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The analyses, opinions and findings of these papers represent the views of the authors, they are not necessarily those of the Banco de Portugal or the Eurosystem

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## Abstract

The Portuguese economy experienced a dramatic 2008–2012 period. Gross Domestic Product fell around 10%, while the unemployment rate jumped 8 percentage points, reaching almost 17% by 2012Q4. A semi-structural model with rational expectations—named, for ease of reference, *Model Q*—largely assigns such developments to “non-cyclical disturbances” in product and labour markets. The economy was also severely hit by two recessive periods in the euro area, and to a lesser extent by abnormally high risk premia. Model Q embodies a relatively robust Okun’s law, but not without important revisions in trend components. Recursive estimates over 2008–2012 include a decrease in the long-run real interest rate, shared by both Portugal and the euro area, as well as a decrease in the long-run growth rate of the trend component of output, mirrored by an increase in long-run unemployment, which raises “secular stagnation” concerns. Model Q fits the characteristics of a small economy integrated in the credible monetary union, and is parametrized with Bayesian techniques.

JEL: C51, E32, E52

Keywords: Small euro area economy, trend-cycle decomposition, Bayesian estimation, Okun’s law.

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## 1. Introduction

The Portuguese economy experienced a dramatic 2008–2012 period. Gross Domestic Product (GDP) fell around 10%, going back to levels observed soon after the euro’s inception, while unemployment soared, reaching 16.7% of the labour force by the end of 2012. Portuguese history is marked over this period by the request in 2011 for international financial assistance, agreed with the European Union (EU) and the International Monetary Fund (IMF).

Several explanations concur to characterize the 2008–2012 events. Among them, (i) spillover effects from the international financial crisis, which intensified in the second half of 2008; (ii) co-movements in sovereign risk hikes across vulnerable euro area countries (Ireland, Greece, Cyprus, Italy, Spain); (iii) the need to reduce macroeconomic imbalances; and, notwithstanding, (iv) sudden stops in credit flows, which intensified financial fragmentation in the monetary union.

The sharp deterioration in product and labour market conditions created at least two challenges: first, what drove such events? Was it a cyclical downturn, motivated by a persistent negative demand shock, partially imported, or the result of deeper structural problems? What was the relative importance of these disturbances? What role has monetary policy played, given that money market interest rates increased between 2010Q4 and 2011Q4? Second, how did standard textbook’s macro-modelling strategies behave under such extreme events? In particular, what happened to Okun’s law (the negative correlation between output and unemployment gaps)? This paper discusses both questions. On the one hand, it quantifies the relative importance of several disturbances using a semi-structural model designed to fit the economic context of Portugal. On the other hand, it evaluates the Okun’s law robustness throughout 2008–2012.

The discussion takes into account the results of a multivariate filter named herein, for ease of reference, “Model Q.” This model belong to a class usually called “Global Projection Models” (Carabenciov *et al.*, 2013) or “Quarterly Projection Models” (European System of Central Banks, 2015). Among key advantages are their flexibility, structural simplicity and tractability, following theoretical and practical advances in stochastic general equilibrium models. They have been used for specific regions, countries or topics, examples of which are remittance inflows, terms-of-trade effects via commodity prices, dollarization, etc. Extensively used by IMF staff, this type of model embeds (model-based) rational expectations, unobserved components, and stochastic shocks, some labelled demand, supply and monetary policy shocks (Carabenciov *et al.*, 2013).<sup>1</sup> This class of models lack microfoundations, however each behavioural equation is a fairly standard textbook’s equation with an economic interpretation (Berg *et al.*, 2006), namely an interest rate

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1. An early effort on the use of multivariate filters can be found in Laxton and Tetlow (1992).

equation, an inflation equation, an output equation and a version of Okuns’ law. For simplicity, all shocks affecting trend components are labelled herein “non-cyclical disturbances.”

Model Q considers two regions, and includes a set of restrictions that fit key characteristics of a small economy integrated in a monetary union. PESSOA—a micro-founded Dynamic Stochastic General Equilibrium (DSGE) model (Almeida *et al.*, 2013)—features similar restrictions. To my knowledge, this is the first attempt to offer a model-based decomposition of the above-mentioned events.

Model Q mixes elements of stringent rigidity with flexible components. A central ingredient is the assumption of a credible monetary union. This restriction implies that the nominal exchange rate is a credible institutional feature, expected to remain fixed, and that the monetary authority of the model—the European Central Bank—sets interest rates in line with a fully credible long-run inflation target, set herein at 2.0%. By design, the ECB reacts only to developments in euro area aggregates. Another key ingredient is the assumption that, in the long-run, both regions share (i) an identical growth rate in the trend component of output; (ii) an identical unemployment rate level; and (iii) an identical real interest rate. The short-run trend component of real interest rates, determined solely by euro area data, is also identical in both regions. Using an expression from the 1980s, the small economy is effectively tying its “hands” with the rest of the union (Giavazzi and Pagano, 1988). To my knowledge, this set of restrictions is a novelty in the literature. Among the flexible components, a special focus should be placed on all trend components, not only in product but also in labour markets. In addition, short and medium-run real interest may differ substantially and persistently, due to region-specific inflation expectations, while price differentials may have persistent effects on real exchange rates. Nominal interest rates can drift apart due to an exogenous risk premium—another key conditioning factor.

The model is parametrized with Bayesian techniques, using real Gross Domestic Product (GDP) data for Portugal and the euro area, as well as unemployment rates, consumer prices and official interest rates of the monetary union. The database is completed with a risk-premium measure of the Portuguese economy, computed as in Castro *et al.* (2014). The main result suggests that Portuguese product and labour markets were mainly hit by low frequency trend developments, and less so by cyclical factors. The economy was also severely hit by two recessive periods that occurred in the euro area, with a negative contribution that surpasses the impact of the sovereign risk hike. This outcome is consistent with the results reported by Castro *et al.* (2014). The increase in the trend component of the unemployment rate confirms the results obtained by Centeno *et al.* (2009), although current estimates are more volatile and depict a steeper outcome.

Model Q estimates include a decrease in the level of the trend component of Portuguese output over the last part of the sample, a result shared by

other methodologies. Empirical evidence is consistent with a robust Okun's law throughout 2008-2012, but not without important revisions in levels and growth rates of trend components. These developments are crucial to obtain sensible relationships, and to stabilize the entire system of equations, but create imprecisions and uncertainties in (pseudo) real time evaluations. It should be emphasized that the model is silent about all drivers of trend components. They can be seen as an "unexplained part" after taking into account all information included in the data, and after respecting the model's discipline, including all long-run restrictions. As a by-product, this paper argues that maybe interest should be placed on avoiding "secular stagnation" problems (Summers, 2014). Recursive estimates over 2008-2012 include a decrease in the long-run real interest rate, shared by both Portugal and the euro area, as well as a decrease in the long-run growth rate of the trend component of output, mirrored by an increase in long-run unemployment.

The structure of the article is as follows. Section 2 briefly describes the database. Section 3 introduces the model and its parametrization using Bayesian techniques. The model is evaluated in Section 4. Model-based decompositions of output and unemployment rates are reported in Section 5. Okun's law is evaluated in Section 6. Section 7 concludes, puts forward some tentative policy implications and possible ways to extend the model.

## 2. The database

The model is estimated with GDP data from the euro area and Portugal, alongside with unemployment rates, consumer prices and interest rates, as well as an estimate of the nationwide risk premium for the Portuguese economy. Their behaviour over the period 1999Q1-2014Q4 is depicted in Figure 1.

After the inception of the euro, real GDP recorded a relatively close upward trend in both regions (Figure 1a). This proximity ceased in 2003, when the Portuguese GDP recorded a permanent downward level shift against the euro area. In 2008, both regions experienced an unprecedented recessive period, which was more severe in the euro area, with real GDP falling around 6% between peak and trough (compares with 4.5% in Portugal). The recovery was short-lived, and a second recessive period followed. On this occasion, however, events unfolded quite differently: GDP fell close to 1% in the euro area, again between peak and trough, but this time plunged in Portugal, where the fall reached around 8.5%. During the period under analysis, between 2007Q4 and 2012Q4, GDP fell around 10% in Portugal and 2.5% in the euro area. During 2013, real GDP re-initiated an upward trend in both regions.

Euro area labour markets recorded a considerable degree of cross-country heterogeneity during the global financial crisis (European System of Central Banks, 2012). In the Portuguese case, the increase in the unemployment rate is sharply different in terms of magnitude (Figure 1b), but the divergence is even



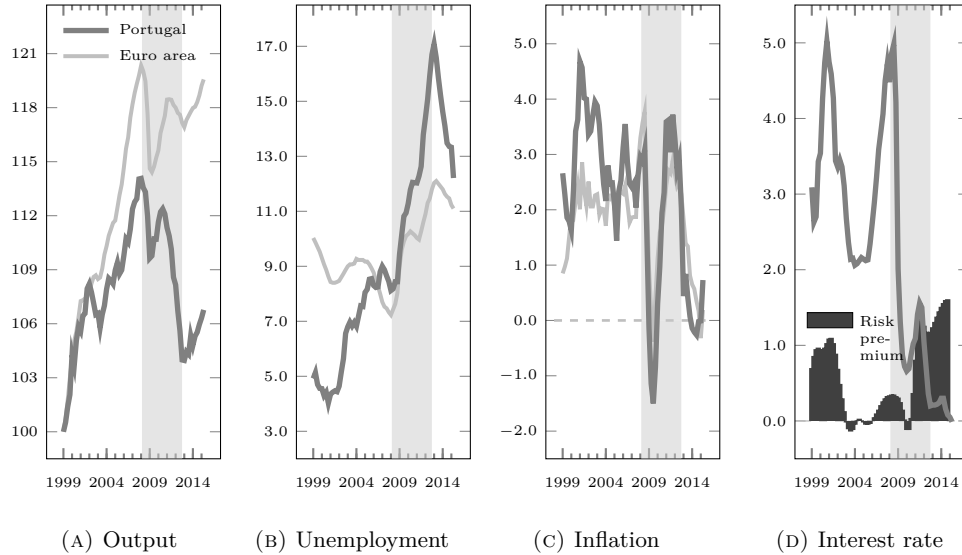


FIGURE 1: Observed variables

Source: Banco de Portugal, Eurostat and own calculations.

Notes: Output is in logs and normalized to GDP=100 in 1999Q1. Inflation is measured by the yearly log change of the HICP. Unemployment is in percentage of the labour force. Interest rates are given by ECB's official interest rates. The risk premium is computed for the Portuguese economy as in Castro *et al.* (2014). The shaded area identifies the 2007Q4-2012Q4 period. See Appendix A for details.

more striking before the crisis. While the euro area experienced a downward low frequency movement until 2008, the opposite occurred in Portugal. Between 2007Q4 and 2012Q4, the unemployment rate increased 8.3 percentage points (pp) in Portugal, and 4.5 pp in the euro area, reaching 16.7% and 11.8%, respectively. In 2013, this upward path was partially reversed in both regions, with Portugal also recording a sharper reduction.

Consumer prices, measured by the Harmonized Index of Consumer Prices (HICP), depicted a steeper increase in Portugal until 2008 than in the euro area (Figure 1c). The average year-on-year rate of change until 2007Q4 stood around 2.9%, which compares with 2.0% in the euro area. Between 2007Q4 and 2012Q4, this outcome changed, with the average values standing at 1.9% and 2.1%, respectively. Portugal also recorded negative changes in 2009 that were higher in absolute values.

Nominal interest rates, measured by ECB's official interest rates, stood on average around 3% until 2008 (Figure 1d). Between 2007Q4 and 2012Q4, the interest rate decreased from 4.2% to 0.8%. This period was however marked by an increased from around 1.0% to 1.5%, between 2011Q1-2011Q4, a period when the euro area showed some signs of recovery, in contrast with

the Portuguese economy. The exogenous risk-premium measure (also reported in Figure 1d) was relatively high by 1999, but soon reached a negligible level. Over the period under analysis, however, the risk premium recorded an upward trend, particularly after 2011, virtually compensating the fall in official interest rates.

Model Q is specifically designed for small countries participating in a monetary union. Ideally, it should only be estimated with an information set respecting these circumstances, and in the current exercise after the inception of the euro. However, given that the available sample period is relatively short, and plagued by an unprecedented crisis, the sample period was extended backwards until 1995Q1, which allows for 82 observations until 2015Q2. The 1995Q1-1998Q4 period is fully ignored.

### 3. A two-country model for a small euro area economy

This section clarifies the working environment of a small economy integrated in a monetary union, namely Portugal (Section 3.1), before presenting Model Q (Section 3.2), and its parametrization using Bayesian techniques (Section 3.3). The main references behind the model are Carabenciov *et al.* (2013) and European System of Central Banks (2015).

#### 3.1. Working environment

The working environment is characterized by the following restrictions:

- i. Developments in Portugal have negligible international impacts;
- ii. The world economy for Portugal is solely the rest of the monetary union;
- iii. Nominal exchange rates are irrevocably fixed and fully credible;
- iv. Monetary policy decisions are only conditional on EA macroeconomic developments;
- v. Portuguese nominal interest rates can deviate from those of the euro area due to an exogenous risk premium;
- vi. The long-run inflation target of monetary authorities is fully credible and set at 2.0%;
- vii. In the long-run, Portugal and the euro area are assumed to share an identical and constant...
  - a. ...growth rate in the trend component of output;
  - b. ...unemployment rate;
  - c. ...real interest rate;
- viii. In the short run, the trend component of the real interest rate is identical in both regions;
- ix. Actual and expected inflation in Portugal and in the euro area may differ (with an impact on the real interest rate).

### 3.2. Behavioural and a-theoretical equations

The model includes one interest rate equation shared by both regions, and three region-specific equations, namely a dynamic version of Okun’s law, an output equation and an inflation equation. Euro area endogenous variables are identified with an asterisk “\*.”

Equations are expressed in “gaps,” *i.e.* in deviations from unobserved trends—identified with a tilde “~.” The two-regions model features (model-consistent) rational expectations. The expectation identifier is omitted.

Okun’s law, which is the only functional form in the model linking product and labour markets, has an identical structure in the euro area and Portugal. Equations (1) and (2) associate current unemployment gaps to its own lead and lagged values, as well as to the output gap. More precisely,

$$(1 + \alpha_1\alpha_2)u_{gap,t} = \alpha_1u_{gap,t-1} + \alpha_2u_{gap,t+1} - \alpha_3y_{gap,t-1} + \varepsilon_{u_{gap},t}, \quad (1)$$

$$(1 + \alpha_1^*\alpha_2^*)u_{gap,t}^* = \alpha_1^*u_{gap,t-1}^* + \alpha_2^*u_{gap,t+1}^* - \alpha_3^*y_{gap,t-1}^* + \varepsilon_{u_{gap},t}^*. \quad (2)$$

Here,

$$u_{gap,t} = u_t - \tilde{u}_t, \quad (1a) \quad u_{gap,t}^* = u_t^* - \tilde{u}_t^*, \quad (2a)$$

$$y_{gap,t} = y_t - \tilde{y}_t, \quad (1b) \quad y_{gap,t}^* = y_t^* - \tilde{y}_t^*, \quad (2b)$$

where  $u_t$  and  $u_t^*$  are region-specific actual unemployment rates, and  $y_t \equiv 100 \times \ln(\text{GDP}_t)$  and  $y_t^* \equiv 100 \times \ln(\text{GDP}_t^*)$  are computed with actual GDP data.<sup>2</sup> The presence of lagged values captures labour market frictions, while lead values allow for expectations to also play a role. Each equation features idiosyncratic disturbance terms ( $\varepsilon_{u_{gap},t}$  and  $\varepsilon_{u_{gap},t}^*$ ).

In contrast with Okun’s law, which considers an identical structure in both regions, output equations consider both common and idiosyncratic structures that account for the specificities of a small euro area economy. These take the following form:

$$(1 + \beta_1\beta_2)y_{gap,t} = \beta_1y_{gap,t-1} + \beta_2y_{gap,t+1} - \beta_3r_{gap,t-1} + \beta_4y_{gap,t-1}^* + \beta_5y_{gap,t-1} + \varepsilon_{y_{gap},t}, \quad (3)$$

$$(1 + \beta_1^*\beta_2^*)y_{gap,t}^* = \beta_1^*y_{gap,t-1}^* + \beta_2^*y_{gap,t+1}^* - \beta_3^*r_{gap,t-1}^* + \varepsilon_{y_{gap},t}^*. \quad (4)$$

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2. Note that  $(1 + \omega_1\omega_2)x_t - \omega_1x_{t-1} - \omega_2E_t x_{t+1} = E_t(1 - \omega_1L)(1 - \omega_2F)x_t$ , where  $E_t$  is the expectation identifier, and  $L = 1$  and  $F = 1$  are the lag and forward operators evaluated at unity, respectively. A DSGE model where the unemployment-inflation relationship considers current, lagged, and future unemployment can be found in Ravenna and Walsh (2008).

Here,

$$r_{gap,t} = r_t - \tilde{r}_t^*, \quad (3a)$$

$$r_{gap,t}^* = r_t^* - \tilde{r}_t^*, \quad (4a)$$

$$r_t = i_t - \pi_{t+1}, \quad (3b)$$

$$r_t^* = i_t^* - \pi_{t+1}^*, \quad (4b)$$

$$q_{gap,t} = q_t - \tilde{q}_t, \quad (3c)$$

where  $i_t^*$  is the official interest rates of the monetary authority,  $p_t \equiv 100 \times \ln(\text{IHPC}_t)$  and  $p_t^* \equiv 100 \times \ln(\text{IHPC}_t^*)$  are computed with Harmonized Indices of Consumer Prices,  $q_{gap,t}$  is the real exchange rate gap, and  $q_t = p_t^* - p_t$ . The common structure in output equations associates current gaps to its own lead and lagged values, as well as to the real interest rate. The presence of lagged values captures adjustment costs and allows shocks to have persistent effects. Lead values allow forward-looking elements to also play a role, a key ingredient of standard micro-founded general equilibrium models.

The negative sign behind real interest rates  $r_t$  and  $r_t^*$  in equations (3) and (4) provide a key link between the common monetary policy and output.<sup>3</sup> They combine a common variable ( $i_t^*$ ) with an exogenous risk premium  $\psi_t$  and idiosyncratic expectations:  $\pi_{t+1}$  and  $\pi_{t+1}^*$ . As in PESSOA, nominal interest rates in Portugal can deviate from  $i_t^*$  by  $\psi_t$ , assumed herein to follow an autoregressive process. More precisely,

$$i_t = i_t^* + \psi_t, \quad (5a)$$

$$\psi_t = \rho_i \psi_{t-1} + \varepsilon_{i,t}, \quad (6a)$$

where  $\psi_t$  is measured by the spread of implied sovereign debt interest rates *vis-à-vis* the euro area average, as in Castro *et al.* (2014), and  $0 < \rho_i < 1$ . The exogenous risk premium is an highly relevant assumption, implying that the model is fully silent about its determinants.<sup>4</sup>

Equation (3) allows the Portuguese output gap to be affected by the euro area output gap, and by the real exchange rate gap. The former captures external quantity effects, *e.g.* a buoyancy or a depressed euro area economy; the later price deviations from its trend component. Real exchange rate gaps are only affected by price differentials and not by time-varying nominal exchange rates, in contrast with Carabenciov *et al.* (2013).<sup>5</sup> The model neglects movements in expected nominal exchange rates—they are assumed to be fully credible and irrevocably fixed at unity within the euro area. In addition, the model allows for price deviations from trend, captured by the following

3. The negative link between the output gap and the real interest rate gap has been highlighted in the empirical literature for the euro area among others by Garnier and Wilhelmsen (2004).

4. A related model with an exogenous premium can be found in Andrieu *et al.* (2014).

5. Carabenciov *et al.* (2013) include an equation capturing uncovered interest rate parities, which are influenced by distinct nominal interest rates, distinct nominal exchange rates, and a measure of expected real exchange rates.

autoregressive process:

$$q_{gap,t} = \rho_{\bar{q}} q_{gap,t-1} + \varepsilon_{q_{gap},t}, \quad (7a)$$

where  $0 < \rho_{\bar{q}} < 1$ . Disturbance terms  $\varepsilon_{y_{gap},t}$  and  $\varepsilon_{y_{gap},t}^*$  in equation (3) are assumed to capture domestic and foreign demand shocks, respectively.

Inflation equations associate current price changes to lagged and expected inflation, the output gap and, in the case of Portugal, to changes in the real exchange rate. Their structure is given by

$$(1 + \lambda_1 \lambda_2)(\pi_t - \pi) = \lambda_1(\pi_{4_{t-1}} - \pi) + \lambda_2(\pi_{4_{t+4}} - \pi) + \lambda_3 y_{gap,t-1} + \lambda_4 \pi_{4_{t-1}} - \varepsilon_{\pi,t}, \quad (8)$$

$$(1 + \lambda_1^* \lambda_2^*)(\pi_t^* - \pi) = \lambda_1^*(\pi_{4_{t-1}}^* - \pi) + \lambda_2^*(\pi_{4_{t+4}}^* - \pi) + \lambda_3 y_{gap,t-1}^* - \varepsilon_{\pi,t}^*, \quad (9)$$

where  $\pi = 2.0\%$  is an inflation anchor set by the monetary authority (assumed to be fully credible), common to both regions, around which actual and expected values fluctuate; furthermore:

$$\pi_t = 4(p_t - p_{t-1}), \quad (8a) \quad \pi_t^* = 4(p_t^* - p_{t-1}^*), \quad (9a)$$

$$\pi_{4_t} = p_t - p_{t-4}, \quad (8b) \quad \pi_{4_t}^* = p_t^* - p_{t-4}^*, \quad (9b)$$

$$\pi_{4_{q,t}} = \pi_{4_t}^* - \pi_{4_t}. \quad (8c)$$

An increase in  $\pi_{4_{q,t}}$  represents a real depreciation, which implies that  $\lambda_4$  is expected to be positive. Disturbance terms  $\varepsilon_{\pi,t}$  and  $\varepsilon_{\pi,t}^*$  are labelled domestic and foreign supply shocks, respectively. The associated negative signs in equations (8) and (9) ensures that a positive supply shock is consistent with downward inflation pressures, as in Carabenciov *et al.* (2013).

The interest rate equation is common to the whole monetary union and given by

$$i_t^* = \gamma_1 i_{t-1}^* + (1 - \gamma_1) \left[ (\tilde{r}_t^* + \pi_{4_{t+4}}^*) + \gamma_2 (\pi_{4_{t+4}}^* - \pi) + \gamma_3 y_{gap,t-1}^* \right] + \varepsilon_{i,t}, \quad (10)$$

where  $\pi = 2.0\%$  is the inflation target, an anchor for the inflation equations. Official interest rates respond to changes in the trend component of real interest rates, to expected inflation, and to the output gap. The presence of lagged interest rates ensures smooth interest rate transitions. Note that the forward looking term  $(\tilde{r}_t^* + \pi_{4_{t+4}}^*)$  has a nominal “flavour” that also affects interest rate transitions. One-year ahead expectations, i.e.  $\pi_{4_{t+4}}^*$ , ties this equation to the euro area inflation equation (9), but not to the PT equation, which

has important implications for impulse response functions (as clarified below). Disturbance  $\varepsilon_{i,t}$  is labelled a monetary policy shock.<sup>6</sup>

As in Carabenciov *et al.* (2013), the trend component of the real interest rate is assumed to evolve around a fixed benchmark  $r$ , namely

$$\tilde{r}_t^* = \rho_r^* r + (1 - \rho_r^*) \tilde{r}_{t-1}^* + \varepsilon_{\tilde{r},t}^*, \quad (11)$$

where  $0 < \rho_r^* < 1$ . It should be noted that if  $\rho_r^* = 0$ , then this equation would become a pure random walk; if  $\rho_r^* = 1$  then  $r$  would also be the short-run key component. The assumed intermediate parametrization allows for short-run deviations from the long-run real interest rate.

Finally, the law of motion of the remaining trend components are a-theoretical equations defined as follows:

$$\tilde{u}_t = \rho_u u + (1 - \rho_u) \tilde{u}_{t-1} + \tilde{u}_{g,t}, \quad (12a) \quad \tilde{u}_t^* = \rho_u^* u + (1 - \rho_u^*) \tilde{u}_{t-1}^* + \tilde{u}_{g,t}^*, \quad (13a)$$

$$\tilde{u}_{g,t} = \rho_{\tilde{u}} \tilde{u}_{g,t-1} + \varepsilon_{\tilde{u},t}, \quad (12b) \quad \tilde{u}_{g,t}^* = \rho_{\tilde{u}}^* \tilde{u}_{g,t-1}^* + \varepsilon_{\tilde{u},t}^*, \quad (13b)$$

$$\tilde{y}_t = \tilde{y}_{t-1} + y_g + \tilde{y}_{g,t}, \quad (12c) \quad \tilde{y}_t^* = \tilde{y}_{t-1}^* + y_g + \tilde{y}_{g,t}^*, \quad (13c)$$

$$\tilde{y}_{g,t} = \rho_{\tilde{y}} \tilde{y}_{g,t-1} + \varepsilon_{\tilde{y},t}, \quad (12d) \quad \tilde{y}_{g,t}^* = \rho_{\tilde{y}}^* \tilde{y}_{g,t-1}^* + \varepsilon_{\tilde{y},t}^*. \quad (13d)$$

$$\tilde{q}_t = \tilde{q}_{t-1} + \varepsilon_{\tilde{q},t}, \quad (12e)$$

Equations (12a)–(12b) and (13a)–(13b) have an identical structure, which encompasses the possibility of identical movements in Portugal and in the euro area. Furthermore, trend components of unemployment have a fixed long-run level, as in Benes *et al.* (2010) or Balgrave *et al.* (2015). The novelty herein is to assume that this level, given by  $u$ , is identical in both regions.

Equations (12c)–(12d) and (13c)–(13d) have also an identical structure, where parameter  $y_g$  represents the growth rate of the trend component of output shared by Portugal and the euro area. Although this is also a novelty in the literature, to my knowledge, it emerges naturally from a theoretical point a view, given that all regions in a monetary union should grow at the same rate in the long run. Finally, the approach herein only considers growth shocks. While a more general set-up typically adds level shocks, the current structure remains sufficiently flexible to capture distinct low frequency outcomes (in line with the empirical evidence reported in Figure 1). Although relatively smoother, the structure preserves the possibility of sharp movements in trend levels, given the adjustment towards long-run growth.<sup>7</sup> The trend component of the real exchange rate is assumed to be a random walk.

6. Carabenciov *et al.* (2008) used a similar structure, except that their inflation expectations are defined as  $\pi 4_{t+3}^*$ .

7. Note for example that the change in Portuguese trend levels ( $\tilde{y}_t - \tilde{y}_{t-1}$ ) is always on the long-run growth  $y_g$ , except when changed by the stationary autoregressive process  $\tilde{y}_{g,t}$ .

By design,  $0 < \rho_{\tilde{u}}, \rho_{\tilde{u}}^*, \rho_{\tilde{y}} < 1$ , which ensures that growth shocks have a temporary nature. Disturbances  $\varepsilon_{\tilde{u},t}$ ,  $\varepsilon_{\tilde{y},t}$ ,  $\varepsilon_{\tilde{u},t}^*$ , and  $\varepsilon_{\tilde{y},t}^*$ , which capture deep-rooted economic features linked to country-specific institutions, are for simplicity named “non-cyclical shocks.” For simplicity,  $\varepsilon_{\tilde{q},t}$  is also added to this group of shocks.

As already mentioned, the model is silent about all drivers of trend components. They simply take into account all information included in the data, and the entire model’s structure, including all long-run restrictions. For instance, the output gap cannot be dynamically nil if inflation is different from the (assumed fully-credible) 2% level. Lastly, there is no assumption of cross correlation in disturbances, in contrast for instance with Carabenciov *et al.* (2008).

### 3.3. Model parametrization

The model is parametrized with Bayesian techniques.<sup>8</sup> Table 1 reports prior and estimated moments of posterior distributions of “Economic parameters,” namely those associated with unemployment, output, inflation and interest rates equations.

Prior distributions incorporate the following general characteristics, except when numerical accuracy and instability problems emerge during the computation process. First, the parameters of the common structure of equations (1)-(9) have identical prior distributions, means and standard deviations, which allows for the possibility of indistinct economic regions. Second, parameters associated with domestic backward- and forward-looking variables have identical starting values, namely 0.5, which implies not taking any *a priori* stance on their relative importance. They are conditioned to vary over  $]0, 1[$ . Third, as already mentioned,  $0 < \rho_i, \rho_{\tilde{q}}, \rho_{\tilde{u}}, \rho_{\tilde{y}}, \rho_{\tilde{u}}^*, \rho_{\tilde{y}}^* < 1$ . Prior means associated with the interest rate equation are close to Carabenciov *et al.* (2008). In some cases, prior distributions take a highly informative nature, with low standard deviations (parameters  $\beta_3$  and  $\beta_3^*$  are two examples). Although the long-run components of output growth, unemployment and real interest rate can be estimated over a wide range of possibilities, the autoregressive parameters are typically constrained, particularly  $\rho_{\tilde{u}}$  and  $\rho_{\tilde{u}}^*$ . In the case of parameter  $\rho_{\tilde{y}}$ , it should be reminded that quarterly data are derived from a disaggregation of annual data, which creates a highly smooth variable—See Appendix A for details. Even so, the posterior mode turned out to be remarkably above the prior mean.

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Balgrave *et al.* (2015), who are among those who allow for alternative speed adjustments back to long-run growth, provide an overview of the role of level and growth shocks.

8. The results are computed with Dynare - version 4 (Adjemian *et al.*, 2011).

Parameter	Prior distribution			Posterior distribution		
	Name	Mean	Stand. Dev	Mode	Stand. Dev	(7)= (6)/(4)
(1)	(2)	(3)	(4)	(5)	(6)	(6)/(4)
<b>Economic parameters</b>						
Unemployment						
$\alpha_1$	$u_{gap,t-1}$	beta	0.50	0.10	0.452	0.091
$\alpha_2$	$u_{gap,t+1}$	beta	0.50	0.20	0.502	0.119
$\alpha_3$	$y_{gap,t-1}$	gamma	0.30	0.10	0.185	0.043
Output						
$\beta_1$	$y_{gap,t-1}$	beta	0.50	0.05	0.465	0.048
$\beta_2$	$y_{gap,t+1}$	beta	0.50	0.20	0.596	0.100
$\beta_3$	$r_{gap,t-1}$	gamma	0.20	0.02	0.180	0.018
$\beta_4$	$y_{gap,t-1}$	gamma	0.20	0.10	0.326	0.065
$\beta_5$	$q_{gap,t-1}$	gamma	0.10	0.05	0.076	0.044
Inflation						
$\lambda_1$	$(\pi 4_{t-1} - \pi)$	beta	0.50	0.20	0.177	0.101
$\lambda_2$	$(\pi 4_{t+4} - \pi)$	beta	0.50	0.20	0.215	0.147
$\lambda_3$	$y_{gap,t-1}$	gamma	0.30	0.05	0.258	0.042
$\lambda_4$	$\pi 4_{q,t-1}$	gamma	0.01	0.01	0.007	0.004
Unemployment*						
$\alpha_1^*$	$u_{gap,t-1}^*$	beta	0.50	0.10	0.608	0.069
$\alpha_2^*$	$u_{gap,t+1}^*$	beta	0.50	0.20	0.690	0.094
$\alpha_3^*$	$y_{gap,t-1}^*$	gamma	0.30	0.10	0.098	0.026
Output*						
$\beta_1^*$	$y_{gap,t-1}^*$	beta	0.85	0.05	0.959	0.015
$\beta_2^*$	$y_{gap,t+1}^*$	beta	0.50	0.20	0.140	0.095
$\beta_3^*$	$r_{gap,t-1}^*$	gamma	0.20	0.02	0.186	0.019
Inflation*						
$\lambda_1^*$	$(\pi 4_{t-1}^* - \pi)$	beta	0.50	0.20	0.164	0.065
$\lambda_2^*$	$(\pi 4_{t+4}^* - \pi)$	beta	0.50	0.20	0.257	0.179
$\lambda_3^*$	$y_{gap,t-1}^*$	gamma	0.30	0.05	0.279	0.042
Interest rate						
$\gamma_1$	$i_{t-1}$	beta	0.60	0.02	0.618	0.019
$\gamma_2$	$(\pi 4_{t+4}^* - \pi)$	gamma	1.50	0.20	1.349	0.180
$\gamma_3$	$y_{gap,t-1}^*$	gamma	0.20	0.05	0.171	0.043
Other parameters						
$y_g$		normal	2.00	0.50	1.801	0.359
$r$		normal	2.00	0.50	0.726	0.221
$u$		normal	7.50	5.00	9.984	1.339
$\rho_u$		gamma	0.05	0.05	0.010	0.012
$\rho_{\bar{u}}$		beta	0.50	0.10	0.620	0.088
$\rho_{\bar{y}}$		beta	0.90	0.05	0.941	0.033
$\rho_{\bar{q}}$		beta	0.75	0.10	0.783	0.104
$\rho_{\bar{i}}^*$		beta	0.75	0.02	0.841	0.015
$\rho_u^*$		beta	0.05	0.05	0.008	0.011
$\rho_{\bar{u}}^*$		beta	0.50	0.10	0.720	0.070
$\rho_{\bar{y}}^*$		beta	0.90	0.05	0.887	0.048
$\rho_{\bar{r}}^*$		beta	0.50	0.05	0.474	0.050

TABLE 1. Priors and Posteriors: economic parameters

Source: Own calculations.

Notes: Abbreviation “invg” refers to the inverse gamma distribution.



Parameter	Prior distribution			Posterior distribution		(7)= (6)/(4)
	Name	Mean	Stand. Dev	Mode	Stand. Dev	
(1)	(2)	(3)	(4)	(5)	(6)	
Standard deviations						
$\sigma_{\varepsilon_{ugap}}$	invg	0.50	$\infty$	0.169	0.027	-
$\sigma_{\varepsilon_{ygap}}$	invg	0.50	$\infty$	0.464	0.050	-
$\sigma_{\varepsilon_{\pi}}$	invg	0.50	$\infty$	2.906	0.234	-
$\sigma_{\varepsilon_{qgap}}$	invg	0.10	$\infty$	0.046	0.019	-
$\sigma_{\varepsilon_{ugap}}^*$	invg	0.50	$\infty$	0.074	0.007	-
$\sigma_{\varepsilon_{ygap}}^*$	invg	0.50	$\infty$	0.435	0.052	-
$\sigma_{\varepsilon_{\pi}}^*$	invg	0.50	$\infty$	2.078	0.168	-
$\sigma_{\varepsilon_i}^*$	invg	0.50	$\infty$	0.140	0.026	-
$\sigma_{\varepsilon_i}$	invg	0.50	$\infty$	0.373	0.036	-
$\sigma_{\varepsilon_{\bar{u}}}$	invg	0.10	$\infty$	0.207	0.037	-
$\sigma_{\varepsilon_{\bar{y}}}$	invg	0.10	$\infty$	0.144	0.053	-
$\sigma_{\varepsilon_{\bar{u}}}^*$	invg	0.10	$\infty$	0.053	0.011	-
$\sigma_{\varepsilon_{\bar{y}}}^*$	invg	0.10	$\infty$	0.159	0.044	-
$\sigma_{\varepsilon_{\bar{r}}}^*$	invg	0.25	$\infty$	0.274	0.075	-
$\sigma_{\varepsilon_{\bar{q}}}$	invg	0.10	$\infty$	0.412	0.032	-

TABLE 2. Priors and Posteriors: standard deviations

Source: Own calculations.

Notes: Abbreviation “invg” refers to the inverse gamma distribution.

The results show that there is a considerable amount of information in the data. Column (7) reports the ratio between the standard deviation of the posterior distribution and the standard deviation of the prior distribution. A lower than unity value is consistent with informative data. Some ratios reported in column (7) are not distant from unity, which suggest that some priors take a highly informative nature, particularly in the case of Portugal.

Several estimates are dependent on technical decisions that should be acknowledged, particularly when numerical problems arose. Parameters  $\beta_1$  and  $\beta_1^*$  are two examples. Due to occasional computation problems, both prior means have low standard deviations, which implies the mode of the former is somehow relatively constrained to remain in the vicinity of 0.5, whereas the latter of 0.85. With an higher prior for the standard deviation, the posterior modes would be relatively close to the one reported in Table 1, but only when the sample includes, for instance, the full period. Recursive estimates that were implemented to validate the model, with short samples, created some computational problems. Parameters  $\beta_3$  and  $\beta_3^*$  are another example, this time due to the tendency for relatively low posterior modes, in part associated to the last part of the sample (where the zero lower limit on nominal interest rates becomes binding). Low prior standard deviations prevented extremely low estimates, paving the way for a more significant role from monetary policy. In

the case of  $\beta_3^*$ , the posterior mode remains, nevertheless, slightly below the one computed by Carabenciov *et al.* (2008).

Parameters of the interest rate equation have also a high ratio of standard deviations. The apparent downward trend in interest rate data—recall Figure 1d—tends to favour a high  $\gamma_1$ , but this was excluded due to instability problems and to unrealistic sinusoidal behaviour in impulse response functions following interest rate shocks.

The results associated with the real exchange rate seem to suggest that its definition, the relative price of final consumption goods, may embed important limitations. The posterior mode of parameter  $\lambda_4$  is relatively close to zero, much lower than the ones reported by Carabenciov *et al.* (2008), suggesting under the current parametrization a virtually nil impact of the real exchange rate on inflation developments. Parameter  $\beta_5$  is also relatively low. Part of these limitations may be due to relative changes in indirect taxes that are being interpreted as real exchange movements.<sup>9</sup>

Among the estimated differences between Portugal and the euro area, a special focus should be placed on output equations, where expectations play a more important role in Portugal. The opposite is valid on Okun’s law, but with a smaller divergence.

Table 2 reports the equivalent results for standard deviations, identified by  $\sigma_x$ , where  $x \in \{\varepsilon_{u_{gap}}, \varepsilon_{y_{gap}}, \varepsilon_\pi, \varepsilon_{q_{gap}}, \varepsilon_{u_{gap}}^*, \varepsilon_{y_{gap}}^*, \varepsilon_\pi^*, \varepsilon_i, \varepsilon_{\tilde{u}}, \varepsilon_{\tilde{u}}^*, \varepsilon_{\tilde{y}}, \varepsilon_{\tilde{y}}^*, \varepsilon_{\tilde{r}}, \varepsilon_{\tilde{q}}\}$ . The ratio reported in column (7) is not defined for the standard deviation of the shocks (because of the assumption of infinity standard deviation of all prior distributions). Their estimated posterior modes are neither systematically below nor above any prior mean. Posterior mode estimates for the standard deviation of the shocks are in general higher in Portugal than in the euro area, consistent with a higher macroeconomic instability, both in real and nominal variables.

#### 4. Model evaluation

This section evaluates Model Q using several criteria. The first criterion is rather practical and simply verifies if the unobserved components of the model, namely the trend components of output and unemployment, classify as a “sensible” outcome (Section 4.1). This includes a brief comparison with alternative estimates.

The second criterion verifies, in line with Carabenciov *et al.* (2008), if the impulse response functions (IRF) are compatible with an acceptable view with respect to the functioning of the economy in response to shocks (Section 4.2).

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9. Over 2008-2012, the Portuguese VAT changed on five occasions.

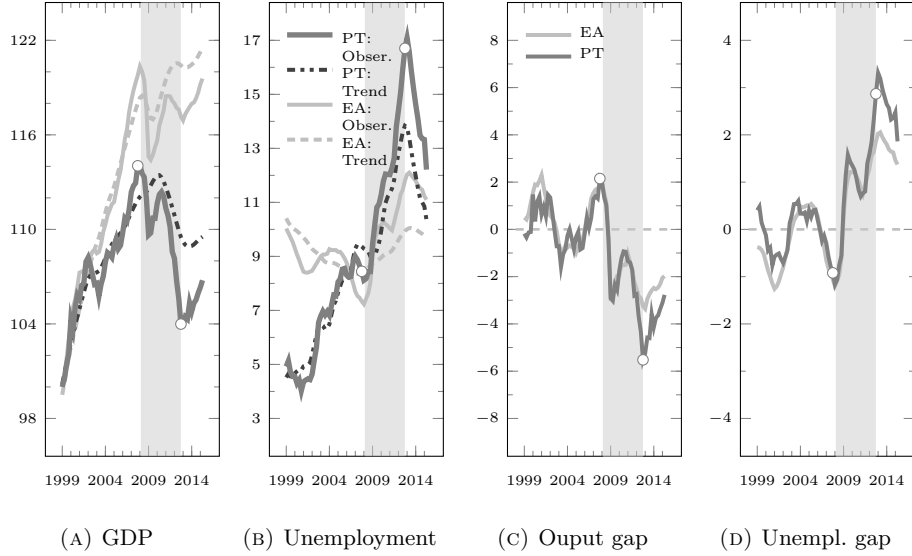


FIGURE 2: Observed variables and trends

Source: Banco de Portugal, Eurostat and own calculations.

Notes: Output gaps are in percentage, and unemployment gaps in p.p.. Portugal and the euro area are identified with PT and EA, respectively.

The last criterion evaluates if the posterior modes are not plagued by instability and instead qualify as useful to analyse the 2008-2012 period (Section 4.3).

#### 4.1. Trends and cycles

Figure 2 depicts the trend components of output and unemployment rates in Portugal, as well as the implied output and unemployment gaps. The results are compared with the outcome for the euro area.

The results seem to represent, in general, an acceptable description of Portuguese events, and are in line with the perception that the economy experienced a dramatic 2008-2012 period. They suggest that actual output was above trend by 2007Q4, around 2%, but rapidly moved below trend as the international financial crisis gained momentum. Actual and trend components came closer around 2011, but only briefly. In fact, the results suggest that this period is marked by the beginning of a persistent downward movement not only in actual GDP, but also in the trend component of output. The model flexibility can thus easily accommodate a constant and positive long-run growth rate of 1.8% (see Table 1), and persistent negative short-run growth rates. The downward movement came to an halt only by 2013, and thus outside the period under analysis.

The trend component of the Portuguese unemployment rate is marked by a sharp upward movement almost over the entire sample period. It only recedes in recent years, namely after 2013. Given that the standard deviation of the shock  $\sigma_{\varepsilon_{\bar{u}}}$  is allowed to have infinity variance, the trend level estimates are also (unsurprisingly) highly volatile. It should be mentioned that the a-theoretical equations cannot isolate the crisis effects from other impacts, and fully ignores any effect from methodological changes in the Labour Force Survey, including the series break in 2011Q1, a period when the trend component increases sharply.<sup>10</sup>

In comparison with the euro area, there are signs of similarities but also of sharp differences. The Portuguese and euro area's output and unemployment gaps reveal high synchronicity. The linear correlation coefficients between output gaps (Figure 2c) or unemployment gaps (Figure 2d) over 1999Q1-2015Q2 are close to 0.9. The Portuguese data is more volatile: the standard deviation of the unemployment and output gaps stand at 1.9 and 1.2, respectively, which compares with 1.7 and 1.0 in the euro area. The results are consistent with the view that the crisis left visible marks in both regions, although the differences are quite impressive by 2012Q4. The larger output gap in the euro area was close to 3% in absolute terms, while the Portuguese was close to 5%. It is also particularly revealing that the trend dynamics of both output and unemployment rates are unequal, although the assumed structure from which the model is estimated is identical. The first euro area recession coincides with an abrupt reduction in the trend component of output that does not occur in Portugal. Moreover, the trend component of the unemployment rate depicts an initial downward trend in the euro area, before the crisis inception, in contrast with the Portuguese case. Differences in the upward trend, afterwards, are also noteworthy, although more correlated.

Figure 3 compares Portuguese trend components with alternative estimates, namely those proposed by Almeida and Félix (2006) and Centeno *et al.* (2009). There are some common results across methodologies, but there are also some significant differences, which imply different economic readings. Point estimates vary substantially, suggesting high uncertainty in unobserved variables.

In general, all statistical filters suggested by Almeida and Félix (2006) feature a downward trend over the recent past, in line with the results of Model Q. In comparison with the Hodrick-Prescott filter (HP), or the Baxter-King filter (BF), the trend components are all relatively close during most part of the sample period, within a  $\pm 1.5$  percentage points differential in trend levels (Figure 3a and 3b). During the period under analysis, the differences are however rather significant. The fall in the trend component implied by both

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10. In 2011, Statistics Portugal introduced a new data collection scheme (associated to the use of telephone interviews); questionnaire changes; and new field work supervision technologies.

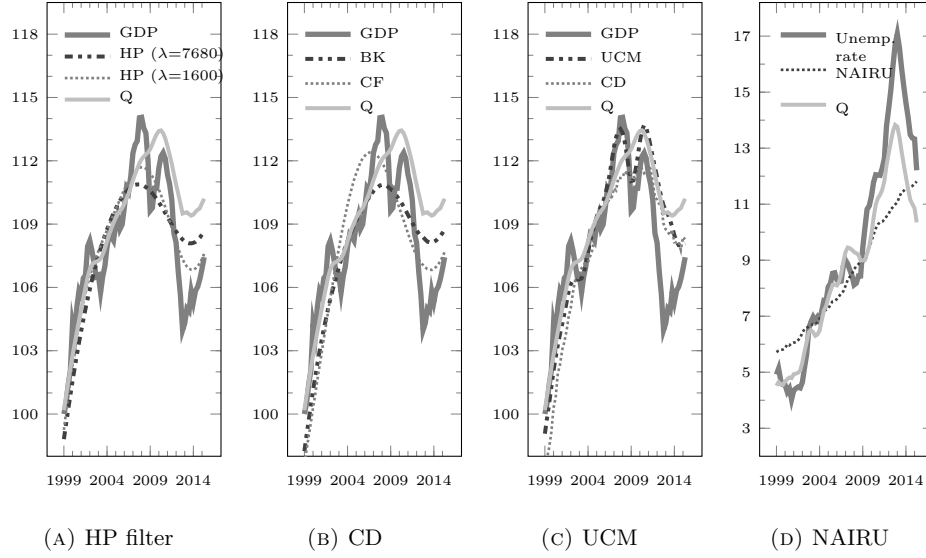


FIGURE 3: Comparisons with alternative estimates for the Portuguese case

Source: Banco de Portugal, Eurostat and own calculations.

Notes: Vertical axis have the same metric as Figure 2. Model Q's results are named "Q." The Baxter-King (BK), Christiano-Fitzgerald (KF), and Hodrick-Prescott (HP) filters, the latter with a smoothness parameter  $\lambda = 7680$ , as well as the Cobb-Douglas (CD) production function estimate are implemented as in Almeida and Félix (2006). All results, including the HP filter with  $\lambda = 1600$ , take into account an exogenous average increase of GDP over 2015Q3-2019Q4. "UCM" and "NAIRU", which refer to the trend components of output and unemployment, respectively, are computed as in Centeno *et al.* (2009).

filters is initiated 6-7 quarters before Model Q's estimates, namely 2008Q1-2008Q2 (and thus before the Lehman Brothers bankruptcy or the collapse of world trade flows), and imply large positive output gaps that are economically difficult to explain. The more standard HP filter with  $\lambda = 1600$  postpones the fall in the trend component to 2008Q3 (also depicted in Figure 3a), and implies smaller gaps, but places the last estimate around actual GDP levels—an odd business cycle position. In comparison with the Christiano-Fitzgerald (CF) filter, the fall in the trend component begins in 2007Q1 (and thus even before the USA sub-prime crisis, by mid-2007). The difficulties in explaining business cycle positions are similar.

In comparison with estimates computed with a Cobb-Douglas (CD) production function, which uses employment levels derived from the NAIRU presented in Figure 3d and a measure of the trend component of Total Factor Productivity (TFP), trend estimates continue on suggesting negative

growth rates over the last part of the sample.<sup>11</sup> Trend levels computed with the production function are relatively stable over 2007Q4–2011Q3, which creates positive output gaps in 2010, in contrast with Model Q, which depicts (systematic) negative output gaps. The (negative) output gap estimate at the end of the sample is also significantly larger in Model Q.

Estimates computed with the methodology suggested by Centeno *et al.* (2009), which already features a system of equations with an Okun’s law and a Phillips curve, continue on depicting a downward trend in output over the recent past, but in this case the main difference is the relatively lower volatility of Model Q’s estimates, particularly over 2008–2012 (Figure 3c). This result is partly explained by Model Q’s inertia, fully absent in Centeno *et al.* (2009), and by a looser relationship between output and unemployment gaps. The trend components of unemployment depicted in Figure 3d share an identical upward trend over the sample period, although steeper (and with a higher volatility) in Model Q’s estimates. The possibility of high dispersion between output and unemployment gaps and the assumption of infinity standard deviations in the prior distributions of all shocks’ standard deviations (as clarified in Table 2) are key explanations behind these differences. In Centeno *et al.* (2009), the volatility of the trend component of unemployment is fixed *ex ante*.

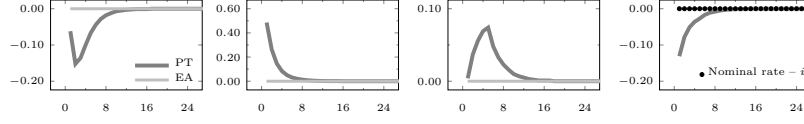
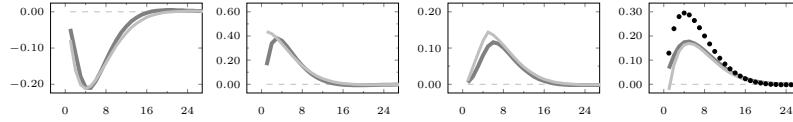
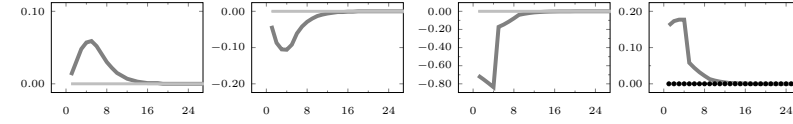
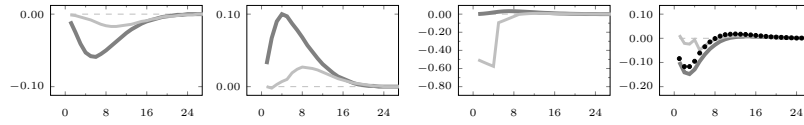
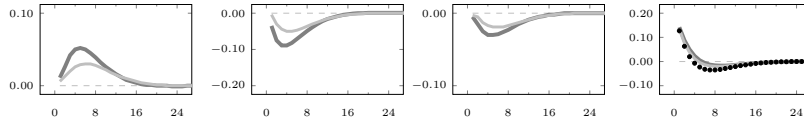
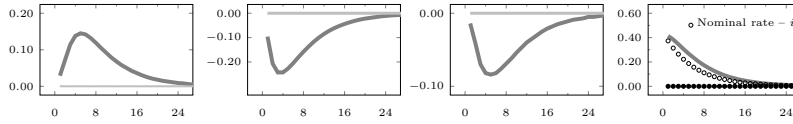
#### 4.2. Impulse Response Functions

Figures 4–9 report selected impulse response functions (IRF) following shocks of 1 standard deviation in the disturbance term. All graphs with interest rates are augmented with nominal rates.

The results are quite revealing and largely as expected on the basis of economic theory and on the basis of the working environment laid out in Section 3.1. For instance, demand or supply shocks in Portugal do not affect the euro area (Figures 4 and 6), while the converse is not true (Figures 5 and 7). Demand shocks depict several humped-shaped propagations in both the euro area and Portugal. A distinctive feature of the model is that, in general, nominal and real interest rates responses depend on the region. Nominal interest rates  $i_t^*$  are always immune to Portugal shocks, whether their origin is from demand or supply, but not to euro area disturbances.

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11. TFP is derived from an HP filter. Balgrave *et al.* (2015) suggest that potential output will have almost identical properties to those arising from a direct HP filtration of GDP data if the employment and TFP series are de-trended using an HP filter.

FIGURE 4: IRF - Demand shock in Portugal ( $\varepsilon_{y_{gap}}$ )FIGURE 5: IRF - Demand shock in the euro area ( $\varepsilon_{y_{gap}}^*$ )FIGURE 6: IRF - Supply shock in Portugal ( $\varepsilon_{\pi}$ )FIGURE 7: IRF - Supply shock in the euro area ( $\varepsilon_{pi}^*$ )FIGURE 8: IRF - Monetary policy shock ( $\varepsilon_{i^*}$ )

(A) Unempl. gap

(B) Output gap

(C) Inflation (yoy)

(D) Interest rate

FIGURE 9: IRF - Risk Premium shock ( $\varepsilon_i$ )

Source: Own calculations.

Notes: Columns of Figures 4–8 have the same labelling as columns of Figure 9.

The propagation of euro area demand shocks in the euro area is in line with Carabenciov *et al.* (2008): output increases, as well as inflation, nominal and real interest rates, while unemployment decreases. The spillover to Portugal is qualitatively similar.

The propagation of Portugal demand shocks in Portugal also brings along positive effects on inflation and output (and a reduction in unemployment). However, the shock increases expected inflation, in sharp contrast with euro area demand shocks. This brings along lower real interest rates and higher output levels. Expected inflation rates return only gradually to initial values, conditional *inter alia* on real developments.

The response to euro area supply shocks in euro area aggregates are also qualitatively similar to existing models of the same class. The shock decreases the inflation rate, which leads to a decline in nominal and real interest rates, and thereby to an increase in the output gap (Figure 7), mirrored by a decrease in unemployment. The magnitude is nevertheless relatively small in comparison with the Portuguese response. In contrast with the euro area, inflation does not decrease in Portugal (Figure 7c), which brings about a larger fall in real interest rates, with amplification effects on output and unemployment. By design, the reduction in nominal rates is only linked to euro area developments. Part of the amplification effect in Portugal is due to negligible impacts from the real exchange rate appreciation, a feature already highlighted in Section 3.3.

The response to Portuguese supply shocks in Portuguese aggregates (Figure 6) is in sharp contrast with the response to euro area supply shocks in euro area aggregates (Figure 7). The key driving difference stems again from inflation expectations. In the Portugal case, there is no monetary policy reaction following the supply shock (Figure 6d), and the decrease in inflation is expected to be long lived. This triggers higher real interest rates, associated with lower output gaps, in contrast with the euro area.

Finally, risk premium shocks (Figure 9) resemble, to a large extent, monetary policy shocks (Figure 8). Higher nominal rates bring along higher real rates, a fall in inflation and in output (which increases unemployment). The short-term impact of the risk premium shock generates nevertheless a higher real interest rate response in Portugal than an interest rate shock in the euro area, and thus amplification effects.

#### 4.3. Parameter stability

Figure 10 plots recursive estimates of selected posterior modes. Dotted lines are euro area results. The first sample period begins in 1995Q1 and ends in 2007Q4, which represents 52 observations. The period



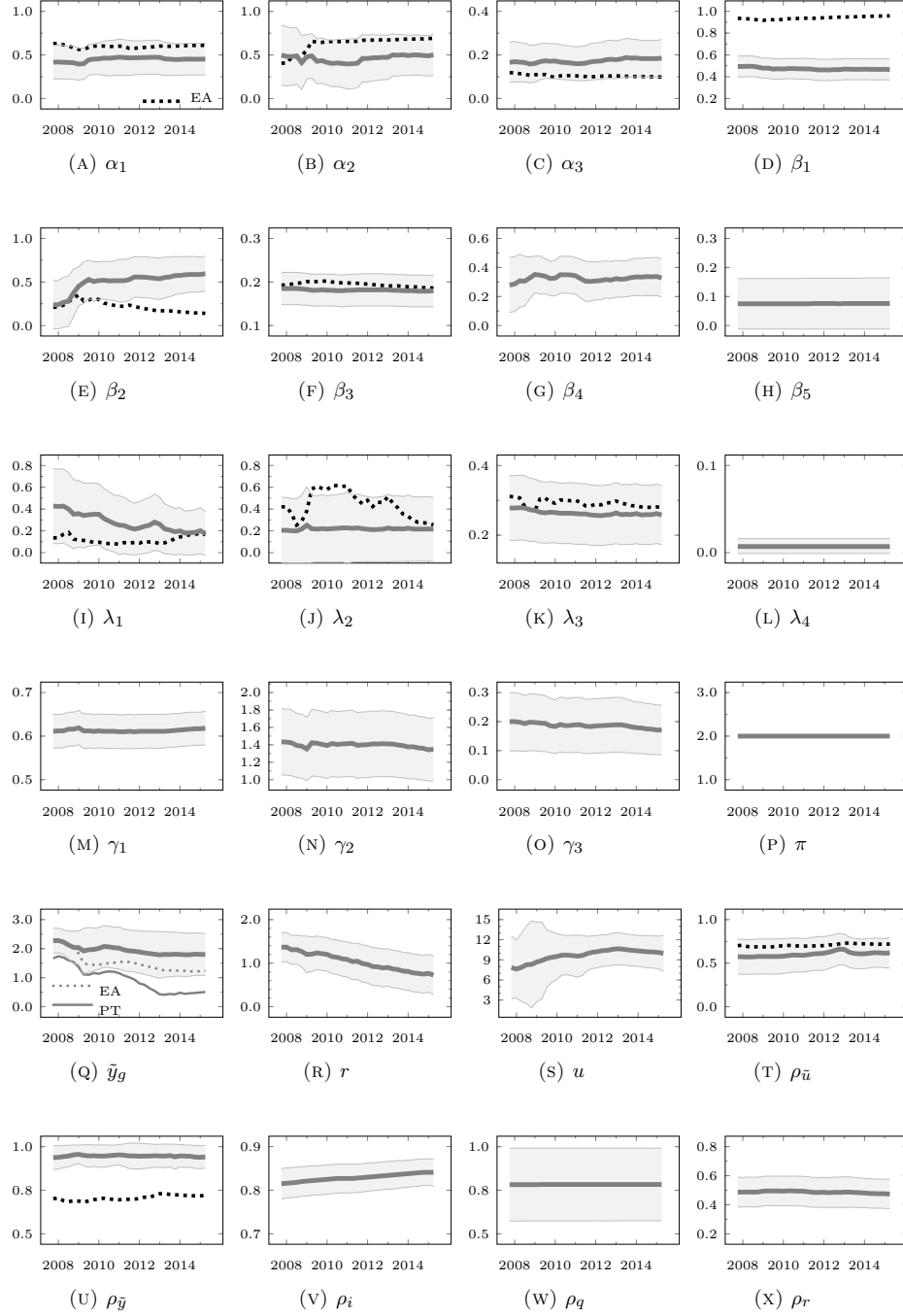


FIGURE 10: Selected posterior modes over 2007Q4–2015Q2

Source: Own calculations.

Notes: Posterior modes in 2007Q4 are computed from the prior distributions reported in Table 1. The remaining results start from the previously computed posterior mode. The shaded area is computed with  $x \pm 2\sigma_x$ , where  $\sigma_x$  is the standard deviation estimate of Portuguese parameter  $x$ . Dotted lines are point estimates of euro area parameters. Figure 10q includes actual growth rates for Portugal (PT) and the euro area (EA), computed recursively as an average of annualized quarterly changes (starting in 1999Q1).

1995Q1-1998Q4 is again fully ignored.<sup>12</sup> Results show that posterior modes of economic parameters, although not constant in Portugal since 2008 and not immune to the informational content of prior distributions, are not plagued by unacceptable instability. For instance, parameter  $\beta_2$  showed an upward trend during 2008-2009, increasing to levels close to 0.5, but remained relatively stable thereafter. Parameter  $\lambda_1$  shows in turn a mild downward trend until 2012, before stabilizing around 0.2. The coefficients of the interest rate equation, reflecting euro area developments, also depict a high stability, influenced in this case by the informational content of prior distributions. Parameter  $\pi = 2.0\%$  is a straight line by assumption.

Some coefficients are however clearly unstable. Among them, a special focus should be placed on long-run parameters shared by both Portugal and the euro area, namely (i) the benchmark real interest rate; (ii) the long-run growth rate of the trend component of output; and (iii) the long-run trend component of unemployment. Parameter  $r$  depicts a clear and persistent downward trend since 2008, from around 1.5% towards 0.7% by 2015Q2. Equation (11) is herein a key conditioning restriction. By allowing short-run deviations from the long-run real interest rate, the system is always evolving around a long-run benchmark.<sup>13</sup> Parameter  $y_g$  falls from 2.3% towards 1.8% over the same period, creating therefore a positive correlation with the decrease of the long-run real interest rate. This growth rate remains above actual average growth rates for Portugal and the euro area, also reported in Figure 10q. Finally, consistently with lower long-run growth, parameter  $u$  shows an upward trend, namely from 7.9% to around 10.0%. The long-run unemployment rate  $u$  is nevertheless relatively stable after 2012. In general, these results raise concerns that maybe interest should be placed on avoiding “secular stagnation” problems (Summers, 2014).

The relationship between inflation and output does not show clear signs of a flattening movement, measured by  $\lambda_3$  or  $\lambda_3^*$ , but this conclusion is highly influenced by the informational content of prior distributions.

The comparison between Portugal and euro area parameters mixes signs of similarities, for instance in  $\lambda_3$  and  $\lambda_3^*$ , with signs of clear differences. The most significant difference is placed again in the output equations, where expectations, measured by the comparison between  $\beta_2$  and  $\beta_2^*$ , play a more important role in Portugal. In contrast,  $\beta_1^*$  is systematically higher in the euro area and although results are not allowed to reach unity, they show nevertheless a slight upward trend. Coefficient  $\lambda_2$  and  $\lambda_2^*$  turn out to be relatively close with a sample period ending in 2015Q2, but recorded some instability in the euro area, particularly around the first recession .

12. Figure C.1 in Appendix C plots recursive estimates of standard deviations of shocks.

13. Experiments assuming  $\rho_{\pi}^* = 1$  created on occasions numerical accuracy problems, in part associated with the estimated decrease of  $\tilde{r}_t^*$ .

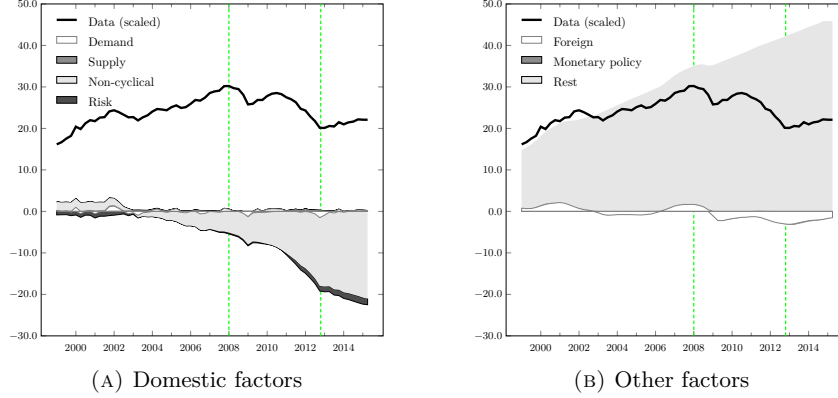


FIGURE 11: Historical decomposition of Portuguese output

Source: Banco de Portugal and own calculations.

Notes: All contributions add up to actual data, which is scaled by a fixed constant. The contribution to the output level of "Rest" includes the exogenous growth rate  $y_g$ .

## 5. Historical decompositions

This section offers model-based historical decompositions of PT output (Section 5.1) and unemployment rates (Section 5.2). The derivations use the posterior modes reported in Table 1. Shocks are divided between domestic and foreign disturbances. The sum of all contributions add up to actual data.

### 5.1. Output

Figure 11 depicts the model-based output decomposition. The sum of all contributions depicted in Figures 11a, with domestic shocks, and 11b, with foreign shocks, equals actual data. Domestic shocks include demand (stemming from  $\varepsilon_{y_{gap}}$ ), supply ( $\varepsilon_\pi$ ) and non-cyclical shocks (which aggregate  $\varepsilon_{\tilde{u}}$ ,  $\varepsilon_{\tilde{y}}$  and  $\varepsilon_{\tilde{q}}$ ). Figure 11a also includes the contribution of risk premium shocks ( $\varepsilon_i$ ).

Over the period 2008-2012, the most significant domestic shock driving the fall in output is the non-cyclical shock (Figure 11a). The results confirm the desirability to achieve one of the main goals of the Economic and Financial Assistance Programme of 2011, namely to reverse main impediments behind potential growth.<sup>14</sup>

Trend components are given by a-theoretical equations and the model cannot isolate the crisis impact, nor explain previous movements before the

14. See Banco de Portugal (2011) for an overview of the Programme.

crisis. However, the results suggest that the successive lower contribution of trend components to output levels begun before the global financial crisis.

Among the remaining domestic shocks, demand played a more important role than supply shocks, although the nominal side of the economy recorded significant changes. The results show that expected inflation remained systematically below actual levels between 2000-2009, in contrast with the euro area, where actual and expected inflation remained relatively close to 2%.<sup>15</sup> In 2009, the reduction in inflation was largely unexpected in both regions. Since 2010, expected inflation has been on average below 2%, particularly in PT. In contrast with relatively small contributions of demand or supply shocks, the risk premium shock gained momentum over 2008-2012, contributing to lower output levels, particularly after 2011.

Shocks originated abroad, reported in Figures 11b, include monetary policy shocks ( $\varepsilon_t^*$ ), and all euro area shocks, namely demand, supply and non-cyclical (*i.e.*  $\varepsilon_{gap}^*$ ,  $\varepsilon_\pi^*$ ,  $\varepsilon_u^*$ ,  $\varepsilon_y^*$  and  $\varepsilon_r^*$ ). The remaining contributions are named “Rest,” which include initial values and the exogenous growth rate  $y_g$ . The results suggest that PT output was significantly affected by the two recessive periods that occurred in the euro area. The impact of the negative foreign shocks by late 2008 is consistent with the real impacts computed by Castro *et al.* (2014), following the sharp contraction in the Portuguese external demand. The negative contribution reported herein gained momentum during 2011 and lasted until late 2012.

Although the model features a high sensitivity to monetary policy shocks, as depicted in Section 4.2, the impact from the increase in money market rates, between 2010Q4-2011Q4, is negligible. Finally, the upward movement recorded by the shocks aggregated under “Rest” is justified by the growth rate  $y_g \simeq 1.8$ .

Table 3 quantifies the contributions of each shock. It includes a disaggregation of domestic non-cyclical shocks, foreign shocks, and adds the outcome for the euro area.

The results show that non-cyclical shocks are the most important disturbances affecting the Portuguese economy over 2007Q4–2012Q4, with a contribution of -11.6 p.p.. Foreign demand shocks amount to -4.7 pp, while domestic demand shocks account for -2.2 pp. The increase in sovereign risk premium is estimated to have decreased output by 0.9 pp.

In the euro area, non-cyclical shocks have also contributed substantially for output developments, namely -6.6 pp. However, in contrast with the Portuguese case, demand shocks also reach a significant contribution (5.0 p.p.).

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15. Appendix B plots actual data and model-consistent inflation expectations, as well as expectations retrieved from Consensus Economics. Model-based and Consensus Economics estimates are relatively close in the EA, particularly before 2008, and seem relatively more anchored around 2.0% in Model Q.

	Portugal: Output			Euro Area: Output		
	2007Q4	2012Q4	$\Delta$	2007Q4	2012Q4	$\Delta$
Actual data	30.2	20.1	-10.1	28.6	26.0	-2.6
Domestic factors						
Demand ( $\varepsilon_{y_{gap}}$ )	0.7	-1.5	-2.2	0.0	0.0	0.0
Supply ( $\varepsilon_{\pi}$ )	0.0	0.3	0.2	0.0	0.0	0.0
Non-Cyclical	-4.8	-16.5	-11.6	0.0	0.0	0.0
Labour market ( $\varepsilon_{\bar{u}}$ )	0.0	0.0	0.0	0.0	0.0	0.0
Output market ( $\varepsilon_{\bar{y}}$ )	-4.8	-16.5	-11.6	0.0	0.0	0.0
Rest	0.0	0.0	0.0	0.0	0.0	0.0
Risk ( $\varepsilon_i$ )	-0.3	-1.2	-0.9	0.0	0.0	0.0
Other factors						
Foreign	1.7	-3.0	-4.7	6.4	-5.2	-11.6
Demand ( $\varepsilon_{y_{gap}}^*$ )	1.7	-2.7	-4.4	1.8	-3.2	-5.0
Supply ( $\varepsilon_{\pi}^*$ )	0.0	-0.4	-0.4	0.0	-0.1	0.0
Non-Cyclical	0.0	0.1	0.1	4.7	-1.9	-6.6
Rest	0.0	0.0	0.0	0.0	0.0	0.0
Monetary Policy ( $\varepsilon_i^*$ )	0.0	-0.1	-0.1	0.0	0.0	0.0
Rest	32.9	42.1	9.3	22.1	31.1	9.0

TABLE 3. Decomposition of output over 2007Q4-2012Q4

Source: Own calculations.

Notes: Actual data is in logs and re-scaled by an additive constant.

The contribution of monetary policy shocks is virtually nil in both regions, while the aggregator “Rest” reaches around 9 pp, largely due to the impact of the long-run growth rate  $y_g$ .

## 5.2. Unemployment

Figure 12 depicts the unemployment rate decomposition. The results mirror to a large extent the above-mentioned output developments.

Over the period 2008-2012, the non-cyclical shock is the most significant shock driving the upward movement in the unemployment rate. As already mentioned, the trend component of the unemployment rate is an object that is not explained by the model.

The behaviour of the trend component of the unemployment rate is consistent with the view that the Portuguese labour market was not only fundamentally unprepared to cope with the crisis, but had also institutional challenges before the crisis (Centeno *et al.*, 2009).

Table 4 quantifies the contributions of each shock over 2007Q4 and 2012Q4, and also reports a disaggregation of domestic non-cyclical shocks, and of foreign shock. The results are also qualitative identical to those already disclosed for output.

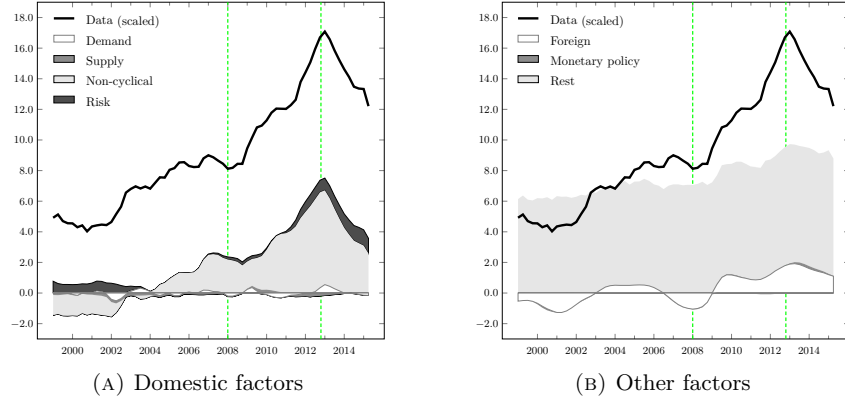


FIGURE 12: Decomposition of unemployment over 2007Q4-2012Q4

Source: Banco de Portugal and own calculations.

Notes: Actual data is scaled by a fixed constant. All contributions add up to actual data.

	Portugal: Unemployment rate			Euro Area: Unemployment rate		
	2007Q4	2012Q4	$\Delta$	2007Q4	2012Q4	$\Delta$
Actual data	-1.5	6.7	8.3	-2.7	1.8	4.5
Domestic factors						
Demand ( $\varepsilon_{ygap}$ )	0.0	0.3	0.3	0.0	0.0	0.0
Supply ( $\varepsilon_{\pi}$ )	0.0	-0.2	-0.1	0.0	0.0	0.0
Non-Cyclical	2.3	6.2	3.9	0.0	0.0	0.0
Labour market ( $\varepsilon_{\bar{u}}$ )	2.3	6.2	3.9	0.0	0.0	0.0
Output market ( $\varepsilon_{\bar{y}}$ )	0.0	0.0	0.0	0.0	0.0	0.0
Rest	0.0	0.0	0.0	0.0	0.0	0.0
Risk ( $\varepsilon_i$ )	0.1	0.8	0.6	0.0	0.0	0.0
Other factors						
Foreign	-1.0	1.8	2.8	-3.8	0.8	4.6
Demand ( $\varepsilon_{ygap}^*$ )	-1.0	1.6	2.6	-1.0	1.8	2.8
Supply ( $\varepsilon_{\pi}^*$ )	0.0	0.2	0.2	0.0	0.0	0.0
Non-Cyclical	0.0	0.0	0.0	-2.8	-1.1	1.7
Rest	0.0	0.0	0.0	0.0	0.0	0.1
Monetary Policy ( $\varepsilon_i^*$ )	0.0	0.0	0.0	0.0	0.0	0.0
Rest	-2.9	-2.2	0.7	1.2	1.0	-0.2

TABLE 4. Decomposition of the PT Unemployment rate over 2007Q4-2012Q4

Source: Own calculations.

Notes: Actual data is re-scaled by an additive constant.

## 6. Okun's law

This section evaluates the behaviour of Okun's law over 2008-2012 (Section 6.1), which is critical to fully apprehend the above-mentioned mirror image

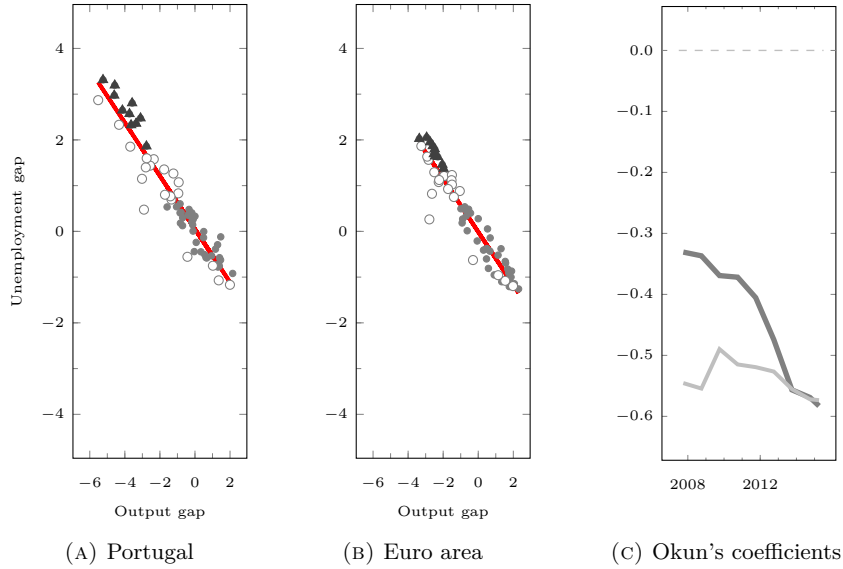


FIGURE 13: Okun's law

Source: Banco de Portugal, Eurostat and own calculations.

Notes: White dots cover the 2008Q1–2012Q4 period. Black triangles cover the 2013Q1–2015Q2 period. Recursive estimates of "Okun's coefficient," defined as the relationship between unemployment and output gaps, cover the period 2007Q4–2015Q2.

between unemployment and output historical decompositions, and assesses the stability of trend component estimates (Section 6.2).

### 6.1. Recursive estimates

Figures 13a and 13b depicts scatter plots with unemployment and output gaps. These static representations reorganize Figures 2c and 2d, which are functionally determined by dynamic versions of Okun's law (defined by equations (1) and (2)).

Model Q embodies a relatively close relationship between unemployment and output gaps, around a linear trend, in both Portugal and the euro area. Over 2008–12, the results have basically moved from positive output gaps towards larger and larger negative output gaps in both regions (given by the white dots), with unemployment gaps depicting a mirror image. The subsequent period is interpreted as a gradual movement backwards (the black triangles). The static relationships are also relatively similar in both regions: if the output gap increases by 1%, the unemployment gap decreases by 0.6 pp.

Figures 13a and 13b are based on information up to 2015Q2 and therefore do not unveil how the negative derivative linking output and unemployment—named

for simplicity an "Okun's coefficient" changed as new data become available after 2008. Figure 13c fills this gap with plots of Okun's coefficients using recursive estimates starting in 2007Q4. These coefficients remained relatively stable in the euro area, around -0.55. In contrast, the Portuguese case is marked by a downward trend, suggesting a considerable movement in this static output-unemployment relationship. By the end of the sample, as expected by the previous result, both coefficients coincide. This coefficient depends among other factors on firm's decisions regarding how to adjust employment in response to temporary deviations in output, degree of job security, social and legal constraints of firm's adjustment of employment (Blanchard, 1997).

Figure 14 takes a step further in the Portuguese case and depicts scatter plots with unemployment and output gaps that are identified up to the end of each sample period, as well as the computed changes. More precisely, squares, circles and triangles highlight how Model Q's outcome changed as new data become available. The results reveal a relatively robust Okun's law, but not without important revisions. Between 2007Q4 and 2009Q4, for instance, there is a considerable movement in data points, both in the degree of clustering and in terms of extreme values. Between 2009Q4 and 2011Q4, the results also changed significantly, as depicted by the movement in the black squares.

Given that observed data is invariant, these results imply that trend component estimates recorded important revisions. Uncertainties about the precise level of structural unemployment and the unemployment gap across euro area countries, using estimates from a number of different sources (EC, Organisation for Economic Co-operation and Development and IMF) is not a novelty in the empirical literature and have been highlighted, for instance, by European System of Central Banks (2012).

## 6.2. Trend stability

Figure 15 plots Portuguese trend components of output and unemployment rates using alternative parametrizations of Model Q.<sup>16</sup> The results confirm the presence of important revisions, particularly around turning points, as well as high imprecisions and uncertainties, with non-negligible impacts in (pseudo) real time evaluations of the business cycle position.

Figures 15a and 15b report trend components based on posterior modes that only take into account information up to 2007Q4, avoiding thus all changes caused by the crisis. In this case, fixing the parametrization would fundamentally imply clockwise rotations in trend levels of output.

Figures 15c and 15d report trend components based on recursive estimates since 2007Q4, and thus fully incorporating all changes caused by the crisis. The revisions are noteworthy, but now extend to growth rates. As quarterly

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16. Figure D.1 in Appendix D plots recursive estimates for the euro area.



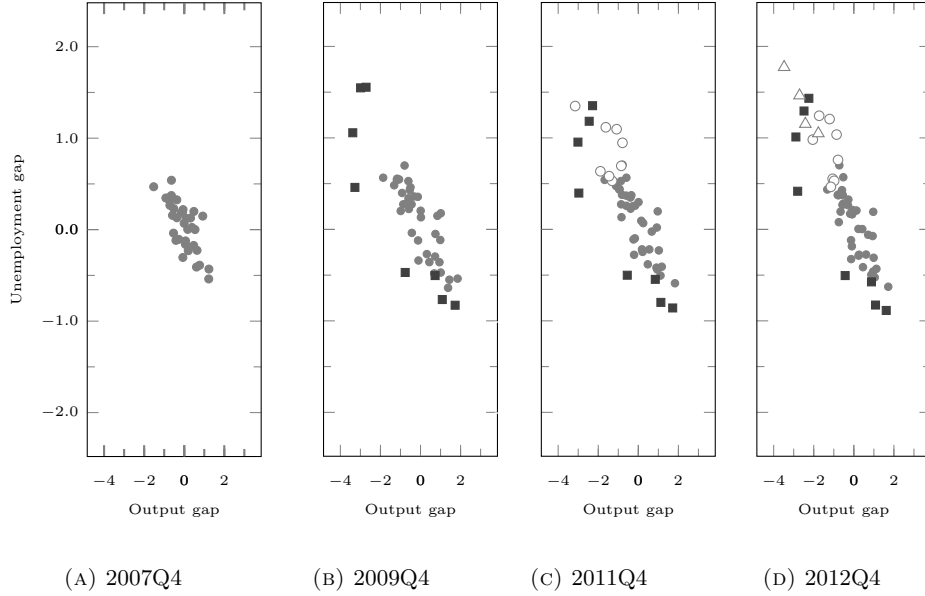


FIGURE 14: Recursive estimates of Portuguese trend components

Source: Banco de Portugal and own calculations.

Notes: Squares represent data points between 2008Q1 and 2009Q4; circles between 2010Q1 and 2011Q4; and triangles between 2012Q1 and 2012Q4.

information become available, previous levels and growth rates changed significantly. The 2009–2010 period is particularly different from Figures 15a and 15b. The main characteristics of the last computed trend, also highlighted in these figures, are only obtained with data at least until 2014. Part of this changes is related with the growth rate of the trend component of output, captured by  $\tilde{y}_g$ , which depicts a clear and persistent downward trend since 2008 (as already mentioned, from around 2.3% growth towards 1.8%).

Finally, Figures 15e and 15f report a counter-factual exercise where the posterior mode reported in Table 1 is assumed to be known already in 2007Q4. In this case, all effects caused by the subsequent period are assumed to be reflected in the initial parametrization. As expected, both trend levels and growth rates are largely unrevised. It is however remarkable that even in this case the crisis period remains marked by non-negligible revisions as new information is incorporated, particularly around turning points and again suggesting imprecisions and high uncertainties surrounding trend estimates.

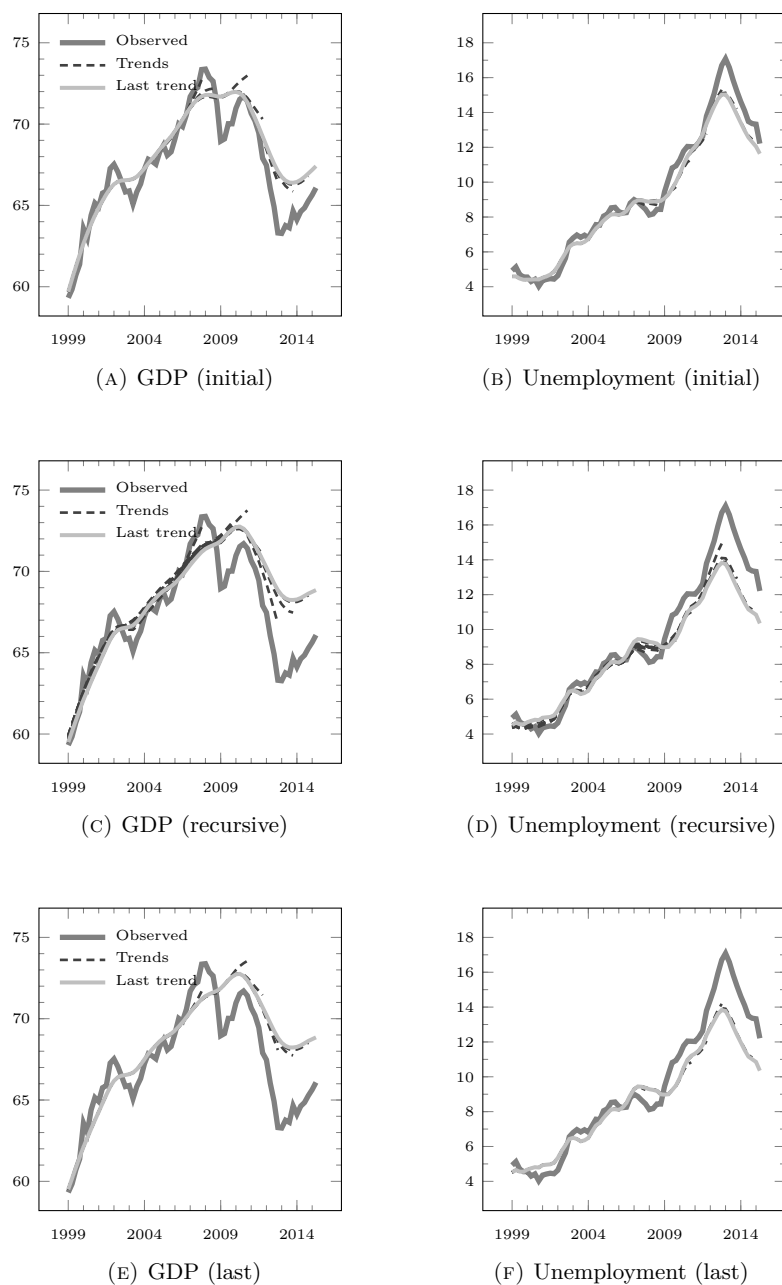


FIGURE 15: Recursive estimates of Portuguese trend components

Source: Banco de Portugal and own calculations.

Notes: Actual GDP is in logs and scaled by a constant. All lines depict data until the last quarter of each year. The last trend depicts information up to 2015Q2.

## 7. Conclusions

This paper introduced a model with rational expectations, unobserved components, and stochastic shocks—*Model Q*—designed to fit key characteristics of a small economy integrated in a credible monetary union. Model Q was parametrized by Bayesian techniques with Portuguese and euro area data.

Results show that product and labour markets in Portugal recorded important changes in trend dynamics over 2008–2012. These markets emerged, in general, structurally unprepared to cope with the global financial crisis, showing signs of institutional deficiencies even before the crisis. The results confirm the desirability to achieve one of the main goals of the Economic and Financial Assistance Programme of 2011, namely to remove structural impediments behind potential growth. A possible way to improve Model Q is to investigate causal relationships behind such developments, given that the current version is silent about all drivers of trend components.

Results also show that the Portuguese economy over 2008–2012 was severely hit by two recessive periods in the euro area, and to a lesser extent by higher risk premia. Okun’s law remained relatively robust, but recursive estimates of trend components recorded important revisions, both in terms of levels and growth rates. These revisions include a decrease in the long-run growth rate of the trend component of output, shared by both Portugal and the euro area, mirrored by an increase in long-run unemployment, as well as a decrease in the long-run real interest rate. These results create “secular stagnation” concerns, and naturally imply that another possible way to improve Model Q is to add other Member States and evaluate the robustness of such concerns.

Additional ways to amend the model are left for future work. This class of models is usually evaluated by their forecast performance, a theme not pursued herein among other factors because unconditional out-of-sample interest rate forecasts hit systematically lower than zero values, which invalidates the entire forecast scenarios, and because the performance was severely harmed by trend instability. It would be relevant to evaluate the forecast performance in the presence of further economic features, including financial frictions. The model may also have additional variables, for instance alternative measures of inflation, or alternative definitions of the real exchange rate. Finally, the analysis of the euro area is acknowledged to be incomplete. Model Q lacks the rest of the world economy, with prices and quantities playing their role.

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## Appendix A: Data definitions

### Portugal

#### Output

Output is measured by real Gross Domestic Product (source: Eurostat).

#### Consumer prices

Between 1995Q1 and 1995Q4, consumer prices were computed with (national) Consumer Price Indexes of Portugal (source: Statistics Portugal). From 1996Q1 onwards, prices are given by the Harmonized Index of Consumer Prices (source: Eurostat).

#### Inflation expectations

Inflation expectations are derived from Consensus Economics (source: Consensus Economics). Quarterly data are given by simple averages.

#### Unemployment

Unemployment is in percentage of the labour force. Quarterly data is seasonally adjusted (source: Banco de Portugal). Between 1995 and 2014Q4, the data was published in the Economic Bulletin of the Banco de Portugal - June 2015. 2015Q1 and 2015Q2 data was constructed with monthly data, seasonally adjusted (source: Statistics Portugal).

#### Risk premium

Between 1995Q1 and 1998Q4, the risk premium is measured in percentage points by the spread between official interest rates of Portugal (source: Banco de Portugal), and the official repo rate of Germany (source: Bundesbank), where quarterly data is given by simple averages. After 1999, the risk premium is measured by the (implied) Portuguese sovereign debt interest rates, *vis-à-vis* the EA, as in Castro *et al.* (2014). Quarterly data is in this case derived from a disaggregation of annual data using a spline. 2015Q1 and 2015Q2 data are treated as missing observations.

### Euro area

#### GPD

Output is measured by real Gross Domestic Product (source: Eurostat).

#### Consumer prices

Between 1995Q1 and 1995Q4, consumer prices were computed with the Area Wide Model (AWM) dataset (See <http://www.eabcn.org//page//area-wide-model> for further information). From 1996Q1 onwards, prices are given by the Harmonized Index of Consumer Prices (source: Eurostat).

#### Inflation expectations

Inflation expectations are derived from Consensus Economics (source: Consensus Economics). Quarterly data are given by simple averages.

#### Unemployment

Unemployment is in percentage of the labour force (source: Eurostat). Quarterly date was computed from an average of monthly data, seasonally adjusted.

#### Interest rates

Between 1995Q1 and 1998Q4, interest rates are given by the repo rate of the Bundesbank (source: Bundesbank). After 1999, interest rates are given by ECB's official interest rates (source: ECB; see also <http://www.ecb.europa.eu/stats/monetary/rates/html/index.en.html>).

## Appendix B: Inflation: actual and expected developments

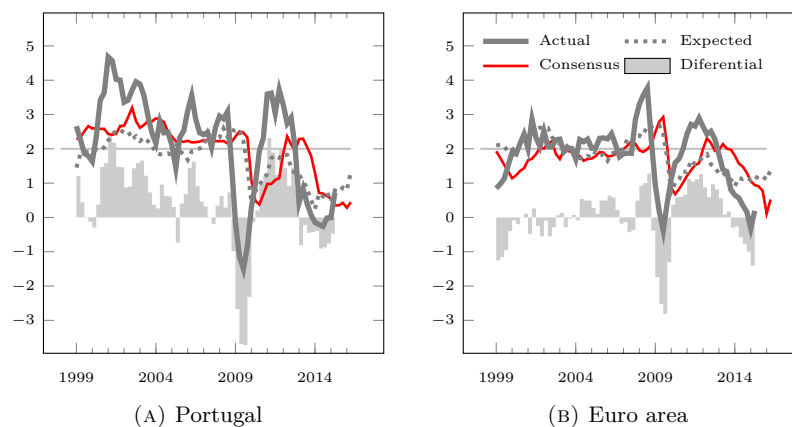


FIGURE B.1: Inflation: expected and actual developments

Source: Banco de Portugal, Consensus, Eurostat and own calculations.

Notes: Inflation  $\pi_t$  is measured in yearly terms by the log change of HICP. Expected inflation is defined as  $E_t\pi_{t+4}$ , *i.e.* one-year-ahead expected inflation. For comparison purposes, expected inflation is lagged four periods. Consensus expectations are quarterly averages.

### Appendix C: Recursive estimates of standard deviations

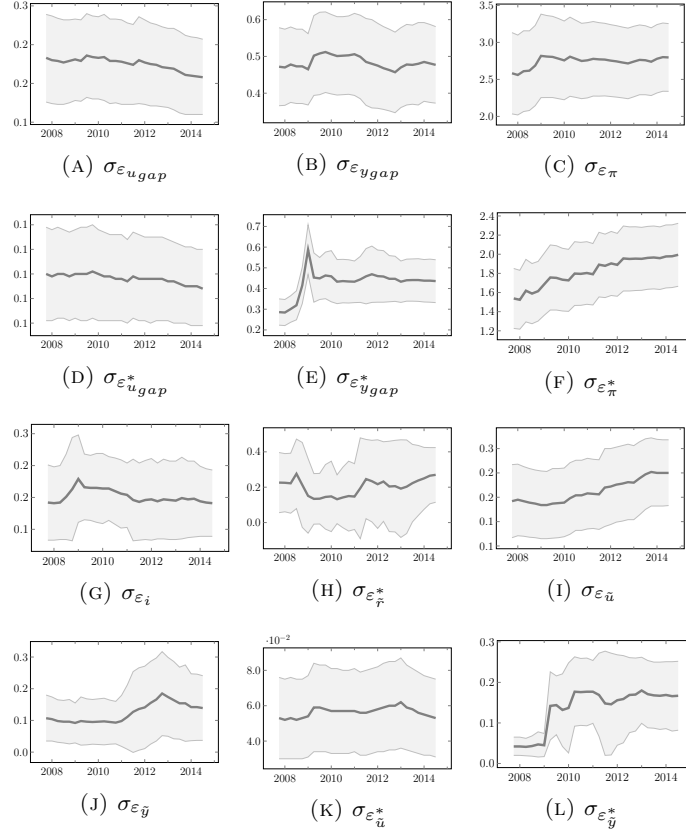


FIGURE C.1: Posterior modes of standard deviations

Source: Own calculations.

Notes: Posterior modes are computed recursively since 2008, assuming for each parameter the prior distributions reported in Table 2. The shaded area is computed with  $\pm 2\sigma_x$ , where  $\sigma_x$  represents the standard deviation of the posterior mode of  $x$ . The last observation plots the posterior modes reported in Table 2.



## Appendix D: Okun's law in the euro area

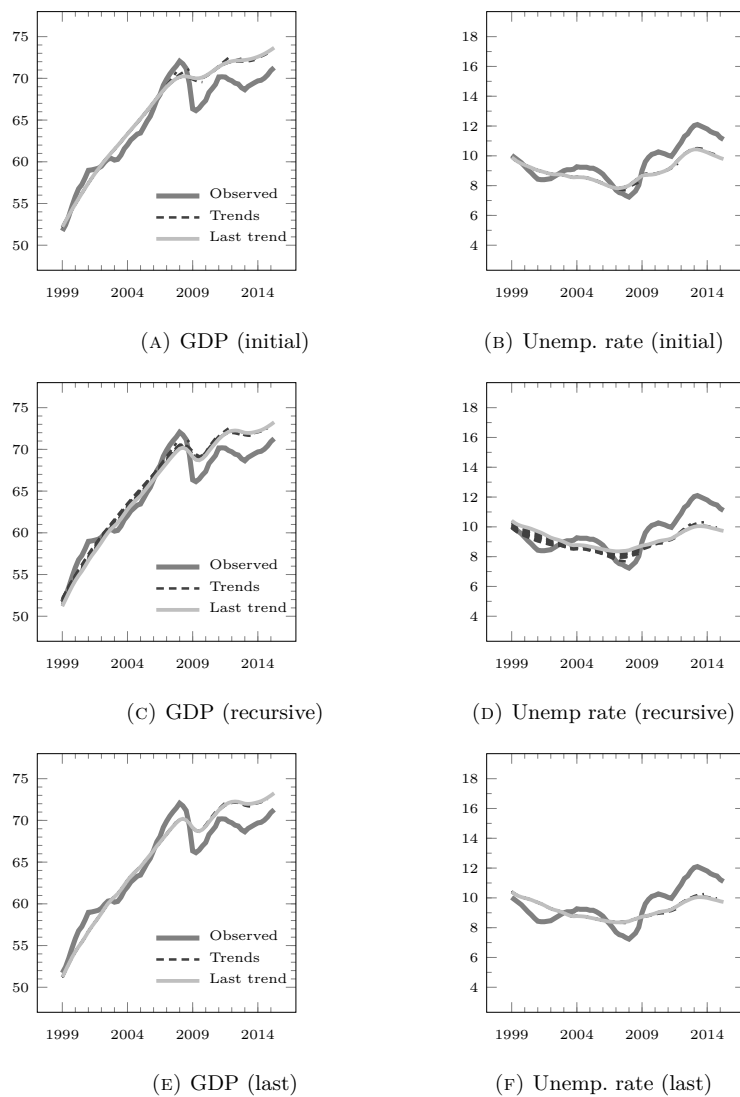


FIGURE D.1: Recursive estimates of euro area trend components

Source: Banco de Portugal and own calculations.

Notes: Actual GDP is in logs and scaled by a constant. All lines depict data until the last quarter of each year. The last trend depicts information up to 2015q2.

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