θ. Defining the reduced-form errors, $\tilde{\epsilon}_t = \Phi_2\epsilon_t$ for $t > 1$ and $\tilde{\epsilon}_1 = \epsilon_1$, and stacking (A1) across time yields:

$$\begin{bmatrix} I_{n_q} & \dots & \dots & \dots \\ -\Phi_1 & I_{n_q} & \dots & \dots \\ \dots & \ddots & \ddots & \dots \\ \dots & \dots & -\Phi_1 & I_{n_q} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_T \end{bmatrix} = \begin{bmatrix} \tilde{\epsilon}_1 \\ \tilde{\epsilon}_2 \\ \vdots \\ \tilde{\epsilon}_T \end{bmatrix} \sim N\left(0_{Tn_q}, \begin{bmatrix} D & \dots \\ \vdots & \Omega \otimes I_{T-1} \end{bmatrix}\right) \tag{A2}$$

where $\Omega \equiv \Phi_2\Phi_2'$, and D is the steady state covariance of the state vector evaluated at the prior mean of Θ. In matrix notation, the above equation reads as

$$Z\xi = \tilde{\epsilon} \qquad , \qquad \tilde{\epsilon} \sim N(0_{Tn_q}, K_{\tilde{\epsilon}}^{-1}) \tag{A3}$$

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

The measurement equation for the $m \times 1 (m > n_\epsilon)$ observation vector Y_t reads as:

$$Y_t = H_0\xi_t + H_1\xi_{t-1} + M_t \quad , \quad M_t \sim N(0_m, \Sigma_M) \tag{A4}$$

$\{H_0, H_1\}$ are $(m \times n_q)$ selection matrices; $H_1\xi_{t-1}$ allows for state augmentation; M_t is a $(m \times 1)$ vector of white noise measurement errors with diagonal covariance Σ_M. Stacking (A4) across time yields:

$$\begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_T \end{bmatrix} = \begin{bmatrix} H_0 & \dots & \dots & \dots \\ H_1 & H_0 & \dots & \dots \\ \dots & \ddots & \ddots & \dots \\ \dots & \dots & H_1 & H_0 \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \\ \vdots \\ \xi_T \end{bmatrix} + \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_T \end{bmatrix} \sim N\left(0_{Tm}, I_T \otimes \Sigma_M\right) \tag{A5}$$

In matrix notation,

$$Y = H\xi + M \quad , \quad M \sim N(0_{Tm}, I_T \otimes \Sigma_M) \tag{A6}$$

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

Bayes rule, $P(\xi|Y, \Theta) \propto P(Y|\Theta, \xi)P(\xi|\Theta)$, yields the block-banded posterior precision: $P = K + H'(I_T \otimes \Sigma_M^{-1})H$. The posterior state $(\widehat{\xi})$ is computed based on the efficient simulation of Chan and Jeliazkov who use forward and backward substitution in (A7) exploiting the nature of P:

$$P\widehat{\xi} = K\xi_0 + H'(I_T \otimes \Sigma_M^{-1})Y \tag{A7}$$

The integrated log-likelihood (likelihood of the data given the parameters but marginally of the states) is evaluated at a high density point along the lines of Chib (1995) and, in particular, at the posterior mean of the states: $\log P(Y|\Theta) = logP(Y|\Theta, \widehat{\xi}) + logP(\widehat{\xi}|\Theta) - logP(\widehat{\xi}|Y, \Theta)$. The Random Walk Metropolis-Hastings algorithm is used to simulate draws from the non-tractable posterior.

Observation Equations

SOE's and Euro Area's trends for output, consumption, investment, and government spending are: $V_t \equiv \widetilde{A}_t/[\widetilde{X}_t \widetilde{\Upsilon}_t^{1/(1+\chi)}]$ and $V_t^* \equiv A_t^*/[X_t^* \Upsilon_t^{*1/(1+\chi)}]$, respectively. Small letters denote stationary variables. "$\hat{\cdot}$" denotes log-deviations from the stationary steady state. The measurement equations for SOE's real p.c. output and government spending are given by

$$\overline{\Delta lnY_t^o} = g_t^{\mathrm{v}} + \Delta\widehat{y}_t + \mu_t^y \quad \text{and} \quad \overline{\Delta lnG_t^o} = g_t^{\mathrm{v}} + \Delta\widehat{g}_t + \mu_t^g \text{ , where} \tag{B1}$$

$$g_t^{\mathrm{v}} \equiv dlnV_t = (\epsilon_t^{a,*} + \Delta\epsilon_t^a) - (\epsilon_t^{\chi,*} + \Delta\epsilon_t^{\chi}) - (\epsilon_t^{w,*} + \Delta\epsilon_t^w)/(1+\chi) \tag{B2}$$

μ_t^y and μ_t^g are measurement errors. The model analogues of the observed real p.c. consumption (C_t^o) and investment (I_t^o) are given by $C_{H,t} + C_{M,t}$ and $I_{H,t} + I_{M,t}$, respectively. Plugging in the demand functions, rendering the expressions stationary, and log-linearizing yields:

$$\overline{\Delta lnC_t^o} = g_t^{\mathrm{v}} + \Delta\widehat{c}_t + \mu_t^c \tag{B3}$$

$$\overline{\Delta lnI_t^o} = g_t^{\mathrm{v}} + \Delta\widehat{i}_t - (1-\lambda)\Delta\widehat{\Phi}_t + \mu_t^i \tag{B4}$$

The term $(1-\lambda)\Delta\widehat{\Phi}_t$ reflects the difference between the data-based and model-based definitions. Moreover, the model analogue of the investment deflator is

$$P_t^I = (P_{H,t}I_{H,t} + P_{M,t}^I I_{M,t})/(I_{H,t} + I_{M,t}) \tag{B5}$$

Using the demand functions and log-linearizing yields: $\overline{\Pi_t^{i,o}} = \widehat{\pi}_t^I + (1-\lambda)\Delta\widehat{\Phi}_t + \mu_t^{inv}$. Defining the CPI index in the same way and following the above steps leads to: $\overline{\Pi_t^{cpi,o}} = \widehat{\pi}_t + \mu_t^{cpi}$. The measurement equations for the GDP deflator and the nominal interest rate are $\overline{\Pi_t^{h,o}} = \widehat{\pi}_{H,t} + \mu_t^h$ and $\overline{R_t} = \widehat{r}_t + \mu_t^r$, respectively. The observation equations for wages and salaries and earnings are:

$$[\overline{\Delta lnW_t^{o,w}}, \overline{\Delta lnW_t^{o,e}}]' = [\epsilon_t^{a,*} + \Delta\epsilon_t^a][1,1]' + [1,\Psi_e]'\Delta\widehat{w}_t^r + [\mu_t^w, \mu_t^e]' \tag{B6}$$

The model-analogue of the exports deflator is given by: $(P_t^x C_{H,t}^* + P_t^x I_{H,t}^*)/(C_{H,t}^* + I_{H,t}^*)$. Log-linearizing and taking first differences of the latter yields: $\overline{\Pi_t^{x,o}} = \widehat{\pi}_t^x + \mu_t^x$. Similarly, the model-analogue of the imports deflator is given by: $(P_{M,t}C_{M,t} + P_{M,t}^I I_{M,t})/(C_{M,t} + I_{M,t})$. Following the previous steps, the resulting observation equation is: $\overline{\Pi_t^{im,o}} = [\tau C/(\tau C + \lambda I)]\widehat{\pi}_{M,t} + [\lambda I/(\tau C + \lambda I)]\widehat{\pi}_{M,t}^I + \mu_t^{im}$.

The measurement equations for the Euro Area are obtained from the above for $\tau = \lambda = 0$ and zero country-specific trend components.

Toy Model With Unit Root Wage Markup Shocks

Consider the closed-economy analogue of the SOE model without capital, government spending, habit formation, indexation, and staggered price and wage setting for simplicity. The only random walk shock is the wage markup. The only stationary shock is the price markup. Firms and labor agencies are monopolistically competitive. In this case, the non-linear model equilibrium is described by:

$$C_t^{-1} = E_t C_{t+1}^{-1} RR_t \quad \text{and} \quad Y_t = C_t \tag{C1}$$

$$Y_t = N_t \quad \text{and} \quad MC_t^r = W_t^r \tag{C2}$$

$$1 = \Upsilon_t^p MC_t^r \quad \text{and} \quad W_t^r = \widetilde{\Upsilon}_t MRS_t \tag{C3}$$

$$MRS_t = C_t N_t^{\chi} \quad \text{and} \quad W_t^r = C_t L_t^{\chi} \tag{C4}$$

(C1) gives the Euler equation (RR_t is the real interest rate) and the resource constraint. (C2) stems from the production function and the marginal cost. (C3) stems from the pricing of firms and labor unions. (C4) yields the marginal labor disutility in consumption terms and the participation constraint.

For a random walk process $\widetilde{\Upsilon}_t$, (C3) implies that either W_t^r or MRS_t inherits the non-stationarity. If it is the former, then MC_t^r becomes non-stationary too from (C2). Nevertheless, this cannot be the case because, according to (C3), MC_t^r is equal to $1/\Upsilon_t^p$ which is stationary. Therefore, MRS_t inherits the random walk behavior of the wage markup. Thus, $mrs_t \equiv \widetilde{\Upsilon}_t MRS_t$ is stationary. Given that $Y_t = C_t = N_t$, multiplying both sides of (C4) by $\widetilde{\Upsilon}_t$ yields: $mrs_t = \widetilde{\Upsilon}_t Y_t^{1+\chi}$. For the right hand side of the latter expression to be stationary, it must be the case that $Y_t^{1+\chi}$ grows (shrinks) at the rate at which $\widetilde{\Upsilon}_t$ shrinks (grows) along the balanced growth path. Thus, Y_t needs to be scaled up by $\widetilde{\Upsilon}_t^{1/(1+\chi)}$. By extension, consumption and employment need to be scaled by the same factor. Furthermore, for the right hand side of the second equation of (C4) to be stationary it must be the case that the stochastic trend of labor supply is $\Upsilon_t^{1/[\chi(1+\chi)]}$. Taking first differences of the stochastic trend of $ln(L_t/N_t)$ yields that the change in the trend of the unemployment rate which is given by $(1/\chi)dln(\widetilde{\Upsilon}_t)$.