Spain in the Euro: a General Equilibrium Analysis*

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March 2009

Abstract

This paper analyzes the determinants of Spain's macroeconomic fluctuations since the inception of the euro in 1999, with a special attention to observed differentials with respect to the rest of the European Monetary Union (EMU). For that purpose we estimate the Banco de España DSGE model of the Spanish economy and the rest of the Eurosystem, BEMOD. Nominal rigidities are estimated to be somewhat smaller in Spain, except for non-tradables, while wage indexation is estimated to be much higher than in the rest of EMU. With respect to the sources of inflation and growth differentials, we find that structural differences (in particular higher nominal wage indexation in Spain) increased the volatility of inflation differentials, whereas asymmetric shocks also played an important role at certain historical dates. Finally, we find that EMU membership has had a non-negligible effect on observed differentials.

1 Introduction

The aim of this paper is to study the determinants of Spain's macroeconomic fluctuations since the inception of the euro in 1999. Economic developments in Spain have been closely related to those of the rest of the European Monetary Union (EMU) but certainly have differed from them at times. Indeed, during the period 1999-2007, Spanish HICP inflation has been almost 1p.p. on average above that of the EMU as a whole, while GDP growth has averaged 0.96p.p. more in Spain than in the EMU (see Figure 1). Policymakers and

*We would like to thank Angel Estrada, Juan Francisco Jimeno, Nooman Rebei and Alberto Urtasun for their help and very useful suggestions. This paper represents the views of the authors and should not be reported as representing the views of the Banco de España or the Eurosystem.

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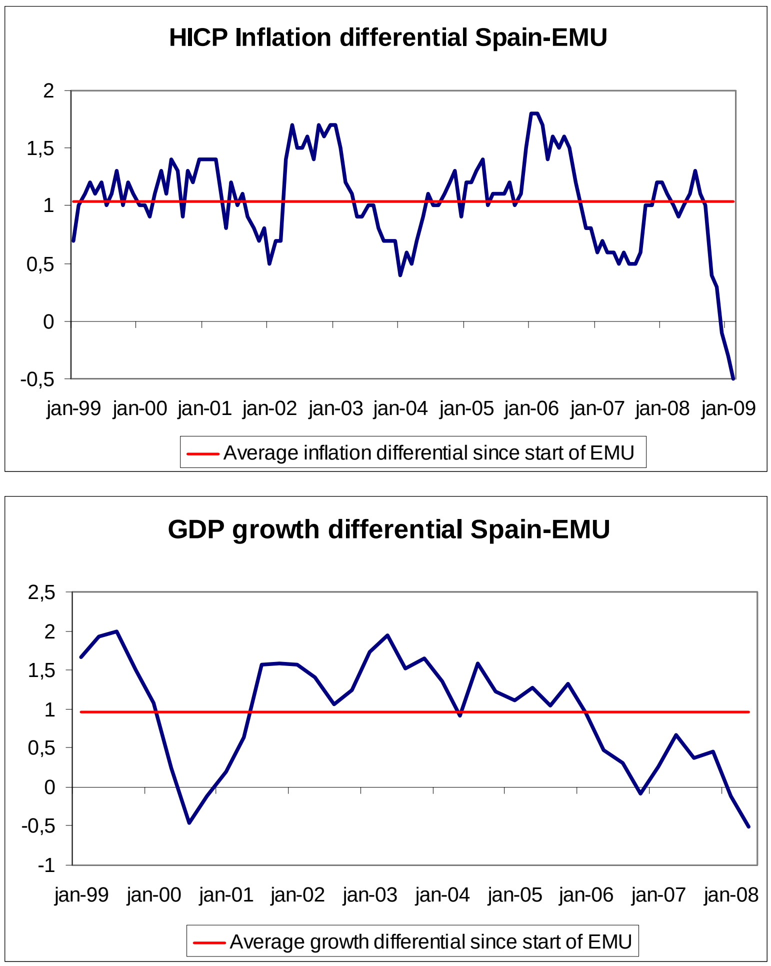
researchers have mentioned several possible reasons behind this distinct behavior of the Spanish economy with respect to the rest of the Eurosystem within a common monetary framework: different economic structures or institutions in several markets, most notably the labor market, different economic policies, different cyclical position, and different shocks hitting the economy. In the meanwhile the monetary policy has been a single one, with all the policy problems these differentials can cause to its effectiveness.

Figure 1. Inflation and growth differentials between Spain and EMU



This paper analyses the sources and implications of the differential behavior of the Spanish economy using the Banco de España DSGE model of the Spanish economy and the rest of the Eurosystem, BEMOD. DSGE models are increasingly used by central banks, both as a laboratory for simulating risk scenarios, to assess the effects of possible economic policies and as a forecasting tool. They have become popular because of their solid economic foundations and because the sources of fluctuations (shocks to technology, preferences, monetary and fiscal policy, etc.) have a clear structural interpretation. Central Banks using DSGE models as their main macroeconomic tool (Tovar, 2008)[1] unmistakably report its usefulness in that they help give a clear structure to the in-house economic discussions.

BEMOD is the model the Bank of Spain developed for policy analysis (see Andrés et al, 2006). It was the first DSGE model in the Eurosystem to incorporate two endogenous country blocks, Spain and the rest of Euro Area, within the European Monetary Union that interact with the rest of the world, and to include as well several production sectors. It consists of three country blocks: Spain, the rest of the EMU, which share a common monetary policy rule, and the rest of the World, which is treated as exogenous. In both Spain and the rest of EMU, we consider three production sectors: tradables, non-tradables and durables. The model also contains all the standard features of the latest vintage of new-Keynesian DSGE models, such as nominal rigidities and indexation of prices and wages, habit formation, investment adjustment costs and variable capital utilization. BEMOD was calibrated to reproduce the main ratios and the dynamics of the corresponding economies, and has been extensively used since then in scenario analysis and policy simulation exercises at the Bank of Spain (see Banco de España Annual Report 2007, López, Estrada and Thomas (2008), or Álvarez, Hurtado, Sánchez and Thomas (2008), among others).

This paper revisits the model and estimates, using standard Bayesian procedures, the main parameters driving its dynamics as well as a wide variety of shocks that have hit the Spanish economy and the Eurosystem in the last decade. In this paper the model has been augmented with respect to its original structure in several ways, such as investment and foreign trade adjustment costs, Calvo-type smoothing employment functions and an EMU-

[1] The Bank of Canada, the Riksbank, the Norges Bank, or the European Central Bank were among the first ones but now the amount of central banks who have a DSGE model for the analysis of their own economy has remarkably increased.

wide common stochastic trend-stationary growth rate among others. We find that data is particularly informative in the estimation of price and wage dynamics. We find that nominal rigidities are found somewhat smaller in Spain, except for non-tradables, while wage indexation is much higher than in its EMU partners. The larger estimated shocks are found those to price and especially wage setting mechanisms, both for Spain and the rest of EMU. Technology shocks in the traded sector are also estimated to be of relevant size, and shocks to world demand and oil prices are also found to be very big.

With the estimated shocks and model dynamics we try to explain Spain's cyclical performance in the euro regime. We focus on two aspects. On the one hand, we want to isolate how the idiosyncratic structure of the Spanish economy has shaped its responses to historical shocks. On the other hand, we want to assess the extent to which the specific shocks that have hit the Spanish economy are responsible for the behavior of its main aggregates in relation to those of the rest of EMU.

Our findings here are threefold. First, growth and inflation differentials between Spain and the rest of EMU would have been different during prolonged periods should the Spanish economy have experienced the same shocks as estimated for its EMU partners. Second, given the historical shocks inferred by the estimation procedure, removing the structural particularities of the Spanish economy would have produced significantly less volatile differentials in CPI inflation. We conjecture that this result is mainly due to the more sticky prices in non-tradables and the considerably higher degree of nominal wage indexation estimated for the Spanish economy. And third, we find that EMU membership has had an important effect on growth and inflation differentials, in the sense that these would have behaved rather differently at certain historical episodes should Spain have retained an independent monetary policy for the peseta. For instance, at the onset of the Euro the Spanish monetary authorities would have hypothetically pursued lower inflation rates relative to EMU, which would have come at the cost of slower relative growth in the same period, and a similar behavior could have been repeated in the high-inflation and growth period in Spain in the middle of the years 2000s. Conversely, the more recent quarters would have witnessed faster GDP growth in Spain relative to EMU, thus producing higher inflation differentials.

The rest of the paper is organized as follows: the next Section describes the main characteristics of the model (for a detailed discussion of the model features see Andrés et al., 2006). Section 3 reports the Bayesian estimation and assesses its properties. Section 4 illustrates the main transmission mechanisms of the estimated model, which exploit its multi-country and multi-sector structure. Section 5 investigates what is behind the inflation and growth differentials between Spain and the rest of the Eurosystem: the different economic structure or the different shocks that have hit the economies since the inception of the EMU. It also shows some of the implications of sharing a common monetary policy in a period where the cyclical evolution has differed within the EMU economies. Finally, section 6 presents some concluding remarks.

2 The model

There are three countries in BEMOD: Spain (H), the rest of the Euro Area (F) and the rest of the world (W). The latter is mainly described by exogenous processes for consumption, investment and prices. In each of the Eurosystem economies there are four types of agents: households, firms, the domestic fiscal authority and a monetary authority common to H and F. The representative household earns wages and rental rates of physical capital and uses his income to purchase a consumption basket, invest in productive capital and in durable goods, and buy nominal bonds (both euro- and dollar-denominated). Firms operate in three sectors: tradables, non-tradables and durables, which are produced with different technologies across sectors using labor, capital and oil. Domestic fiscal authorities collect (distortionary) taxes, consume a fraction of each country's output and issue nominal government bonds. Finally, the common monetary authority sets short-run nominal interest rates according to a Taylor rule.

The structure of production in each of the Eurosystem economies is represented by Figure 2. Monopolistically competitive firms produce in Stage I output in each sector, set prices and set factor demands. At Stage II competitive intermediaries aggregate sector outputs and imports into final goods ready to be exported, invested or consumed. A final layer of perfectly competitive aggregators rearrange in Stage III these final goods into the bundles demanded by the agents, thus replicating the final demand aggregates in the national accounts.

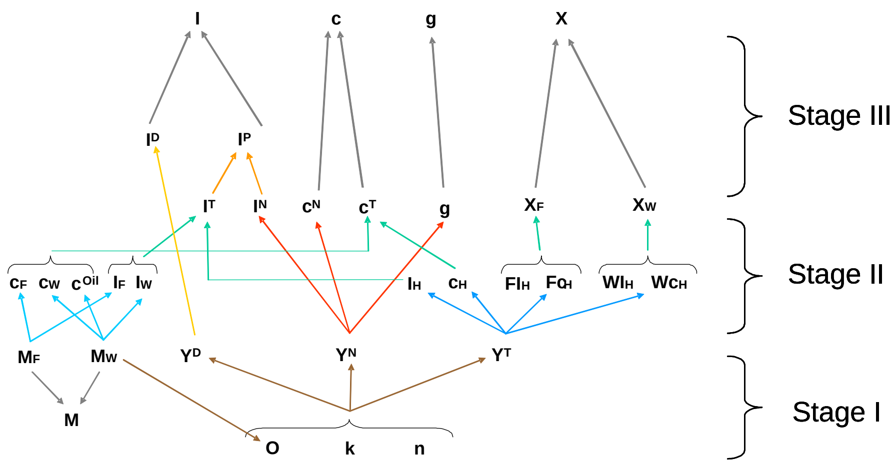


Figure 2. Structure of production in each country

The model contains similar departures from the competitive flexible-price model as in the latest vintage of DSGE models. These include nominal and real frictions. Nominal frictions affect goods and labour markets. There is monopolistic competition in both of them. Firms set prices in the goods markets according to a Calvo price-setting mechanisms and there is price indexation to the corresponding sector deflator. In turn, there is also a Calvo setting mechanism for wages, which are indexed to CPI. The real frictions included in BEMOD are investment adjustment costs, foreign trade adjustment costs, variable capital utilization and habit formation in consumption.

There is a total of 21 possible sources of fluctuations in BEMOD. Four of them occur outside the Euro area, these are shocks to the oil price and to the rest of the world nominal interest rate, prices and demand. Three are shocks common to the whole Euro Area: to the common trend-stationary growth rate, to TFP and to the Eurosystem nominal interest rate. Finally, there are six country-specific shocks to Spain and the rest of Euro Area: to sector TFP in the tradables and non-tradables sectors, to investment, to preferences, to government expenditure and to price and wage mark-ups.

2.1 Households' preferences

Households maximize their welfare defined on consumption (c_t), the stock of durables (D_t) and leisure ($1 - n_t$)

$$E_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^a \left[\frac{\left(c_t / c_{t-1}^{\gamma}\right)^{1-\sigma}}{1-\sigma} + \frac{D_t^{1-\sigma_D}}{1-\sigma_D} - \frac{n_t^{1+\varphi}}{1+\varphi} \right],$$

subject to the following budget constraint

$$\frac{B_t(i)}{R_t \Psi(a_{t\text{-}1})} + \frac{s_t^{-1} A_t(i)}{W R_t \Psi(a_{t\text{-}1})} + PI_t^P I_t^P(i) + P_t^D I_t^D(i) + (1+\tau_c) PC_t c_t(i) + PC_t T_t \leq$$
$$B_{t\text{-}1}(i) + \frac{A_{t-1}(i)}{s_t} + \left((1\text{-}\tau_k) r_t k_{t\text{-}1}(i) + \sum_S h(cu_t^S(i)) \right) PC_t + (1\text{-}\tau_w) W_t n_t(i) + \int_0^1 \omega_t(j) dj.$$

β is the rate of time preference, ε_t^a a is preference shock, σ^{-1} and σ_D^{-1} are the intertemporal elasticity of substitution of consumption and durables services respectively. φ represents the (inverse of) the elasticity of labour holding the marginal utility of consumption constant, γ captures the effect of habits in consumption. All households are Ricardian and there is no explicit role for money in the model.

Households own durables and capital, which is supplied to producing firms at the rental cost r_t, and hold their wealth in a menu of assets including domestic bonds (B) and international (dollar-denominated) assets (A). s_t is the nominal exchange rate. There are portfolio adjustment costs, $\Psi(.)$, which are increasing in the ratio of net foreign asset position over value-added, $a_t \equiv A_t/(va_t Pv_t)$, and which guarantees stationarity of this ratio.[2]

[2] See e.g. Schmitt-Grohe and Uribe (2001).

Final consumption goods are produced by competitive firms with a technology represented by the following CES aggregator,

$$c_t = \left[\left(\omega_C^N\right)^{\frac{1}{\rho}} \left(c_t^N\right)^{\frac{\rho-1}{\rho}} + \left(\omega_C^T\right)^{\frac{1}{\rho}} \left(c_t^T\right)^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}} \tag{1}$$

where ρ is the elasticity of substitution between traded (c_t^T) and non-traded goods (c_t^N). The associated price index is given by,

$$PC_t = \frac{PC_t^N c_t^N + PC_t^T c_t^T}{c_t} \tag{2}$$

where PC^N represents the consumption price of the non-traded good and PC^T the corresponding price for the traded goods. The relative demand of non-traded versus traded goods only depends on its relative prices

$$\frac{c_t^N}{c_t^T} = \frac{\omega_C^N}{\omega_C^T} \left(\frac{PC_t^N}{PC_t^T} \right)^{-\rho} \tag{3}$$

A similar CES technology holds for traded consumption c_t^T as a composite good home produced consumption goods, $c_{H,t}$, goods imported from the Euro area, $c_{F,t}$, and goods imported from the rest of the world, $c_{W,t}$ as well as oil, c_t^{Oil}:

$$c_t^T = \left[\begin{array}{c} (\omega_{HC})^{\frac{1}{\rho^T}} (c_{H,t})^{\frac{\rho^T-1}{\rho^T}} + (\omega_{FC})^{\frac{1}{\rho^T}} (c_{F,t})^{\frac{\rho^T-1}{\rho^T}} + \\ + \left(\omega_C^{Oil}\right)^{\frac{1}{\rho^T}} \left(c_t^{Oil}\right)^{\frac{\rho^T-1}{\rho^T}} + (\omega_{WC})^{\frac{1}{\rho^T}} (c_{W,t})^{\frac{\rho^T-1}{\rho^T}} \end{array} \right]^{\frac{\rho^T}{\rho^T-1}} \tag{4}$$

A similar structure is defined for c_t^N, I_t, I_t^P, I_t^T and their associated price indices.

We also assume, as Erceg, Henderson and Levin (2000), that each household supplies a differentiated type of labour and thus enjoys some degree of monopoly power. Furthermore, households are price-setters in the labour market but only a fraction 1-θ^W of workers reset their nominal wage each period. This generates the following log-linear wage inflation equation,

$$\begin{aligned} \widehat{\pi}_t^W - \xi^W \widehat{\pi}_{t-1}^{CPI} &= \beta \; E_t \left(\widehat{\pi}_{t+1}^W - \xi^W \widehat{\pi}_t^{CPI} \right) \\ &\quad + \frac{(1-\beta\theta^W)(1-\theta^W)}{\theta^W(1+\varphi\varepsilon_W)} \left(\widehat{mrs}_t - \widehat{w}_t + \varepsilon_t^w \right). \end{aligned}$$

where ξ^W is the degree of indexation and ε_t^w is an economy wide wage-push shock.

2.2 Firms' technology and price setting

The production technology of each $j \in [0,1]$ firm in sector $S = \{N, T, D\}$ is represented by

$$y_t^S(j) = \left[\varkappa_T^{\frac{1}{\psi^S}} O_{t,j}^{S\ \frac{\psi^S-1}{\psi^S}} + (1\text{-}\varkappa_S)^{\frac{1}{\psi^S}} \left[\left(cu_{t,j}^S k_{t,j}^S \right)^{\alpha_S} \left(z_t^{EA} z_t z_t^S n_{t,j}^S \right)^{1-\alpha_S} \right]^{\frac{\psi^S-1}{\psi^S}} \right]^{\frac{\psi^S}{\psi^S-1}}$$

where $O_{t,j}^S$, is the oil input in production[3], $cu_{t,j}^S$ is capital utilization and z_t^{EA}, z_t and z_t^S represent an Euro-Area-wide technology shock, a country-wide technology shock and a sector-specific technology shock, respectively.

Likewise we assume Calvo pricing with different probability of changing prices in each sector/country $(1-\theta^S)$. This yields the following sector specific deflator inflation equation,

$$\widehat{\pi}_t^S - \xi^S \widehat{\pi}_{t-1}^S = \beta E_t \left(\widehat{\pi}_{t+1}^S - \xi^S \widehat{\pi}_t^S \right) + \frac{(1-\beta\theta^S)(1-\theta^S)}{\theta^S} \left(\widehat{mc}_t^S + \varepsilon_t^p \right),$$

where ξ^S represents the degree of indexation and ε_t^p is an economy wide cost-push shock.

2.3 Monetary policy and fiscal policies

The model is closed with the policy rules: one fiscal rule for each country and a common monetary rule. The government budget constraint is defined as:

$$\frac{B_t}{R_t} = B_{t-1} + P_t^N g_t + PC_t T_t - \tau^k PC_t r_t k_t - \tau^w W_t n_t - \tau^c PC_t c_t \tag{5}$$

Fiscal policy is designed to prevent the level of debt from exploding. All τ^w, $\tau^k$and τ^c are assumed constant and we shall assume that lump-sum taxes (T_t) respond sufficiently to deviations of the level of debt as a proportion of GDP (b_t) from target $\overline{b}$,

$$T_t = T_0 - T_1 \left(\frac{B_{t-1}}{Pv_{t-1} va_{t-1}} - \frac{\overline{B}}{\overline{Pv}\,\overline{va}} \right) \tag{6}$$

[3] Following the evidence from input-output tables, we assume that oil is used in the production of tradable and non-tradable goods, but not in the production of durables.

Monetary policy is modeled as a Taylor rule as (in log-linear form),

$$\begin{aligned}\widehat{R}_t &= (1-\rho_R)\left[\rho_\pi\left(0.1\widehat{\pi}_t^{CPI}+0.9\widehat{F\pi}_t^{CPI}\right)+\rho_{va}\left(0.1\widehat{\Delta va}_t+0.9\widehat{\Delta Fva}_t\right)\right] \\ &\quad +\rho_R\widehat{R}_{t-1}+\varepsilon_t^R.\end{aligned}$$

where $\widehat{\pi}_t^{CPI}$ and $\widehat{F\pi}_t^{CPI}$ are the home and EMU CPI inflation rates, and first differences in value added represent the output gap. ρ_R captures the degree of interest rate smoothing and ρ_π and ρ_y the elasticity of response to deviations of inflation and output from target. The weights attached to domestic and foreign variables in the rule correspond to the relative size of the two economies; Spain represents roughly 10% of EMU GDP. ε_t^R represents the unanticipated component of monetary policy.

3 Model parameterization and assessment

The parameterization strategy consists of keeping some parameters fixed and estimating those related to model dynamics using Bayesian techniques. The estimated parameters make a total of 60, which include those governing (i) the dynamics of sector output prices and wages, including both Calvo and indexation coefficients, (ii) adjustment dynamics of investment and employment, (iii) the Taylor rule coefficients describing the systematic behavior of the common monetary policy, and (iv) the stochastic processes driving all 21 model shocks, including their first order autocorrelations and standard deviations. The parameters we choose to keep fixed at their calibrated values correspond to the steady state ratios (share of non-tradables in consumption, etc., calibrated to match long-run averages in the data), the preferences (including the discount factor, inter- and intra-temporal elasticities of substitution, labor supply elasticity, habits)[4] and the technology of production (factor shares and capital depreciation and utilization, calibrated to match input-output tables and long-run shares in the data).

[4]We choose the intertemporal elasticity of consumption goods and of durables $\sigma = 1$ since we need log-utility in both to guarantee balanced growth, while we calibrate the habits in consumption because the estimated value was systematically almost 1, which was inconsistent with balanced growth.

The following table summarizes the main calibrated parameters. The rest of the calibrated values can be found in Andrés et al.(2006).

Table 1. Main calibrated parameters

	Spain / EMU	Description
β	0.99	inter-temporal discount factor
$\sigma^{-1}, \left(\sigma^{D}\right)^{-1}$	1	inter-temporal elasticity of substitution
γ	0.85	habits in consumption
φ^{-1}	1	labor supply elasticity
ρ, ρ^{T}, ρ^{N}	0.5	intra-temporal elasticity of substitution
ω_{N}^{C}	0.47 / 0.58	weight of non-tradables in consumption
ω_{H}^{CT}	0.46 / 0.43	home bias: weight of home goods in tradables consumption
ω_{F}^{CT}	0.33 / 0.08	weight of other EMU goods in tradables consumption
δ	0.021	depreciation rate of productive capital
δ^{D}	0.005	depreciation rate of stock of durables
α^{T}	0.69 / 0.68	labor share in tradables
α^{N}	0.52 / 0.54	labor share in non-tradables
α^{D}	0.64 / 0.62	labor share in durables

The Bayesian estimation process involves combining the estimation of the parameters by maximum likelihood using an observed set of data with the information obtained from prior distributions defined for those same parameters.

The data set used includes quarterly observations of the 19 macroeconomic aggregates we care for explaining and which describe the main aspects of the Spanish economy and its relationship to the Eurozone, as well as the multi-country and multi-sector dimensions included in the model. We have tried to enlarge the data set but no other combination of relevant series provided better fit[5]. These are:

- For Spain: total real value added, employment in the traded and the non-traded sectors, real private consumption, real private productive investment, HICP inflation, real wages, and total exports.

[5] In particular, it seems very problematic to include the aggregate import series and the sectoral value added deflators for the case of Spain. They do not provide added information and significantly worsen the fit of the estimated model.

- For the Eurosystem: same as for Spain except the exports, plus deflator of value added in non-traded sector, and the nominal 3-month interest rate.

- For the rest of the world: nominal 3-month interest rate in the US.

Non-stationary series (consumption, investment, etc.) are logged and linearly detrended while stationary series (inflation and interest rates) are simply demeaned. All suitable series are transformed into per-capita terms for conformity with model variables.

The estimation period used is 1997Q1–2007Q4 which covers the EMU but also two years prior to the start of the common monetary policy, since in practice the Spanish monetary policy and exchange rate was already closely linked to that of its future EMU partners.

The prior distributions we have assumed follow standard practice in Bayesian estimation of similar DSGE models. In particular, we assume Inverse Gamma prior distributions for non-negative parameters (like the standard deviations of the shock processes), Beta prior distributions for parameters between 0 and 1 (like the shocks autocorrelations, the Calvo and indexation parameters and the coefficient on interest rate smoothing in the Taylor rule), and prior Normal distributions for the Taylor rule coefficients on the reaction to deviations of inflation and valued added growth from target or for investment adjustment costs.

Tables 2 and 3 show the posterior modes of the main parameters of interest, together with their prior mean. For the parameters referring to the rest of the Euro Area economy, we include a comparison to the closest estimated coefficients in the New Area Wide Model of the ECB for the Eurosystem economy as a whole, which is modelled there as a small open economy (see Christoffel, Coenen and Warne (2008)).

Table 2. Parameter estimates: structural parameters

	Prior mean	Post. mode		Prior mean	Post. mode	NAWM
	Spain			Rest of Euro Area		
Calvo. Tradables θ^T	0.75	0.69	$F\theta^T$	0.75	0.92	θ^X=0.77
Calvo. Non-tradables θ^N	0.83	0.92	$F\theta^N$	0.80	0.83	θ^H=0.92
Calvo. Wages θ^W	0.75	0.62	$F\theta^W$	0.75	0.71	0.77
Indexation. Tradables ξ^T	0.30	0.10	$F\xi^T$	0.30	0.16	ξ^X=0.49
Indexation. Non-tradables ξ^N	0.40	0.28	$F\xi^N$	0.40	0.13	ξ^H=0.41
Indexation. Wages ξ^W	0.75	0.76	$F\xi^W$	0.25	0.19	0.63
Investment adjustment Φ	4	0.86	$F\Phi$	4	2.36	5.17
				Monetary Policy		
Taylor rule. Inflation			ρ_π	1.5	1.28	1.9 (0.18$\rho_{\Delta\pi}$)
Taylor rule. Output growth			ρ_{va}	0.5	0.61	0.15
Taylor rule. Lagged interest rate			ρ_R	0.9	0.82	0.86

In terms of price and wage dynamics, there are several aspects to point out. First, the data is particularly informative since, as can be seen in figures 3 and 4, it shifts the prior, quite remarkably in some cases: the black line representing the posterior distribution estimated for each Calvo (*"theta"*) parameter departs noticeably from its assumed prior distribution, in grey (the green vertical line indicates the posterior mode value). In the case of the indexation parameters, *"psi"*, the information contents of the data is less clear. However, it has to be born in mind that the prior distributions have been calibrated with care using all microeconometric evidence available (see Álvarez and Hernando (2006), Dhyne et al.(2006), Du Caju et al.(2008) and Druant et al.(2008), among others), hence it is not surprising that aggregate data may not add much to the evidence used when choosing the priors.

Figure 3. Prior and posterior distributions of Calvo parameters

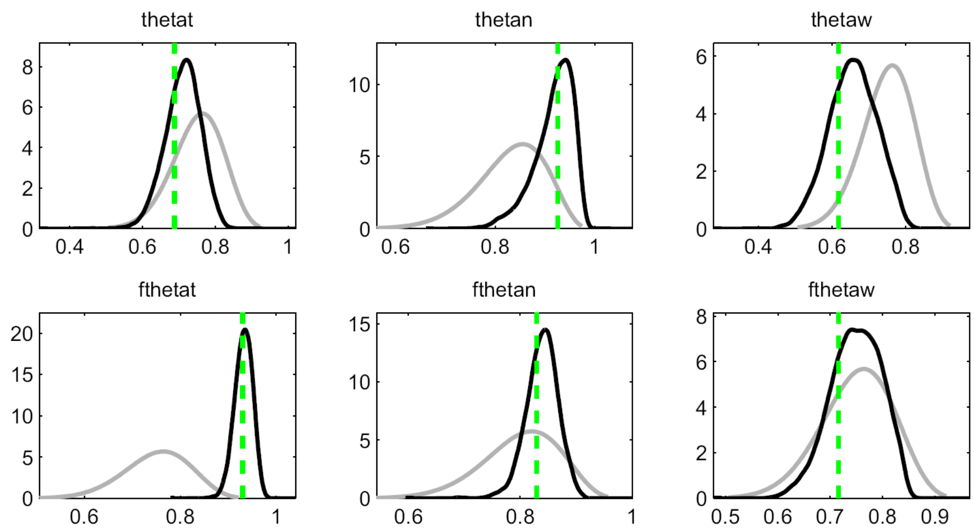
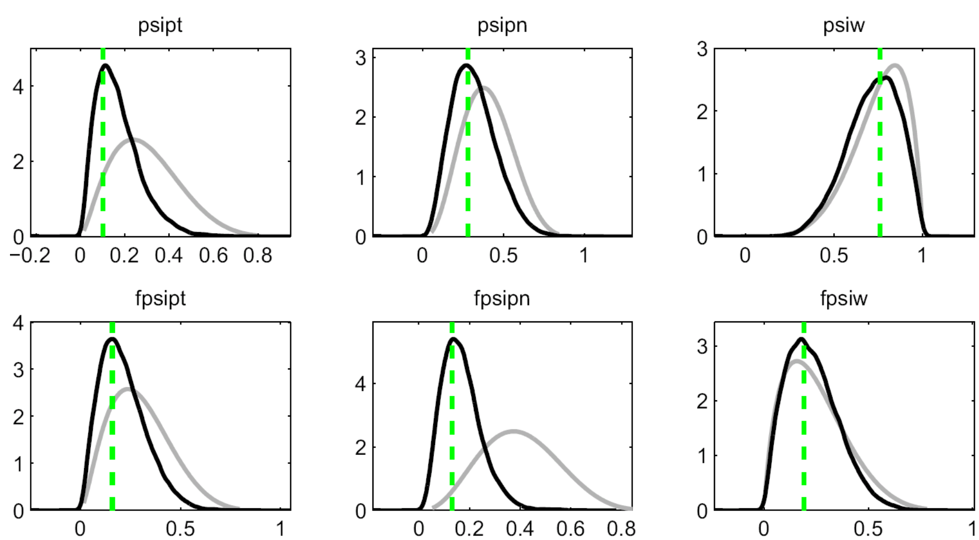


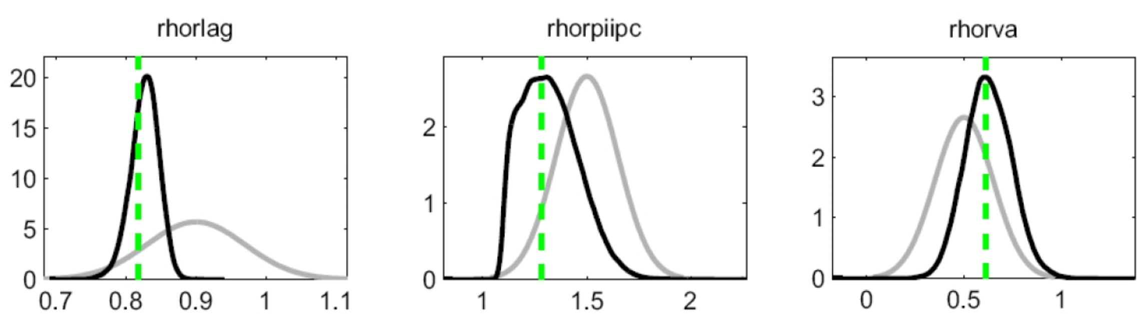
Figure 4. Prior and posterior distributions of indexation parameters



Second, the estimated degree of nominal price and wage stickiness, as measured by the Calvo parameter, is found higher in the rest of the Eurozone than in Spain; the posterior modes obtained for the Euro area are similar to those estimated in the NAWM, although that model does not separate between tradables and non-tradables but rather between home consumed and exported. Third, in Spain prices of non-tradables are found stickier than those of tradables and than wages, consistently with estimations elsewhere. In contrast, in the Eurozone traded goods are found very sticky, more than wages and even non-tradables, although the estimated parameter is similar that estimated in the NAWM for the home-consumed goods[6]. Fourth, the degree of price indexation is found small in both countries, smaller than the micro-evidence used to build the priors and than the estimates in the NAWM.[7] Fifth, real wage indexation is found similar to our priors and substantially larger in Spain than in its EMU partners, due to the widespread inclusion of indexation clauses in the Spanish wage negotiations.

The monetary policy rule estimated shows substantial interest rate smoothing and point estimates that are quite close to the canonical $1.5-0.5$ Taylor rule. This higher response to inflation than to output is consistent with the inflation objective of the European Central Bank. The estimation of these coefficients is relatively precise, as can be seen by the shape of the posterior distribution (black solid lines) in figure 5. The comparison with the NAWM estimates is more difficult here since in that model the reaction to inflation is specified differently, both in levels and in growth rates.

Figure 5. Prior and posterior distributions of Taylor rule coefficients



[6] In our estimation sample we have used only one series of sectoral prices: non-traded value added deflator for the Eurozone. This may explain the different behaviour of the estimated $F\theta^T$.We experimented with different combinations of sectoral prices in enlarged datasets but they worsened the estimation properties.

[7] Adolfson Laséen, Lindé and Villani (2005) obtain a similar result of low indexation in prices, consistent other estimates that also obtain strongly forward looking Phillips curves.

Regarding the estimated processes for the shocks of the model, a few things are worth noting. First, the larger shocks are those to the price and wage setting mechanisms: cost-push shock to prices and especially wage-push shocks; and they are found more volatile and more persistent in Spain than in the rest of the Euro Area. Second, technology shocks in the traded sector are also estimated to be of relevant size, especially in the Eurozone where they are estimated to be also more persistent. Third, shocks to world demand and oil prices are also found to be very big. In general, the data is found very informative for the estimation of the shocks processes: their posterior distributions generally differ substantially from priors.

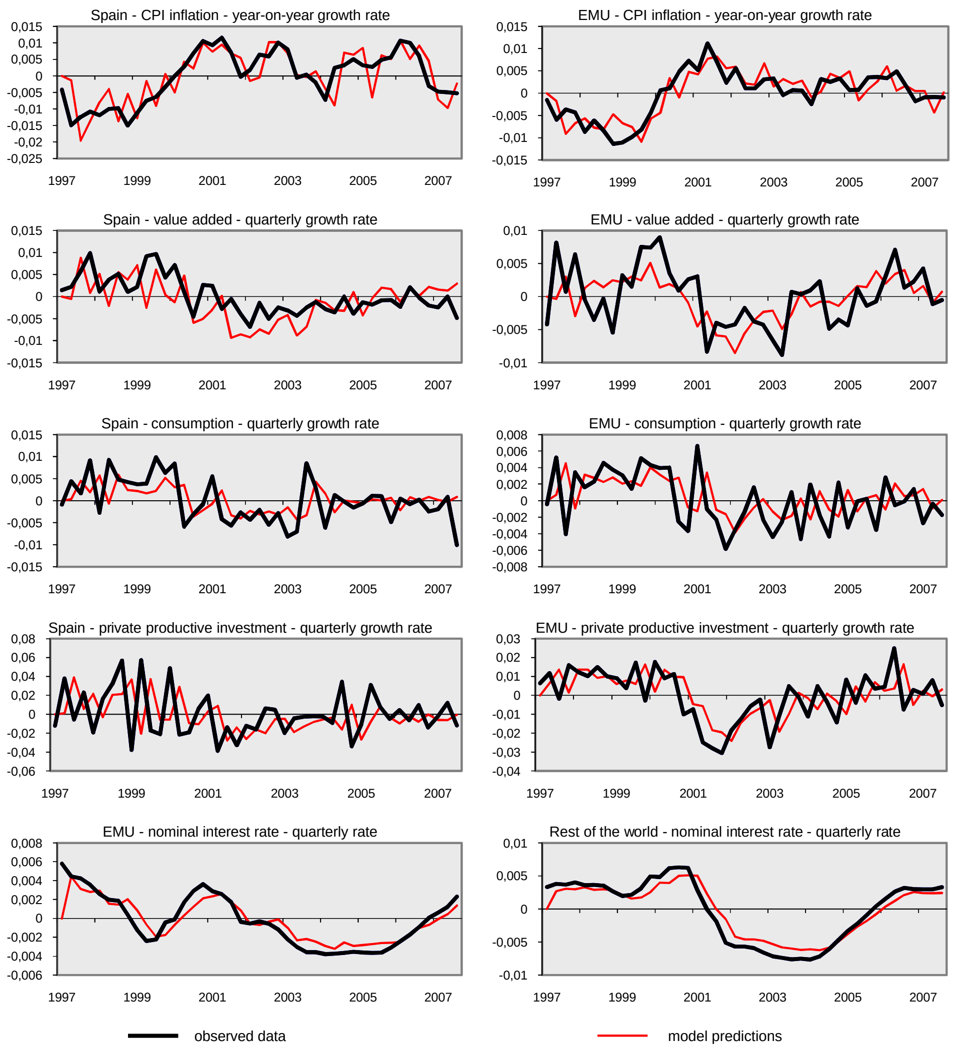
Table 3. Parameter estimates: shocks.

Post.modes	Spain		Rest EA		EA-wide		
	%S.D.	AR(1)	%S.D.	AR(1)		%S.D.	AR(1)
preferences	1.5	0.75	1	0.73	technology	0.2	–
gov.exp.	1.4	0.78	1.6	0.81	trend growth	0.2	–
tech traded	4.6	0.64	6.9	0.74	Interest rate	0.1	–
tech non-tr	1.5	0.82	1.8	0.82	Rest of the World		
tech inv.	1.6	0.68	1.2	0.74	demand	4.9	0.77
cost-push	3.7	0.78	3.4	0.75	prices	0.2	0.77
wage mkup	9.1	0.77	8.3	0.73	oil prices	3.1	0.80
					interest rate	0.15	0.81

3.1 Assessing the model fit

Before investigating what the model implications are for understanding the similarities and divergences between the Spanish economy and the rest of the Eurosystem we need to assess the model's overall goodness of fit. One first test is to compare the evolution of the series used in the estimation process to that predicted by the model for the same variables. Figure 6 makes such a comparison of observed data and model predictions for several of the series included in the estimation data set: value added and private consumption and investment quarterly growth rates and inflation in Spain and the Euro Area, and the nominal quarterly Eurozone and US interest rates, always in terms of deviations with respect to sample average. These results are representative of the fit that is observed in the rest of the series: despite the discrepancies observed for some periods and variables, the fit seems remarkably good. We feel comfortable interpreting model predictions as closely representing the Spanish economy within the EMU.

Figure 6. Data and one-period-ahead forecast



Another useful measure of fit is the comparison of sample and model moments for the observed variables. Calculations not reported here show substantial differences between the autocovariance function of the observed variables in the data and the corresponding theoretical moments in the estimated model. In particular, the model generates substantially more volatility in the observed variables than in the data, with the by-product that autocovariances and cross-covariances at different leads and lags also tend to be off target. This result contrasts with the reasonably good fit of the observed historical paths in Figure 6. We attribute this discrepancy to the short sample period used in the estimation (44 observations), which makes the comparison between the theoretical model moments (based on the assumption of iid shocks) and the sample moments problematic[8]. It should be noted however that the model captures the main qualitative features of the data reasonably well. Thus, the model correctly predicts higher inflation volatility in Spain than in the rest of the Euro area (posterior mean standard deviations of 2.3% and 1.5%, respectively) although both are almost three times the ones found in the actual data (0.8% and 0.5%, respectively). Similarly, the model succeeds in predicting similar output volatility in Spain and EMU, although again the standard deviations are twice as volatile as in the data (1% and 0.4% respectively). This higher variability of the fitted series causes lower contemporaneous correlations than the observed ones. For instance, in the data the contemporaneous correlation between Span and the Eurozone is 0.57 for value added and 0.90 for inflation. The model correctly predicts that value added fluctuations are less synchronized in EMU than in the case of inflation, but obtains lower contemporaneous correlations, of 0.35 and 0.43 respectively.

3.2 Model properties

Two additional model properties are useful to assess the reliability of the model to account for the recent historical developments of the Spanish economy within the EMU: the decomposition of how much of the model series variability is due to the various shocks, by means of the forecast error variance decomposition, and the implied transmission mechanisms for the various shocks, as showed by the impulse response functions.

[8] Also, it is important to note that model moments are conditional on the functional forms assumed and the estimated parameters and shocks, whereas sample moments are completely unconditional.

Starting with the forecast error variance decomposition of the main variables in the model, we have grouped the 21 shocks of the model into nine categories:

1. **Rest of the world**: shocks to world demand, world prices, oil price and world interest rate.

2. **Common shocks**: to the exogenous trend growth and TFP processes, which are common to Spain and the rest of EMU

3. **Interest rate shocks**: shocks to the euro nominal interest rate

4. **EMU-Prices**: shocks to rest of EMU markups in prices and wages (or "cost-push" shocks).

5. **EMU-Productivity**: shocks to rest of EMU TFP in the tradables and non-tradables sectors and investment-specific technology shocks.

6. **EMU-Demand**: shocks to rest of EMU government spending and to household preferences.

7. **Spain-Prices**: shocks to Spanish markups in prices and wages (or "cost-push" shocks).

8. **Spain-Productivity**: shocks to Spanish TFP in the tradables and non-tradables sectors and investment-specific technology shocks.

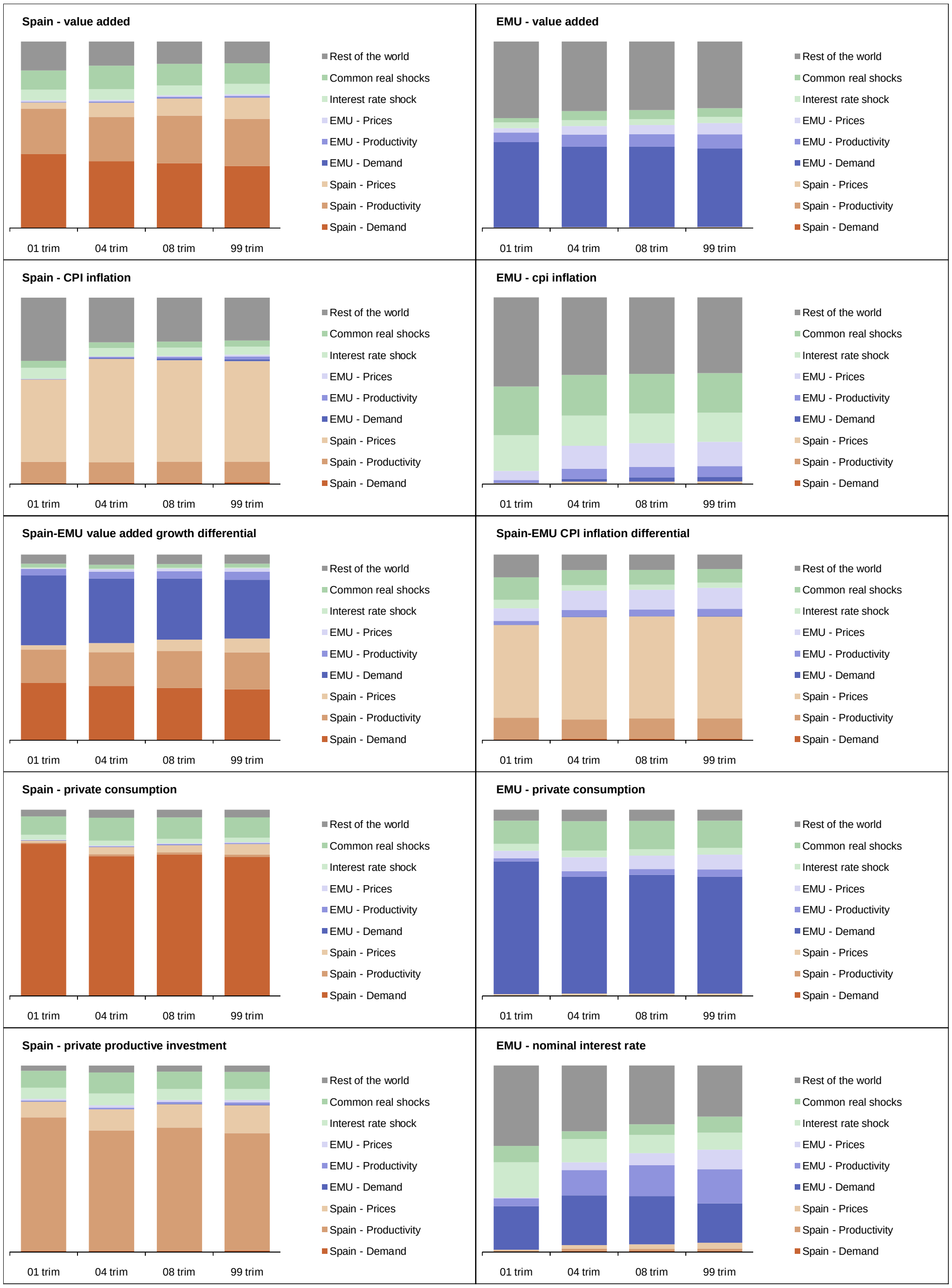
9. **Spain-Demand**: shocks to government spending and household preferences in Spain.

Figure 7 decomposes the forecast error variance at various horizons: 1, 4, 8 quarters and in the very long-run. Again the estimated contribution of each shock to the more relevant variables looks very reasonable. Spanish value added forecast error variance is mainly explained by domestic demand and productivity, while shocks common to the whole Euro area matter as well. That of Spanish inflation depends mostly on national price and wages shocks and, to a lesser extent, on shocks coming from the rest of the world —mainly oil price shocks. The results for the Eurozone are also satisfactory: the forecast error variance of its value added depends mostly on European and rest-of-the-world demand shocks, while that of inflation depends mainly on common productivity and interest rate shocks, oil price shocks, and exchange rate shocks.

The forecast error variance of the value added growth differential between Spain and the Eurozone is, then, mainly due to both areas specific demand and supply shocks, although demand shocks play a higher role. Idiosyncratic shocks to the Spanish economy seem to have a somewhat higher weight, especially at longer horizons. Common and rest of the world shocks affect but to a much lesser extent. The CPI inflation differential, in turn, depends mostly on the specific shocks that drive Spanish inflation (cost push and wage push).

As expected, the main contributor to private consumption forecast error variance in both economies is the domestic demand shock, and to an even larger extent in the case of Spain. Private productive investment fluctuations are, on the contrary, mainly driven by domestic productivity shocks, while cost-push shocks and common real and monetary shocks play a significant but much lower role, smaller in Spain than in the rest of the EMU. Finally, it is worth noting that the forecast error variance of nominal interest rates is explained to a higher extent by the variables to which the Eurozone common monetary authority reacts through its Taylor rule —thus the importance of the shocks that drive the variance of Eurozone inflation and output: oil price and world interest rates, plus European and world demand— than to intrinsic interest rate shocks.

Figure 7. Variance decompositions in the estimated model



With respect to the impulse response functions, we will present only the effects of an interest rate shock, and those of a productivity shock in the Spanish tradable goods sector. They illustrate well the multi-country and multi-sector features of the model within a monetary union. Figure 8 displays the economy's reaction to a 1% shock to the nominal common interest rate. The increase in nominal interest rate depresses private consumption and investment both in Spain and the rest of EMU. Since EMU is Spain's main trading partner, total Spanish exports fall accordingly. As a result, production in the tradables sector drops more sharply than in the non-tradables sector. The fall in production and the stickiness of nominal wages (not shown in the figure) produce a substantial fall in Spanish employment, with a maximum drop of about 2.5%.

Figure 8. Impulse-responses to a positive nominal interest rate shock

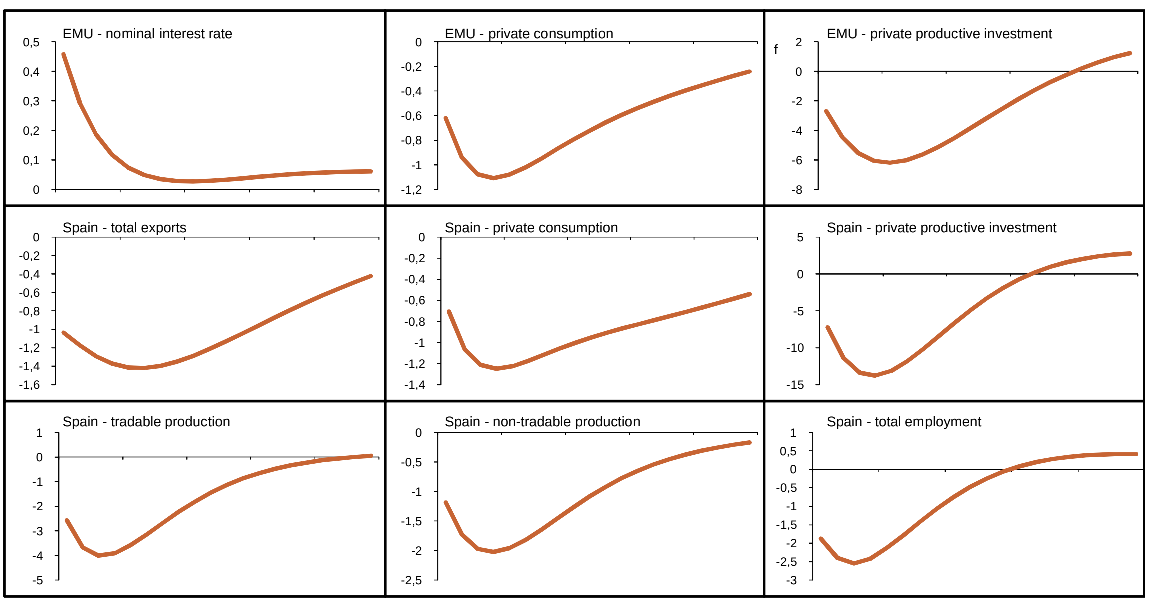
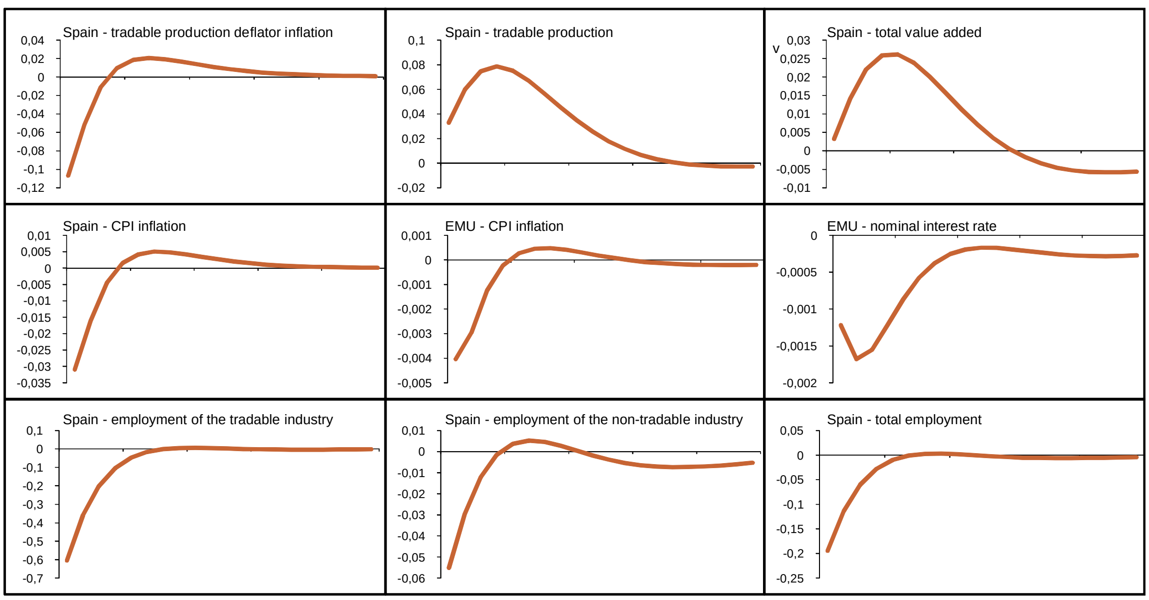


Figure 9 displays the responses to a 1% shock to productivity in Spain's tradables sector. The improvement in productivity leads to a fall in tradables producer price inflation. Spanish tradables become cheaper vis-à-vis home non-tradables and tradables from the rest of EMU and the rest of the World. As a result, tradables production increases. The latter outweights the drop in non-tradables production (not shown in the figure), such that total value-added in Spain increases. Cheaper tradables in Spain lead to lower consumer price inflation in Spain and, to a much lesser extent, in the rest of EMU. Since the latter is the main argument in the ECB monetary policy rule, nominal interest rates fall by a tiny amount. The resulting increase in domestic demand in Spain (not shown) is not large enough to compensate for the fact that firms now need less labor to produce the same output. As a consequence, employment in the tradables industry falls, with the resulting negative effects on total employment.

Figure 9. Impulse-responses to a positive productivity shock in Spain's tradables sector



4 The sources of growth and inflation differentials

Now we turn to analyzing the sources of the observed growth and inflation differentials between the Spanish economy and the rest of the Eurosystem. Here we focus on three potential explanations: differences in economic structure (as represented by the structural parameters), asymmetries in the country-specific historical shocks, and Spain's membership of the Euro Area.

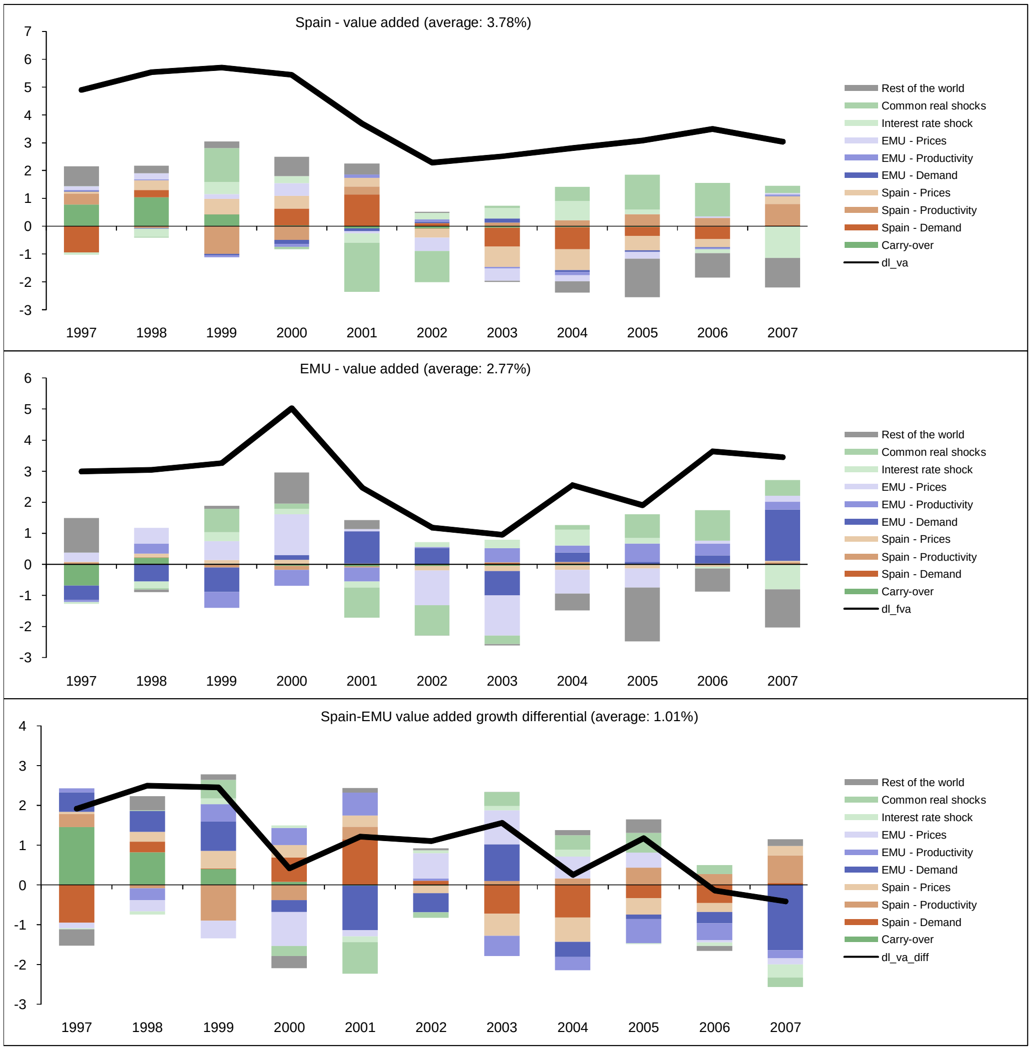
Once the model is estimated, it is possible to combine the observed series and the state-space representation of the estimated model so as to calculate the series of historical shocks that would have produced exactly the observed series.[9] By simulating the path of the endogenous variables conditional on each series of historical shocks, we can then calculate the contribution of each particular type of shock to the observed series.

Figure 10 displays the contribution of different groups of shocks to observed year-on-year GDP growth in Spain and the rest of EMU in each year of our sample period, as well as their contribution to the observed growth differential.[10] The solid line represents the observed **series**, in annual averages of quarterly observations. It is important to note that, since all our observable series have been demeaned prior to estimation, the structural shocks of the model explain only the deviations of each variable with respect to its steady state value, or long-run average. Hence, the contributions of the diverse type of shocks add up to the observed differential (solid line) minus its sample average, e.g. 1.01% growth differential in favour of Spain since the start of EMU in 1999.

[9] The estimated historical shocks are available upon request from the authors.

[10] Part of the evolution of the series at the start of the sample period is determined by the starting conditions estimated for the shocks processes ("carry-over", dark green bars in Figures 10 and 11), but it quickly disappears with time.

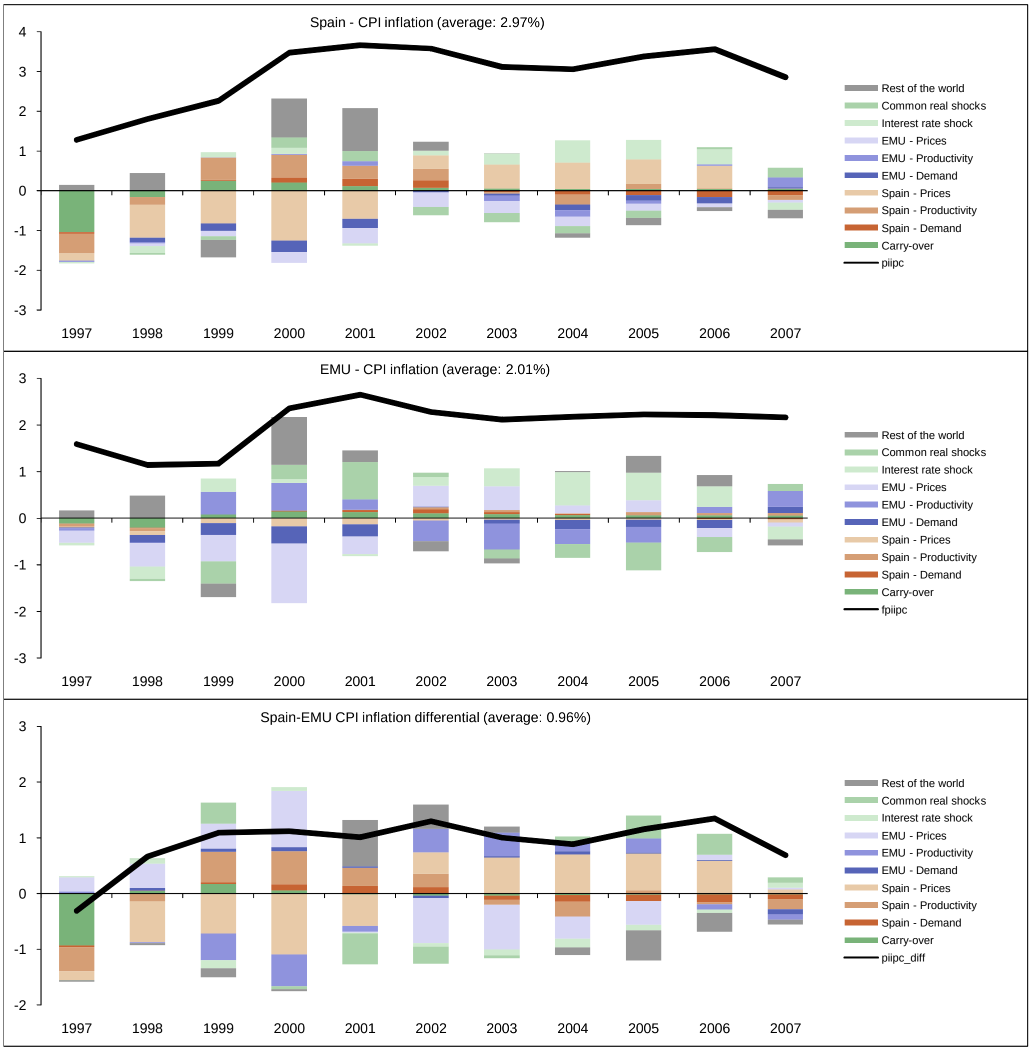
Figure 10. Contribution of each group of shocks to GDP growth differentials



As the figure shows, growth differentials all throughout the sample period are largely the result of shocks specific to Spain (beige, brown and dark brown bars) and shocks specific to the rest of EMU (light blue, blue and dark blue bars). For instance, the significant reduction in Spain's relative growth in 2000 was mainly due to the positive effect of EMU-specific wage and price shocks (cost-push shocks) on rest-of-EMU growth. Intuitively, such shocks improved EMU's competitiveness vis-a-vis the rest of the World, which combined with EMU's relatively high degree of openness led to stronger growth. Similarly, the fall in growth differentials in 2006 can be explained by negative Spain-specific demand shocks as well as positive EMU-specific productivity shocks. Note finally that, although shocks from the rest of the World have had an important effect on each region's GDP growth at certain historical dates, the fact that their effects are fairly symmetric implies that they have not made an important contribution to growth differentials.

Figure 11 shows the contribution of each group of shocks to observed CPI inflation rates and their differential over our sample period. The latter series has remained fairly stable since 1999. The reason, as suggested by the figure, is that the effects of the different groups of shocks on inflation differentials have tended to offset each other. In particular, the effect of Spain-specific cost-push and productivity shocks was largely compensated by simultaneous EMU-specific cost-push and productivity shocks. On the other hand, demand shocks have been largely irrelevant for inflation in both regions. Finally, unlike in the case of GDP growth differentials, shocks from the rest of the World do seem to have played an important role for inflation differentials, the reason being that their effects on country-specific inflation rates have not been as symmetric as on GDP growth rates. A clear example is the year 2001. The estimated historical shocks imply large rises in the real price of crude oil in that year, consistently with the evidence. Given Spain's stronger dependence on oil both in the consumption basket and in production processes, such oil shocks had larger effects on Spain's CPI inflation relative to EMU, thus leading to higher inflation differentials.

Figure 11. Contribution of each group of shocks to CPI inflation differentials



4.1 The role of asymmetric shocks and asymmetric structure

The contribution of each group of shocks to growth and inflation differentials are the result not only of different shocks hitting the Spanish and rest of EMU economies, but also of different economic structures shaping the transmission of a given shock in both regions. In fact, both elements interact in a way that makes it impossible to decompose the actual differentials as the sum of the effect of shocks plus the effect of economic structure.

It is however possible to identify the contribution of each of these two elements vis-à-vis the baseline model, by doing the following counterfactual exercises. Let (P, P^*) denote the parameter estimates specific to Spain and the rest of EMU, respectively. Let also (S, S^*) denote the historical shocks specific to Spain and the rest of EMU, respectively. Let $y(p, p^*; s, s^*)$ be the path of Spain's observable variables generated by the state-space representation of the model for certain parameter values (p, p^*) and certain exogenous shocks (s, s^*), and let $y^*(p, p^*; s, s^*)$ be the corresponding function for the rest-of-EMU observables. Evaluating y and y^* at the estimated parameters and historical shocks and taking differences, we obtain exactly the observed differentials, which we denote by

$$y_{diff} \equiv y(P, P^*; S, S^*) - y^*(P, P^*; S, S^*).$$

4.1.1 The effect of shocks asymmetries

We now define

$$y_{diff}^S \equiv y(P, P^*; S^*, S^*) - y^*(P, P^*; S^*, S^*),$$

which is the set of differentials that would have been observed if the shocks specific to the Spanish economy had been exactly the same as the shocks specific to the rest of EMU. By comparing these counter-factual differentials to the actual differentials (y_{diff}), we can isolate how the latter have been affected by the occurrence of country-specific shocks.

Figure 12 compares y_{diff} (solid blue line) and y_{diff}^S (dotted green line) for the case of year-on-year GDP growth and CPI inflation. As indicated by the upper panel, in the counterfactual scenario with symmetric country-specific shocks the growth differential would have been *lower* in 2001-2003 and *higher* in 2004-2007. Figure 10 above gives some guidance for interpreting these results. According to that figure, in 2001 growth rates in both regions benefited from region-specific positive demand shocks, but the positive effect Spain-specific shocks on the growth differential was stronger than the negative effect EMU-specific shocks. Therefore, if Spain-specific demand shocks had had the same magnitude as EMU-specific shocks, relative growth in Spain would have been weaker in 2001, and this situation would have persisted during 2002-2003. Similar interpretations can be made for explaining the higher counterfactual differentials in 2004-2007.

Regarding inflation differentials, the lower panel of Figure 12 shows that they would have been lower in the second half of 1999 and all of 2000, but fairly similar during the rest of the sample. The decomposition of observed inflation differentials in Figure 11 above indicates that the contribution of Spain-specific cost-push shocks tended to be offset by cost push shocks specific to the rest EMU. As a result, making cost-push shocks in Spain equal to those in the rest of EMU would have left inflation differentials largely unaltered.

Figure 12. The effect of shock asymmetries on growth and inflation differentials

4.1.2 The effect of structural asymmetries

Let us now define

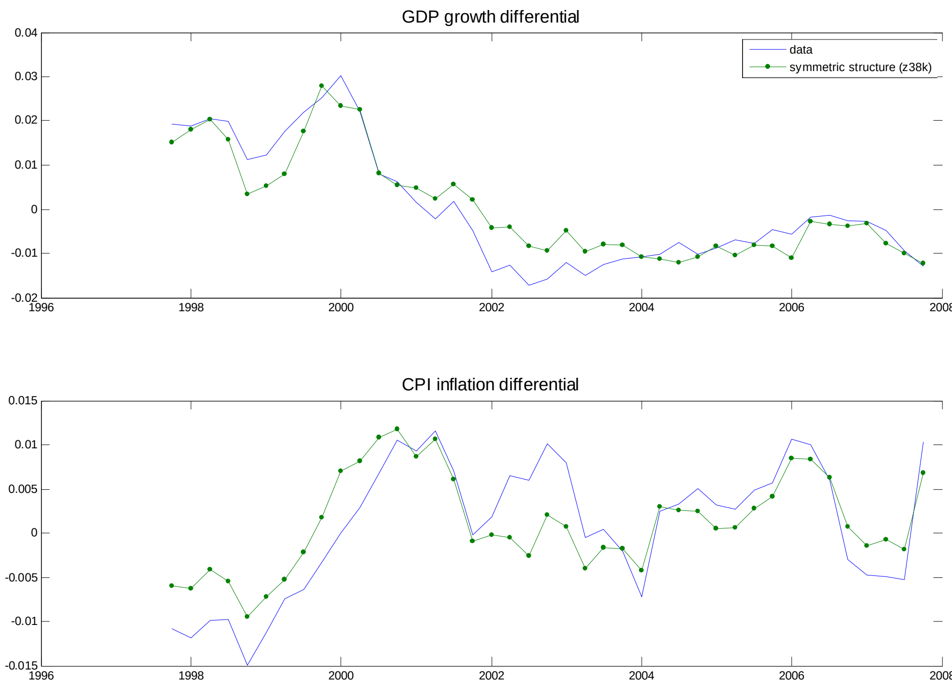
$$y^P_{diff} \equiv y(P^*, P^*; S, S^*) - y^*(P^*, P^*; S, S^*),$$

that is, the set of differentials that would have been observed if the structural parameters specific to the Spanish economy had been exactly the same as the parameters estimated for the rest of EMU. We can then compare these counter-factual differentials to the actual ones in order to isolate the extent to which the latter are the result of differences in economic structure between Spain and the rest of EMU. Such structural differences include:

1. Average frequency of adjustment of nominal prices and wages,
2. Degree of backward-looking indexation of nominal prices (to producer price inflation) and nominal wages (to consumer price inflation), and
3. Investment adjustment costs.

Figure 13 compares observed y_{diff} (solid blue line) and counter-factual y^P_{diff} (dotted green line) again for year-on-year GDP growth and CPI inflation. According to the upper panel, growth differentials would have been very similar in the counter-factual scenario with symmetric structural parameters. Regarding inflation differentials, the lower panel shows that, even though they would have been qualitatively similar (i.e. peaks and troughs would have been largely coincident in time), quantitatively they would have been less volatile for most of the sample period. Table 2 above provides us with a hint for interpreting these counter-factual results. According to our estimation results, Spain's economic structure differs from that of the rest of EMU mainly in its lower degree of nominal wage indexation. As a consequence, any shocks that produce changes in Spanish CPI inflation lead to changes in nominal wage inflation, which end up having second-round effects on CPI inflation. Therefore, had the Spanish degree of nominal wage indexation been the same as in the rest of EMU, CPI inflation differentials would have been more stable.

Figure 13. The effect of structural asymmetries on growth and inflation differentials



4.2 The effects of EMU membership

We finally analyze to what extent inflation and growth differentials between Spain and the rest of EMU have been affected by Spain's membership of the European Monetary Union. Once again, our estimated DSGE model provides us with a helpful tool in order to address this question. Our approach here is to build a counter-factual model economy in which the economic structure and shocks in Spain and the rest of EMU would be exactly the same as in the estimated model, except for the fact that Spain retains its own currency (the 'peseta') and hence the ability to set its own nominal interest rates. In particular, we define the function $y(p, p^{*}, BdE; s, s^{*})$, which is the set of differentials implied by certain parameter values (p, p^{*}) and certain shocks (s, s^{*}) in a version of BEMOD in which the

Banco de España (BdE) carries out its own monetary policy independently of the ECB. We then define

$$y_{diff}^{peseta} \equiv y(P, P^*, BdE; S, S^*) - y^*(P, P^*, BdE; S, S^*),$$

which is the set of differentials that would have been observed in the counter-factual scenario with independent monetary policy in Spain, given the parameters and historical shocks estimated in the baseline model. In particular, we assume that the coefficients in Spain's monetary policy rule would have been the same as those estimated for the ECB in Table 2, with the difference that the peseta interest rate responds to deviations of *Spain*'s CPI inflation and output growth from their respective targets. By comparing y_{diff} and y_{diff}^{peseta}, we can isolate how the fact that Spain belongs to EMU affects its macroeconomic behavior in relation to the rest of the currency area.

Figure 14. The effect of Spain's EMU membership on growth and inflation differentials

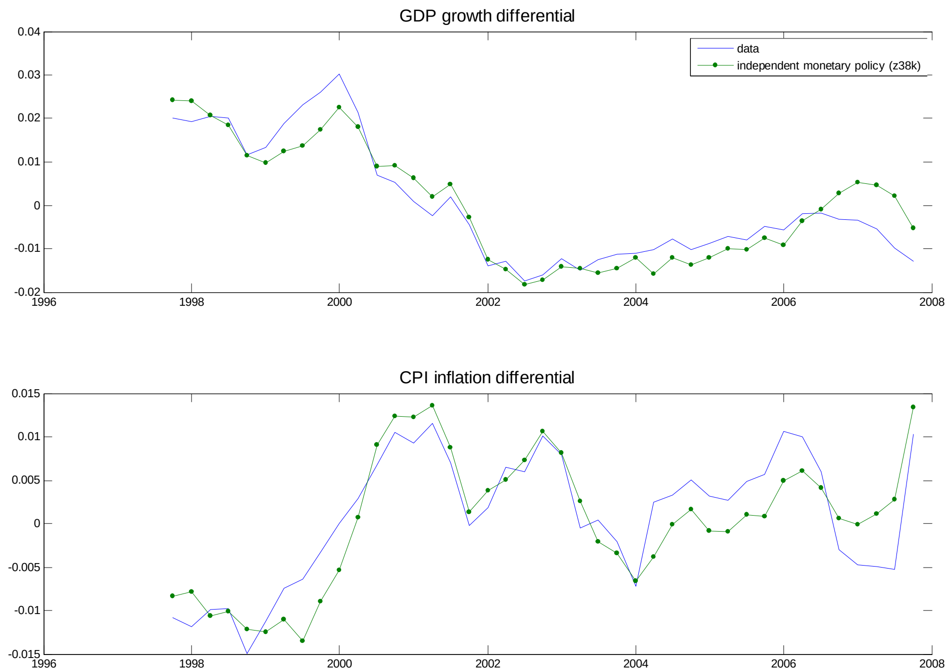


Figure 14 compares y_{diff} (solid blue line) and y_{diff}^{peseta} (dotted green line) over the sample period, for both GDP growth and CPI inflation. The figure suggests that an independent monetary policy in Spain would have led to different growth and inflation developments at certain historical episodes. For instance, at the onset of the Euro in 1999 and early 2000 the Spanish monetary authorities would have hypothetically pursued lower inflation rates relative to EMU, which would have come at the cost of slower relative growth in the same period. Conversely, the last five quarters in the sample would have hypothetically witnessed faster GDP growth in Spain relative to EMU, thus producing higher inflation differentials. Overall, these results suggest that EMU membership does have an important effect on the cyclical behavior of Spain's growth and inflation differentials.

5 Concluding remarks

Since the launch of the Euro, the evolution of the Spanish economy has been remarkably different from that of the rest of the Euro area. Both the rate of growth of GDP and the inflation rate have been systematically higher in Spain, and so has been the rate of employment creation. These differentials stem partially from the ongoing process of convergence and from the integration of financial markets with strong repercussions in an economy that has resorted traditionally to foreign funds to finance a substantial gap between domestic savings and investment. These differences deserve a more careful scrutiny in the context of models combining high and low frequency fluctuations in the data.

Leaving aside these long term features there are shorter term, business cycle frequency, relevant differences in the macroeconomic performance of Spain *vis-a-vis* the EMU. These differences can be explained by a combination of idiosyncratic shocks and the unequal speed of adjustment of labour and goods and services markets that still prevail among the two economies.

BEMOD is designed to capture these features. The model displays a symmetric theoretical structure but the econometric estimation reveals substantial differences both in the stochastic and in the deterministic components. The data is informative regarding the Calvo parameters and the stochastic processes of the shocks, although the indexation parameters are more dependent on the choice of the priors. The estimation reveals some moderate differences in these parameters across the two countries. In particular we find that nominal rigidities are somewhat smaller in Spain, except for non-tradables, while wage indexation is much higher than in its EMU partners.

The model fit is good and the variance decomposition suggests that the cost-push shocks play a very important role in accounting for the dynamics of inflation in both countries. The dynamics of value added is more balanced with shocks to the rest of the world, to domestic demand and (to a lesser extent) productivity shocks playing a significant role. The historical contribution of shocks confirms these results for more specific episodes, uncovering the main reasons behind the evolution of the inflation and growth differentials.

The estimated model is used to perform three counterfactual exercises. We find that growth and inflation differentials between Spain and the rest of EMU would have been different during prolonged periods should the Spanish economy have experienced the same shocks as estimated for its EMU partners. This is particularly true for the evolution during the early years of the Euro. Similarly, the structural specificities of the Spanish economy account for a non-negligible proportion of the volatility of differentials in CPI inflation. We conjecture that this result is mainly due to the more sticky prices in non-tradables and the considerably higher degree of nominal wage indexation estimated for the Spanish economy. We also find that EMU membership has had a non-negligible effect on the volatility of growth and inflation differentials, should Spain have retained an independent monetary policy for the peseta, the dynamics of these differentials would have behaved rather differently at certain historical episodes. The counterfactual analysis reveals that at the onset of the Euro, as well as during the high-inflation and growth period in Spain (2004-2006), the Spanish monetary authorities would have hypothetically pursued lower inflation rates relative to EMU at the cost of slower relative growth. The opposite is true for the more recent quarters in which an independent monetary authority would have helped to achieve faster GDP growth in Spain relative to EMU, thus producing higher inflation differentials.

The specification and estimation of BEMOD is an ongoing project. There are many issues in the research agenda regarding both the theoretical structure and the estimation process. The model will be augmented with credit frictions and public investment as well as with Calvo frictions in the import and export aggregators. On the empirical side, some robustness checks regarding the set of observables are due and we also plan to extend the estimation to other parameters that have been calibrated in the current version. Finally, although the model contains a wide range of exogenous shocks, there is room for improvement on this front too, e.g. including stochastic variations in the various home biases in the model.

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