Inflation Differentials Between Spain and the EMU: A DSGE Perspective

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Abstract

This paper estimates a Dynamic Stochastic General Equilibrium (DSGE) model of a currency union with nominal rigidities to explain the sources of inflation differentials between the EMU and one of its member countries, Spain. The paper finds that productivity shocks account for 85 percent of the variability of the inflation differential. Demand shocks explain a large fraction of output growth volatility, but not variability in inflation differentials. In addition, the estimated model finds evidence that inflation dynamics are different across countries in the nontradable sector only. Finally, the Balassa-Samuelson effect does not appear to be an important driver of the inflation differential during the EMU period.

JEL Classification: F41, F42, C51.

Keywords: Balassa-Samuelson effect, Bayesian Estimation, European Monetary Union.

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1 Introduction

1.1 Motivation

Since the launch of the euro in January 1999, a topic that has received a lot of attention is the study of inflation differentials in the european Economic Monetary Union (EMU).[1] When the euro was introduced, the Harmonised Index of Consumer Prices (HICP) in the EMU was increasing at a 12-month rate of 0.9 percent, with a weighted standard deviation of 1.1 percent across member countries (using the country weights in the HICP). Nine years later, in December 2007, the EMU inflation rate was at 3.1 percent, while the weighted standard deviation was 3.2 percent. This increase in inflation dispersion can be striking given that in January 1999, EMU countries seemed to have achieved nominal convergence. Figure 1 plots the weighted standard deviation of the 12-month inflation rate using the country weights that Eurostat uses to compute the HICP. After an all-time low in 1999, inflation dispersion has increased significantly since, with some fluctuations. This is also true for its main components (core, goods and services).

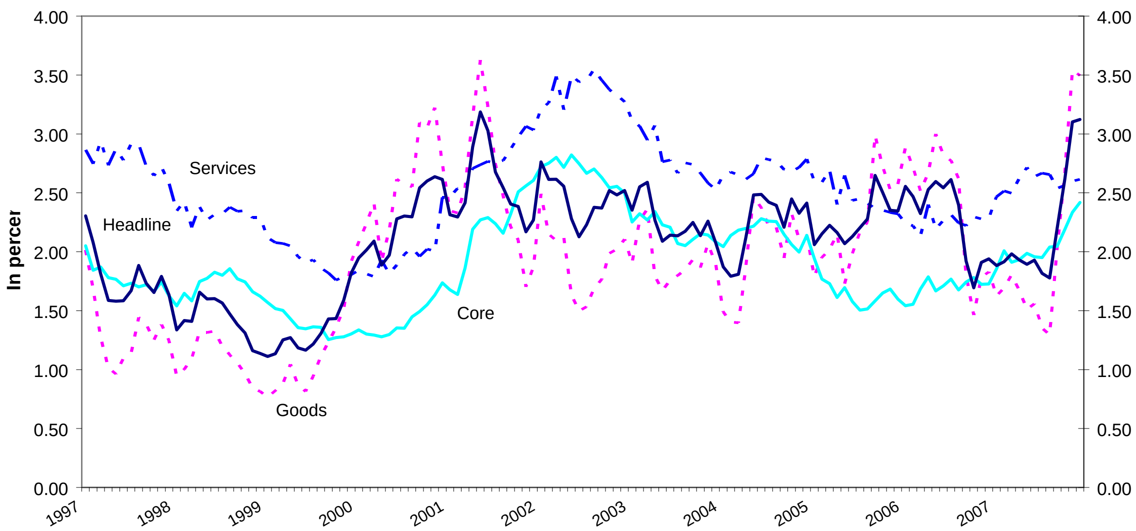

Figure 1: Weighted standard deviation of the 12-month inflation rate in the EMU.

Another interesting feature of the recent period is the persistence of inflation differentials. What makes the study of the case of Spain vis-à-vis the rest of the EMU

[1] See for instance ECB (2003), Angeloni and Erhmann (2007), López-Salido et al. (2005), Andrés et al. (2003).

interesting is that, in the last decade, Spain has had almost permanently higher inflation. In Figure 2 we present the difference of headline inflation rates between Spain and the rest of the EMU. As the solid line shows, except for two brief periods (three months in 1997 and two months in 2001), Spain has had higher inflation than its partners in the monetary union.[2]

In order to understand what explains the inflation differential between Spain and the rest of the EMU, in Figure 2 we perform a decomposition that is standard in the open economy macroeconomics literature.[3] The inflation differential between Spain's year-on-year HICP inflation and the rest of the EMU is given by:

$$\Delta p_t - \Delta p_t^* = \Delta p_t^T - \Delta p_t^{T*} + (1-\gamma^*)(\Delta p_t^{T*} - \Delta p_t^{N*}) - (1-\gamma)(\Delta p_t^T - \Delta p_t^N) \quad (1)$$

where Δ is the year-on-year difference operator, p_t, p_t^T, p_t^N are the natural logarithms of the headline HICP, its tradable component, and its nontradable component for Spain, $p_t^*, p_t^{T*}, p_t^{N*}$ are the same variables for the rest of the EMU, and γ and γ^* are the share of tradable goods in the HICP in Spain and in the rest of the EMU. Therefore, deviations from purchasing power parity can be explained by: (i) deviations from the law of one price for tradable goods, and (ii) movements of relative prices between tradable and nontradable goods inside each country. If the fraction of tradable goods in the CPI is the same across countries ($\gamma = \gamma^*$), and the law of one price holds ($\Delta p_t^{T*} = \Delta p_t^T$) then fluctuations in the inflation differential would be due to nontradable inflation only. If the consumption basket differs across countries and there are deviations from the law of one price then fluctuations in the price of tradable goods will also matter.

The inflation differential in the tradable component (dotted line) is proxied by the "goods" component of the HICP as published by Eurostat. The "relative" series (dashed-dotted line) is simply the difference between the headline differential and the tradable inflation differential, and collects the second term of equation (1). In the period between early-2002 and mid-2006, the tradable component explains most of the headline inflation differential. This suggests that any model trying to explain

[2] In the 1999-2007 period, Spain has had an average inflation rate of 3.12 percent, while in the rest of the EMU the average has been 1.96 percent. Greece, Portugal and Ireland have also had average inflation rates higher than 3 percent, but the inflation rate has gone through long periods where it has been lower than the EMU as a whole.

[3] This decomposition was used by Engle (1999), Betts and Kehoe (2006) and Chari, Kehoe and McGrattan (2002) to disentangle fluctuations of the real exchange rate. Here, our variable of interest is the inflation differential. The spirit of the decomposition is the same.

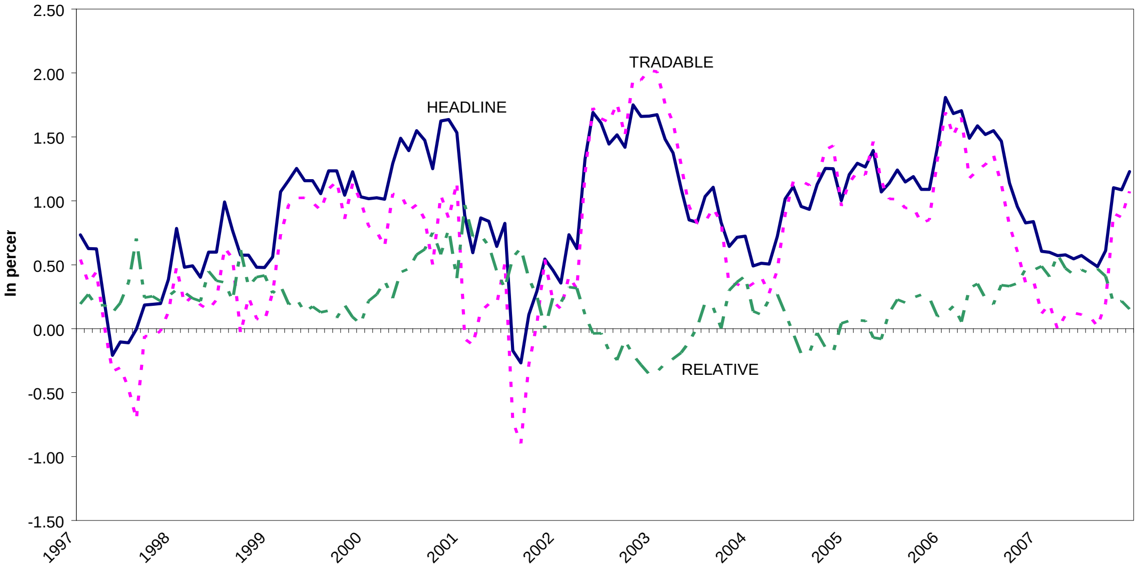

Figure 2: Decomposition of the inflation differential between Spain and the rest of the EMU.

the evidence should introduce monopolistic competition and product differentiation of tradable goods, to allow for tradable goods inflation to differ across countries. However, in other periods, the role of tradable goods inflation differentials has diminished, suggesting that any model trying to explain the facts should also include nontradable goods. Therefore, the model that we estimate in this paper will include both tradable and nontradable goods.

1.2 Related Literature

Cross country studies of inflation dynamics, and in particular in the EMU, have focused on three main explanations. The first explanation studies the role of productivity growth differentials, and also brings the Balassa-Samuelson effect (Altissimo et al., 2005). Table 1 presents labor productivity growth rates for Spain and the rest of the EMU for the tradable and nontradable sectors. Two facts stand out: first, the rest of the EMU has had higher productivity growth rates than Spain. Second, in both regions, productivity growth in the tradable sector has been much higher than in the nontradable sector. In fact, Spain has experienced negative productivity growth in the nontradable sector in the last ten years. Therefore, productivity growth differentials are likely to be a main factor behind Spain's higher inflation.

Table 1: Labor Productivity and Real GDP Growth, 1996-2007

Labor Productivity	Tradable	Nontradable
Spain	1.65	-0.65
Rest of EMU	2.96	0.52
Real GDP Growth	**Tradable**	**Nontradable**
Spain	2.60	4.00
Rest of EMU	2.10	2.12

Note: The Tradable sector includes the Agriculture, Forestry, Fishing and Industry sectors, while the Nontradable sector includes Construction and Services. Labor productivity is obtained by dividing real GDP by the number of employees in each sector. All data are taken from Eurostat.

The Balassa-Samuelson effect is typically used to explain inflation differentials for those countries experiencing a catching-up process.[4] As the relatively poorer countries adopt new technologies in those sectors that are open to international trade (i.e. the tradable sector), they will experience higher productivity growth in the tradable sector, increased wages, and higher inflation in the sectors that are not open to international trade (the nontradable sectors). Therefore, the Balassa-Samuelson hypothesis could be a candidate to explain the higher inflation rate in the service sector (as a proxy for the nontradable sector) than in the goods sector (as a proxy for the tradable sector), and hence leading to higher headline inflation.[5]

The second explanation focuses on the role of the demand-side effects (López-Salido et al., 2005). During the same period, as Table 1 shows, real GDP growth has been higher in both sectors in Spain, with the differences being more important in the nontradable sector. Therefore, supply (productivity) factors cannot be the only explanation for the evolution of the inflation differential between Spain and the EMU, because declining productivity in the nontradable sector would imply higher inflation but lower output in this sector. Real GDP growth in the nontradable sector has increased despite negative productivity rates because of higher employment. Therefore, in order to observe both an increase of output and prices in the nontradable sector, demand factors must have played an important role.

[4] See Balassa (1964) and Samuelson (1964).

[5] Regarding inflation differentials in the tradable sector, as trade barriers fall and countries adopt a common currency (hence, price comparisons are easier), then price level convergence implies that some countries will experience higher inflation rates than others in the transition. However, Rogers (2006) finds that price level convergence in the EMU seemed to happen already during the 1990s, and that current levels of price dispersion across european cities are similar to those in the USA.

Finally, Angeloni and Ehrmann (2007), and Andrés et al. (2003) suggest that, due to different product and labor market structures, there is heterogeneity of inflation dynamics processes in each country of the union. As a result, even when economies are hit by symmetric shocks (such as oil prices, world demand, and the euro exchange rate), the response of inflation will be different across countries.

1.3 Contribution

These three main hypotheses have been useful to explain the individual inflation country experiences of EMU member countries, and are not mutually exclusive. Surprisingly, the existing literature lacks a methodology to test their relative importance in explaining overall inflation differentials. This paper estimates a two-country, two-sector New Keynesian dynamic stochastic general equilibrium (DSGE) model of a currency union, using Spain and EMU data, and using Bayesian methods. The advantages of the Bayesian approach have been discussed elsewhere.[6] In the context of the present paper, we want to explain the EMU experience so we are forced to use a short sample at a quarterly frequency. Hence, the Bayesian approach is particularly helpful, and carefully specified priors become more important. A potential limitation of our approach is that by constructing a two-country model, external shocks to the EMU are not modelled explictly, and hence are not allowed to play a role in explaining the inflation differential.

Typically, the literature that estimates DSGE models demeans or detrends the observable variables in a non-model consistent way, and is concerned about fitting second moments of the data only. In this paper, we complement this analysis by trying to explain the first moments of the data. In order to do so, we introduce different trends in the country- and sector-specific technology shocks. The approach of jointly fitting first and second moments of the data in a model-based way has been previously used in one-sector models of the U.S. economy by Schorfheide (2000) and Ireland (2004); in multisector models of the U.S. economy, such as Iacoviello and Neri (2008), and Edge, Kiley and Laforte (2007); in multisector small open economy models of the euro area (Adolfson et al., 2008a) and Canada (Ambler et al., 2003); and in two-country models of the U.S. and euro area economies with tradable goods only, such as Lubik and Schorfheide (2006). As far as we are aware of, this is the

[6] See An and Schorfheide (2007) for a survey on the estimation of DSGE models using Bayesian methods.

first attempt to explain sector-specific inflation rates in a two-country, two-sector, currency union model economy. As we will show, the estimated version with the model-consistent inflation and growth rates delivers a worse fit to the data than the estimated version that detrends the data in a non-model consistent way. This is so because Spain has had both higher inflation and higher real GDP growth, and the two facts cannot be explained with just one parameter, the productivity growth differential.

The results of the paper can be summarized as follows: first, the most important explanation for the inflation differential between Spain and the euro area comes from tradable sector productivity shocks. These shocks explain about 65 percent of the variability of the inflation differential, while nontradable sector technology shocks explain about 18 percent of the inflation differential. Demand shocks are mostly useful to explain a significant fraction of output growth volatility, but only explain 14 percent of inflation dispersion. Second, we find that the estimated coefficients that determine inflation dynamics in Spain and in the rest of the euro area are different in the nontradable sector only. However, the differences are quantitatively small. Third, our estimated impulse responses to tradable sector technology shocks suggest that the Balassa-Samuelson effect has not been an important source of inflation differentials during the EMU period.

The rest of the paper is organized as follows: in Section 2 we outline the model, while section 3 briefly describes the Bayesian econometric approach. In Section 4 we present the results in terms of posterior parameter distributions, impulse responses, and second moments. Section 5 concludes.

2 The Model

We study the interactions between Spain and the rest of the Euro Area inside a currency union by constructing and estimating a two-country New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model of a currency union. The model extends the two-country setup of Lubik and Schorfheide (2006), by including the nontradable sector and assuming that both countries share the same currency and monetary policy.[7] Most importantly, the model introduces time trends for the country- and sector-specific technology shock processes that can give rise to perma-

[7]Similar DSGE models include Altissimo et al. (2005), and Duarte and Wolman (2006).

nent inflation differentials in the model. The optimizing conditions of the model imply that, in the steady state, the following ratio holds

$$\frac{Z^T}{Z^N}\frac{P^H}{P^N} = 1$$

where Z^T and Z^N are the levels of technology in the production of tradable and nontradable goods, and P^H and P^N are the price levels for domestically-produced tradable goods and nontradable goods, respectively. Therefore, it is possible to have different inflation rates across sectors and countries in the model if the levels of technology grow at different rates. In order to make the equilibrium conditions stationary, the same methods as in King, Plosser and Rebelo (1988) can be applied.

The main ingredients of the model are as follows. To study the behavior of inflation, the model introduces nominal rigidities using the Calvo (1983) model with indexation, as Smets and Wouters (2003). To test for the presence and importance of the Balassa-Samuelson effect, the model includes tradable and nontradable goods in both countries, and productivity shocks that affect all countries and sectors. To understand the role of demand factors, the model incorporates demand shocks in the form of government spending in both tradable and nontradable goods. The model also incorporates a monetary policy shock which is the residual of a Taylor-type interest rate rule that targets the EMU HICP inflation. We assume that production technologies and preferences are the same across countries, but countries differ in the composition of the consumption indices and in the degrees of nominal rigidity and indexation. Since the model is quite large, we present the main functional forms and shocks for the home country, while an appendix available upon request presents the full set of equilibrium conditions.

2.1 Preferences

We assume that there are two countries in the european monetary union, home (H) and foreign (F), of unequal size. The home country is of size s, while the foreign country is of size $1 - s$. Brands of tradable goods are indexed by $h \in [0, s]$ in the domestic country and by $f \in [s, 1]$ in the foreign country. Countries produce differentiated tradable goods that are imperfect substitutes of each other, but there is no price discrimination for the same type of good across countries. Brands of nontradable goods are indexed by $n \in [0, s]$ in the home country and by $n^* \in [s, 1]$.[8]

The preferences of a typical household in the home country, indexed by $j \in [0, s]$ are:

$$U_t = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[\log \left(C_t^j - bC_{t-1} \right) - \frac{\left(L_t^j \right)^{1+\varpi}}{1+\varpi} \right] \right\}, \tag{2}$$

where E_0 denotes the expectation conditional on the information set at date $t = 0$, and β is the intertemporal discount factor. C_t^j denotes the level of consumption in period t, L_t^j denotes labor supply. The utility function displays external habit formation, and depends on the home country's lagged aggregate consumption (C_{t-1}). $b \in [0, 1]$ denotes the importance of the habit stock, which is last period's aggregate consumption. $\varpi > 0$ is inverse elasticity of labor supply with respect to the real wage. The labor disutility index includes hours allocated to tradable and nontradable activities:

$$L_t = L_t^T + L_t^N \tag{3}$$

We define the consumption index (C_t) as a constant elasticity of substitution (CES) aggregate of tradable (C_t^T) and nontradable goods (C_t^N):

$$C_t = \left[\gamma^{\frac{1}{\varepsilon}} \left(C_t^T \right)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\gamma)^{\frac{1}{\varepsilon}} \left(\xi_t^{N,C} \right)^{\frac{1}{\varepsilon}} \left(C_t^N \right)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{4}$$

where γ is the share of tradable goods in the consumption basket at home. $\varepsilon > 1$ is the elasticity of substitution between tradable and nontradable goods, and $\xi_t^{N,C}$ is a deterministic preference shock that affects the units of effective nontradable consumption. The introduction of preference shocks allows us to estimate the different elasticities of substitution across types of goods and be consistent with balanced growth when each sector grows at a different rate

The sub-index of consumption for tradable goods is defined as the following function of domestically produced tradable goods (C_t^H) and imported goods (C_t^F):

$$C_t^T = \left[\lambda^{\frac{1}{\nu}} \left(C_t^H \right)^{\frac{\nu-1}{\nu}} + (1-\lambda)^{\frac{1}{\nu}} \left(\xi_t^{F,C} \right)^{\frac{1}{\nu}} \left(C_t^F \right)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}, \tag{5}$$

where λ represents the fraction of home-produced consumption goods in the tradable consumption index. ν is the elasticity of substitution between home and foreign

[8] We use an asterisk to denote the counterpart in the foreign country of a variable or parameter in the home country (i.e. aggregate consumption is C in the home country, and C^* in the foreign country).

goods, and $\xi_t^{F,C}$ is another deterministic preference shock that affects the units of consumption of the imported consumption good. C_t^H and C_t^F are indexes of consumption across the continuum of differentiated goods produced in country H and F, and are given by:

$$C_t^H \equiv \left[\left(\frac{1}{s}\right)^{\frac{1}{\sigma}} \int_0^s c_t(h)^{\frac{\sigma-1}{\sigma}} dh\right]^{\frac{\sigma}{\sigma-1}}, C_t^F \equiv \left[\left(\frac{1}{1-s}\right)^{\frac{1}{\sigma}} \int_s^1 c_t(f)^{\frac{\sigma-1}{\sigma}} df\right]^{\frac{\sigma}{\sigma-1}}, \tag{6}$$

where $\sigma > 1$ is the elasticity of substitution across goods produced within country H, denoted by $c_t(h)$, and country F, denoted by $c_t(f)$. Similarly, the consumption of nontradables in the home country is given by

$$C_t^N \equiv \left[\left(\frac{1}{s}\right)^{\frac{1}{\sigma}} \int_0^s c_t^N(n)^{\frac{\sigma-1}{\sigma}} dn\right]^{\frac{\sigma}{\sigma-1}}, \tag{7}$$

where $c_t^N(n)$ denotes the consumption of each individual nontradable good. In this context, the home country consumer price index (P_t) is given by:

$$P_t^{1-\varepsilon} = \left[\gamma \left(P_t^T\right)^{1-\varepsilon} + (1-\gamma)\xi_t^{N,C} \left(P_t^N\right)^{1-\varepsilon}\right] \tag{8}$$

where the home country price index for tradable goods (P_t^T) has the following form:

$$\left(P_t^T\right)^{1-\nu} = \left[\lambda \left(P_t^H\right)^{1-\nu} + (1-\lambda)\xi_t^{F,C} \left(P_t^F\right)^{1-\nu}\right] \tag{9}$$

Finally, prices of home $\left(P_t^H\right)$ and foreign $\left(P_t^F\right)$ tradable goods, and non-tradable goods (P_t^N) are also obtained by setting the appropiate zero profit conditions.

Households have access to a set of contigent bonds that pay one unit of currency in every possible state of nature in $t+1$. In order to keep notation simple we do not explicitly introduce the portfolio of state-contingent assets that allows households to obtain insurance against idiosyncratic risk. We also assume that households can trade a riskless nominal bond denominated in euros (which, given the assumption of complete markets is redundant) that pays a gross rate of R_t. Then, the budget constraint of the domestic households in euros is given by:

$$\frac{B_t}{P_t R_t} \leq \frac{B_{t-1}}{P_t} + W_t L_t - C_t + \zeta_t \tag{10}$$

where W_t is the real wage, and ζ_t are real profits for the home consumer. As shown by Chari, Kehoe and McGrattan (2002) combining optimality conditions between home and foreign households delivers the following risk sharing condition under complete markets:

$$RER_t = \frac{P_t^*}{P_t} = \frac{\mu_t^*}{\mu_t} \tag{11}$$

where μ_t and μ_t^* denote the marginal utility of consumption in both countries.

2.2 Price Setting and Technology

Price setting follows a modified version of the Calvo-type restriction with indexation. In every period, intermediate goods producers receive a stochastic signal that allows them to change prices. This signal arrives with probability $1-\theta_N$ in the non-tradable sector, and $1-\theta_H$ in the tradable sector. In addition, we assume that when firms are not allowed to reoptimize, a fraction φ_N indexes its price to last period's inflation rate in the nontradable sector, while a fraction $1-\varphi_N$ indexes its price to the sector's steady-state rate of inflation (the analogous coefficients in the tradable sector are φ_H and $1-\varphi_H$).[9]

The model includes a euro-area technology process with a deterministic trend, that gives growth to the model. An advantage of this approach is that real variables in the model and in the data will be nonstationary in levels, but stationary in first differences, and hence provides a model-based method to detrend the data.

2.2.1 Non-Tradable Sector

Each firm produces according to the following production function, with labor as the only input, $L_t^N(n)$:

$$y_t^N(n) = X_t Z_t^N L_t^N(n) \tag{12}$$

where X_t is a labor augmenting aggregate euro-area wide technology shock which has a deterministic trend:

$$X_t = (1+x)^t X_0 \tag{13}$$

[9]This type of indexation mechanism is introduced to avoid steady-state effects of a positive inflation rate, since inflation rates can be non-zero and different across countries and sectors.

with $X_0 > 0$. Z_t^N is the country-specific productivity shock to the non-tradable sector, that evolves as follows:

$$\begin{aligned} Z_t^N &= (1+\alpha^N)^t \tilde{Z}_t^N \\ \log(\tilde{Z}_t^N) &= \rho^{Z,N} \log(\tilde{Z}_{t-1}^N) + \varepsilon_t^{Z,N}. \end{aligned} \tag{14}$$

Firms in the non-tradable sector face the following profit maximization problem, which is quite standard under a Calvo-type restriction:

$$Max_{p_t^N(n)} E_t \sum_{k=0}^{\infty} \theta_N^k \Lambda_{t,t+k} \left\{ \left[\frac{p_t^N(n) \left(\frac{P_{t+k-1}^N}{P_{t-1}^N} \right)^{\varphi_N} \left(\Pi^N \right)^{k(1-\varphi_N)}}{P_{t+k}} - MC_{t+k}^N \right] y_{t+k}^{N,d}(n) \right\} \tag{15}$$

subject to

$$y_{t+k}^{N,d}(n) = \frac{(1-\gamma)}{s} \left[\frac{p_t^N(n)}{P_{t+k}^N} \left(\frac{P_{t+k-1}^N}{P_{t-1}^N} \right)^{\varphi_N} \left(\Pi^N \right)^{k(1-\varphi_N)} \right]^{-\sigma} Y_{t+k}^N \tag{16}$$

where $\Lambda_{t,t+k} = \beta^k \frac{\lambda_{t+k}}{\lambda_t}$ is the stochastic discount factor, $y_{t+k}^{N,d}(n)$ is total individual demand for a given type of nontradable good at time $t+k$ when the firm last reoptimized at t, which comes from the consumer's optimal choice. Y_t^N is aggregate demand for nontradable goods, to be defined below. MC_t^N corresponds to the real marginal cost in the non-tradable sector. From cost minimization, the marginal cost is simply the real wage adjusted by the level of aggregate and sector-specific productivity:

$$MC_t^N = \frac{W_t}{X_t Z_t^N}. \tag{17}$$

The supplier maximizes (15) with respect to $p_t^N(n)$ given the demand function (16) and taking as given the sequences of all other prices. The pricing condition is the usual one coming from the Calvo model, extended for the fact the steady state inflation might not be zero, and with the two indexation mechanisms in place.[10] The evolution of the price level of nontradables is

$$P_t^N \equiv \left\{ \theta_N \left[P_{t-1}^N \left(\Pi_{t-1}^N \right)^{\varphi_N} \left(\Pi^N \right)^{(1-\varphi_N)} \right]^{1-\sigma} + (1-\theta_N) \left(\hat{p}_t^N \right)^{1-\sigma} \right\}^{\frac{1}{1-\sigma}} \tag{18}$$

where $\hat{p}_t^N$ is the optimal price and $\Pi_{t-1}^N = \frac{P_{t-1}^N}{P_{t-2}^N}$.

[10] An appendix available upon request provides the pricing equations.

2.2.2 Tradable Sector

Most expressions in the tradable sector are analogous to those of the nontradable sector. Each firm produces according to the following production function

$$y_t^H(h) = X_t Z_t^T L_t^T(h). \tag{19}$$

Z_t^T is the productivity shock to the tradable sector, which evolves as:

$$\begin{aligned} Z_t^T &= (1+\alpha^T)^t \tilde{Z}_t^T \\ \log(\tilde{Z}_t^T) &= \rho^{Z,T}\log(\tilde{Z}_{t-1}^T) + \varepsilon_t^{Z,T} + \varepsilon_t^Z. \end{aligned} \tag{20}$$

The productivity shocks in the two sectors are different in two important aspects. First, the growth rates can be different. As a result, inflation differentials across sectors are permanent in the model when $\alpha^N \neq \alpha^T$. Second, the tradable sector shock has a country-specific innovation component, $\varepsilon_t^{Z,T}$, and a euro-area innovation component, ε_t^Z, which also affects $Z_t^{T^*}$. As long as the standard deviation of ε_t^Z is positive, there will be some correlation in the tradable sector productivity shocks across countries, as in most of the International Real Business Cycle literature (see Stockman and Tesar, 1995; and Baxter and Crucini, 1993).

Firms producing differentiated goods cannot price-discriminate in the currency area, and set the price in euros to sell in both markets, facing a downward sloping demand. Proceeding the same way as with the nontradable sector, we arrive at optimal expressions analogous for the marginal cost, the optimal price, and the evolution of the price level in the tradable sector.

2.3 Monetary Policy

Monetary policy is conducted by the ECB with a Taylor rule that only targets the EMU HICP:

$$R_t = \bar{R}^{1-\rho_r} R_{t-1}^{\rho_r} (\Pi_t^{EMU}/\Pi)^{(1-\rho_r)\gamma_\pi} \exp(\varepsilon_t^m) \tag{21}$$

where ε_t^m is an iid monetary policy shock, and $\pi = \log(\Pi)$ is the ECB's (quarterly) target for HICP inflation. The gross inflation rate is given by $\Pi_t^{EMU} = P_t^{EMU}/P_{t-1}^{EMU}$, where

$$P_t^{EMU} = P_t^s (P_t^*)^{1-s}. \tag{22}$$

2.4 Market Clearing

Market clearing conditions for the each type of tradable and non-tradable good imply that production equals demand. Also, aggregate labor supply in both sectors equals aggregate labor demand. The following conditions hold in the aggregate product markets:

$$Y_t^H = C_t^H + C_t^{H^*} + G_t^T \tag{23}$$

$$Y_t^N = C_t^N + G_t^N \tag{24}$$

where G_t^T and G_t^N are exogenous government spending shocks, that we specify below. In order to abstract from fiscal policy considerations, it is assumed that government spending in the two areas is financed through lump sum taxes. Aggregate real GDP aggregates tradable and nontradable goods using the appropriate relative prices:

$$Y_t = \frac{P_t^H}{P_t} Y_t^H + \frac{P_t^N}{P_t} Y_t^N \tag{25}$$

2.5 Normalizing Equilibrium Conditions

Due to the effects of deterministic trends in the model, the system of equilibrium conditions includes several non-stationary variables. In order to apply standard solution methods, these variables need to be detrended.[11] For instance, for the production of the home nontradable good, we make variables stationary by defining

$$\tilde{y}_t^N(n) = y_t^N(n) / \left[(1+x)(1+\alpha^N)\right]^t = X_0 \tilde{Z}_t^N L_t^N(n). \tag{26}$$

Since variables in the tradable and nontradable sectors can grow at different rates, we set the time trend of the deterministic preference shocks to ensure that all variables in the system are stationary. For instance, the normalized optimality conditions imply the following ratio for consuming tradable and nontradable goods:

$$\frac{\tilde{C}_t^N}{\tilde{C}_t^T} = \frac{(1-\gamma)}{\gamma} \tilde{\xi}_t^{N,C} \left(\frac{\tilde{P}_t^N}{\tilde{P}_t^T}\right)^{-\varepsilon} \tag{27}$$

where $\tilde{C}_t^i = C_t^i / \left[(1+x)(1+\alpha^i)\right]^t$, and $\tilde{P}_t^i = \left[(1+\alpha^i)^t P_t^i\right] / \Pi^t$, for $i = N, T$. Hence we set $\tilde{\xi}_t^{N,C} = \xi_t^{N,C} \left[(1+\alpha^T)/(1+\alpha^N)\right]^{(1-\varepsilon)t}$. We assume that the normalized pref-

[11] An Appendix available upon request details how to detrend each variable and take a linear approximation of the model.

erence shocks are constant, such that they play no role in the normalized linearized model. The processes for government spending are as follows:

$$
\begin{aligned}
G_t^i &= \left[(1+\alpha^i)(1+x)\right]^t \tilde{G}_t^i \\
\log(\tilde{G}_t^i) &= \rho^{G,i} \log(\tilde{G}_{t-1}^i) + \varepsilon_t^{G,i}, \text{ for } i = N, T.
\end{aligned} \tag{28}
$$

Government spending in each sector grows at the same rate than the other real variables in that sector, to ensure balanced growth.

3 Parameter Estimation

We estimate the model using standard methods to simulate the posterior distribution of the model's parameters. In our case, we make use of the Metropolis-Hastings algorithm and obtain 125,000 draws, after allowing for a burn-in phase of 25,000 draws. This method has been extensively discussed in the literature that estimates DSGE models with Bayesian methods.[12] The main departure from the literature is that we include a constant term (κ) in the measurement equation of the state-space representation of the model. This constant term depends on parameters of the model and plays an important role to fit the first moments of the data.

3.1 Data

The euro and the common monetary policy were launched in January 1st, 1999, and this paper attempts to study the behavior of inflation in a currency union. Spain has suffered many changes in monetary policy regimes besides joining the euro: it joined the European Monetary System of fixed exchange rates in 1989, and launched inflation targeting in 1995 to converge in nominal terms with the rest of countries of the euro area. All these changes are likely to result in changes in the behavior of agents and parameter instability, and hence series before the launch of the euro are not useful.

Figure 3 presents the 3-month T-bill rate in Spain, Germany, an average of the euro area before 1999, and the euro area 3-month T-bill after 1999. Monetary policy in

[12] See An and Schorfheide (2007), Smets and Wouters (2003) and Rabanal and Rubio-Ramírez (2005) for a description.

Spain did not follow that of the Bundesbank or a european aggregate during the 1980s and even most of the 1990s. Hence, it would not be appropiate to follow the Smets and Wouters (2003) modelling choice and assume that monetary policy was conducted by a "synthetic" ECB for the euro area as a whole, and that Spain was part of it.

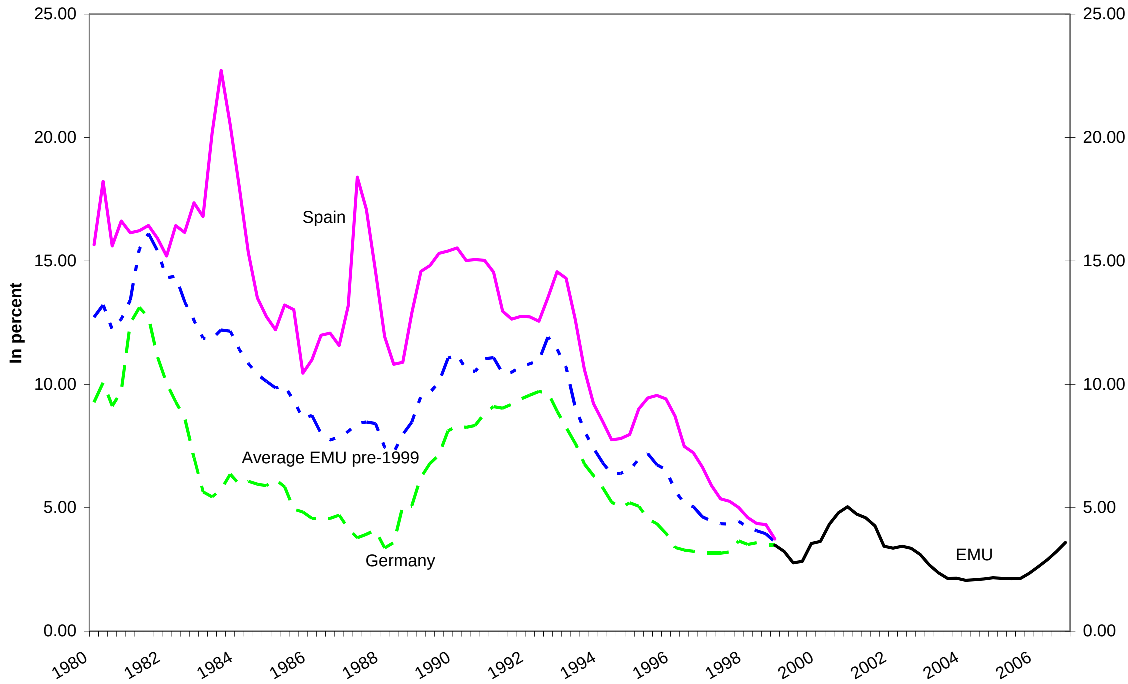

Figure 3: Interest Rates, 3 Month Treasury Bills. Source: Eurostat and ECB.

Hence, we start our sample period in 1996:01, so we extend our sample period three years by making the assumption that agents anticipated that the EMU would occur. This starting date is also chosen due to data availability: it is when Eurostat starts publishing harmonized series for the HICP and GDP for the EMU as a whole and for member countries. This leaves our sample with 48 observations. This is a short sample, but the Bayesian estimation of the model allows the introduction of information via the prior distribution, and also allows to extract information from the data via the likelihood function, so it is an important improvement over just calibrating the model.

The model is estimated with nine observable variables, that we list in Table 2. We also list their counterpart in the model, where lower case variables denote percent deviations from trend. We take logs and first differences of the real GDP and price level series and multiply them by 100 to obtain percent quarterly growth rates. We divide the interest rate by four to obtain a percent quarterly equivalent. The home country is Spain and the foreign country is the rest of the euro area. In Table 2, we also show the restrictions implied by the model-consistent growth and inflation rates on the vector of constants κ. Note that we have seven parameters (π, x, β, and the four α's) to fit the nine constants. The α parameter in each sector has the double role of explaining real growth differentials and inflation differentials of each variable with respect to the aggregate.

Table 2: Model-Consistent Growth and Inflation Rates

Observable Variable	Model Counterpart	Constant (κ)
HICP Inflation Spain	Δp_t	$\pi - \alpha^T$
Services Inflation Spain	Δp_t^N	$\pi - \alpha^N$
HICP Inflation Rest of EMU	Δp_t^*	$\pi - \alpha^{T^*}$
Services Inflation Rest of EMU	$\Delta p_t^{N,*}$	$\pi - \alpha^{N^*}$
Real GDP Growth Spain	Δy_t	$x + \alpha^T$
Services Real GDP Growth Spain	Δy_t^N	$x + \alpha^N$
Real GDP Growth rest of EMU	Δy_t^*	$x + \alpha^{T^*}$
Services Real GDP Growth rest of EMU	$\Delta y_t^{N,*}$	$x + \alpha^{N^*}$
3-month T-bill rate	r_t	$x + \pi - \log(\beta)$

Notes: All data come from Eurostat. The constant term (κ) is used in the measurement equation of the state-space representation of the model. π is the steady state EMU inflation rate, x is the growth rate of aggregate real GDP in the EMU, and α^i for i=T,N,T*,N* are the sector-specific productivity growth rates. β is the discount factor.

3.2 Priors

Since our sample is short, we opt for calibrating some parameters of the model and focus on estimating the coefficients of the Taylor rule, the degrees of nominal rigidity in each sector and country, the elasticities of substitution in the consumption aggregates, and the autoregressive parameters and standard deviations of the shocks. Table 3 presents the parameter values that we calibrate, and the sources that we use. For the parameters involving preferences, we use previous studies on the euro area. The remaining parameters are calibrated from Eurostat data on the HICP and real GDP.

Table 3: Calibrated Parameters

Parameter	Description	Value	Source
β	Discount Factor	0.99	Smets and Wouters (2003)
ϖ, ϖ^*	Labor Disutility	1	Smets and Wouters (2003)
b, b^*	Habit Persistence	0.6	Rabanal and Tuesta (2006)
s	Average weight of Spain in EMU HICP	0.11	Eurostat 1996-2007
η	Average ratio G/Y in Spain	0.18	Eurostat 1996-2007
η^*	Average ratio G/Y in Euro Area	0.20	Eurostat 1996-2007
γ	Proportion of goods in Spain HICP	0.66	Eurostat 1996-2007
γ^*	Proportion of goods in Euro Area HICP	0.61	Eurostat 1996-2007
λ	Average ratio of imports from EMU	0.16	Eurostat 1996-2007
λ^*	Average ratio of imports from Spain	0.015	Eurostat 1996-2007

Table 4 displays the prior distributions over the estimated parameters. While we make specific choices regarding the prior distribution and prior means, in all cases the prior standard deviations are large enough to accommodate a wide enough range of parameter values. We assume that all Calvo lotteries have a prior mean probability of 0.75, implying that prices are reset optimally every 4 quarters. These values are in line with the survey evidence in Fabiani et al. (2006). The degree of indexation has a prior mean of 0.6, which is somewhat larger than the survey evidence presented in Fabiani et al. (2006), but tries to reflect the fact that inflation differentials are highly persistent. The Taylor rule coefficients have prior means which are quite conventional in the literature. The elasticities of substitution between different types of goods are centered at one, which would imply Cobb-Douglas preferences in equations (4) and (5), a common assumption in the literature. The quarterly growth rates of real GDP and inflation are centered at their average values for the EMU, and the sector-specific trends are centered at zero. The prior distribution over the productivity and demand shocks autorregresive coefficients have prior means of 0.7. To reduce the parameter space, we have assumed that the AR coefficients are the same for the same type of shock across countries (i.e. $\rho^{i,j} = \rho^{i,j^*}$, for $i = Z, G$, and $j = T, N$). Different volatilities of the same type of shock across countries are allowed through different standard deviations of the innovations, which have Gamma prior distributions to ensure a positive support.

Table 4: Priors

Parameter	Description	Distribution	Mean	Std. Dev.
$\theta_N, \theta_H, \theta_{N^*}, \theta_{F^*}$	Calvo lotteries	*Beta*	0.75	0.15
$\varphi_N, \varphi_H, \varphi_{N^*}, \varphi_{F^*}$	Indexation	*Beta*	0.6	0.2
γ_Π	Taylor rule Inflation	*Normal*	1.5	0.1
ρ_R	Interest rate smoothing	*Beta*	0.7	0.1
ε	Elasticity. of subs. T and N goods	*Gamma*	1	0.5
ν	Elasticity. of subs. H and F goods	*Gamma*	1	0.5
x	Growth rate in the EMU (in %)	*Normal*	0.6	0.1
π	Target inflation in the EMU (in %)	*Normal*	0.5	0.1
$\rho^{Z,N}, \rho^{Z,T}, \rho^{G,N}, \rho^{G,T},$	AR(1) coefficients of shocks	*Beta*	0.7	0.1
$\sigma(\varepsilon_t^Z), \sigma(\varepsilon_t^{Z,i})$, in %	Std. Dev. technology innovations	*Gamma*	0.7	0.3
$\sigma(\varepsilon_t^{G,i})$, in %	Std. Dev. govt. spending innov.	*Gamma*	1	0.5
$\alpha^i, i = N, T, N^*, T^*$	Sector-specific trends	*Normal*	0	0.1
$\sigma(\varepsilon_t^m)$	Std. Dev. monetary shocks	*Gamma*	0.4	0.2

4 Results

4.1 Posterior Distributions

Table 5 presents the posterior mean and 90 percent confidence interval for the model's parameters. In the first column we present the estimated parameters of the model we presented in Section 2, and with model-consistent inflation and growth rates as described in Table 2. We call this model "Restricted". For comparison purposes, we also estimate a model where the vector of constants, κ, is left unrestricted, and hence the name of the column.[13]

The estimates of the structural parameters do not differ importantly across models, and they are quite similar to what has been obtained before in the literature. In order to save space and focus on the implications of the model, we briefly comment on them. The Calvo lotteries for tradable goods are quite similar across countries and imply average durations between optimal price changes of less than 2 quarters.

[13]When we estimate the unrestricted model, we set $x = \Pi = \alpha_i = 0$, for $i = N, T, N^*, T^*$. We use normal priors, center the prior of each constant at their sample mean, and set a standard deviation of 0.1 percent. In the nine cases, the posterior mean equals the prior mean. See the results in Table 6.

The nontradable sector is stickier in both countries: prices are reset optimally every 3 quarters in Spain and every 6 quarters in the rest of the euro area. The degrees of backward looking behavior in the Phillips Curve are low: they amount to being between one quarter and one half.

Table 5. Posterior Distributions

	Restricted	*Unrestricted*		*Restricted*	*Unrestricted*
θ_H	0.35 (0.24- 0.45)	0.34 (0.23- 0.45)	γ_Π	1.43 (1.24 - 1.65)	1.44 (1.25 - 1.61)
θ_{F^*}	0.43 (0.31- 0.54)	0.41 (0.28- 0.53)	ρ_R	0.73 (0.68 - 0.78)	0.69 (0.63 - 0.75)
θ_N	0.66 (0.57 - 0.73)	0.66 (0.59 - 0.74)	$\rho^{Z,T}$	0.65 (0.51- 0.79)	0.69 (0.52- 0.82)
θ_{N^*}	0.85 (0.81 - 0.89)	0.85 (0.80 - 0.88)	$\rho^{G,T}$	0.96 (0.94- 0.97)	0.86 (0.82- 0.91)
φ_H	0.44 (0.13 - 0.75)	0.48 (0.14 - 0.81)	$\rho^{Z,N}$	0.77 (0.65 - 0.89)	0.77 (0.69 - 0.89)
φ_{F^*}	0.37 (0.07 - 0.66)	0.38 (0.07 - 0.65)	$\rho^{G,N}$	0.98 (0.97 - 0.99)	0.89 (0.86 - 0.94)
φ_N	0.28 (0.05 - 0.49)	0.23 (0.04 - 0.39)	$\sigma(\varepsilon_t^m)$	0.14 (0.10 - 0.17)	0.13 (0.09 - 0.16)
φ_{N^*}	0.46 (0.17 - 0.75)	0.44 (0.17 - 0.68)	$\sigma(\varepsilon_t^Z)$	0.54 (0.36 - 0.71)	0.51 (0.33 - 0.66)
ε	0.51 (0.21 - 0.83)	0.49 (0.23 - 0.73)	$\sigma(\varepsilon_t^{Z,T})$	0.59 (0.39 - 0.79)	0.59 (0.40 - 0.78)
ν	0.52 (0.14 - 0.92)	1.16 (0.47 - 1.83)	$\sigma(\varepsilon_t^{Z,T^*})$	0.46 (0.28 - 0.64)	0.51 (0.29 - 0.71)
x	0.57 (0.5 - 0.65)	–	$\sigma(\varepsilon_t^{Z,N})$	0.72 (0.51 - 0.93)	0.71 (0.46 - 0.92)
π	0.50 (0.40 - 0.62)	–	$\sigma(\varepsilon_t^{Z,N^*})$	0.88 (0.62 - 1.14)	0.85 (0.59 - 1.09)
α_N	-0.11 (-0.2 - 0)	–	$\sigma(\varepsilon_t^{G,T})$	3.07 (2.55 - 3.63)	2.33 (1.95 - 2.71)
α_T	0.04 (-0.1 - 0.13)	–	$\sigma(\varepsilon_t^{G,T^*})$	3.26 (2.69 - 3.76)	2.59 (2.16 - 2.96)
α_{N^*}	-0.03 (-0.1 - 0.04)	–	$\sigma(\varepsilon_t^{G,N})$	4.58 (3.83 - 5.29)	2.63 (2.27 - 3.06)
α_{T^*}	0.06 (-0.04 - 0.1)	–	$\sigma(\varepsilon_t^{G,N^*})$	2.34 (1.93 - 2.71)	1.95 (1.62 - 2.25)
Log-L	-101.32	17.61			

Note: Sample period 1996:01 to 2007:04. For each parameter we present the posterior mean and 90 percent interval. The restricted model uses the vector of constants $\mathcal{K}$ described in Table 2. The unrestricted model does not impose the model-consistent restrictions on $\mathcal{K}$.

In the restricted model, the two elasticities of substitution ε and ν have posterior means of one half. These low values are quite common in the literature that estimates open economy sticky price models, because low elasticities are needed to explain higher volatility of relative prices than relative quantities.[14] On the other hand, the elasticity of substitution between home and foreign goods (ν) in the unrestricted model is higher, with a posterior mean of 1.16. The estimates for the Taylor rule also do not change much across model specifications and suggest that the ECB targets inflation with a large coefficient on the reaction of nominal interest rates to inflation, of about 1.43, with a high degree of monetary policy inertia, of 0.73. In annualized terms, we obtain a real growth rate of 2.3 percent, and an inflation rate of 2 percent, close to their average values for the EMU. Out of the four sector-specific trends in technology shocks, the one that is quantitatively the largest is the trend in the nontradable sector in Spain. It has a posterior mean of -0.11, implying that the model can explain about 44 basis points of higher inflation in that sector in annualized terms with respect to the average.

While the estimates of the structural parameters of the model do not change much across model specifications, the posterior estimates for the AR coefficients of the demand shocks change importantly. The AR coefficients for demand shocks in both sectors are higher in the restricted model: this model imposes restrictions on the constant term, and hence shocks need more persistence to explain why the data are away from the steady-state values. Finally, we compare models using the log-difference of marginal likelihoods, also known as the log-Bayes factor. The Bayes factor tells the researcher how she would update her priors on which model is closer to the true one after observing the data (Fernández-Villaverde and Rubio-Ramírez, 2004). The model with unrestricted constants easily beats the restricted model: the log-Bayes factor is about 118. Hence, the restrictions imposed in the models on inflation, growth and nominal interest rates imply a worse fit to the data.[15]

In Table 6 we present the actual first and second moments of the data, and compare them to posterior means from the two versions of the model, together with a 90 percent interval. In addition to the moments for the nine observable variables that we use for estimation, and we also study the properties of the inflation differential directly, $\Delta p - \Delta p^*$. The restricted model underpredicts both real growth and inflation by a large margin in Spain, and hence it has a hard time explaining the level of the inflation differential. The model predicts real quarterly growth rates of

[14] See Lubik and Schorfheide (2006) and Rabanal and Tuesta (2006).

[15] We have also estimated the two models where all the price and quantity observable series are introduced in (log) levels rather than in first differences. Estimating the model with the variables in levels includes more information than doing so with the variables in first differences, as in Chang, Doh, and Schorfheide (2007). The results we obtain are not so different from what we report in Table 5, and they are available upon request.

0.63 (0.45 in the nontradable sector) while they are 0.86 (0.90 in the nontradable sector) in the data. Also, even though the model can explain higher inflation in the services sector in both regions with respect to the aggregate, and while it can explain higher headline inflation in Spain than in the rest of the EMU, it is not quantitatively enough to explain the full differential: it can only explain 3 basis points (quarterly) out of 26 in the data. Also, the estimates of the restricted model imply larger volatility of the inflation differential than in the data.

Table 6. Moments in the Models and in the Data

	Data		*Restricted*		*Unrestricted*	
	Mean	St.Dev.	Mean	St.Dev.	Mean	St.Dev.
Δp	0.72	0.33	0.47 (0.36- 0.57)	0.5 (0.42- 0.56)	0.73 (0.66- 0.78)	0.39 (0.35- 0.45)
Δp^N	0.92	0.17	0.62 (0.48- 0.70)	0.34 (0.29- 0.39)	0.92 (0.84- 0.98)	0.29 (0.24- 0.34)
Δp^*	0.46	0.20	0.43 (0.32- 0.52)	0.33 (0.27- 0.38)	0.48 (0.43- 0.54)	0.27 (0.23- 0.31)
$\Delta p^{N,*}$	0.53	0.12	0.53 (0.43- 0.63)	0.19 (0.14- 0.24)	0.54 (0.48- 0.59)	0.17 (0.13- 0.22)
Δy	0.86	0.31	0.63 (0.59- 0.66)	0.47 (0.42- 0.52)	0.86 (0.84- 0.90)	0.38 (0.33- 0.42)
Δy^N	0.90	0.44	0.45 (0.41- 0.50)	0.44 (0.41- 0.50)	0.92 (0.86- 0.96)	0.53 (0.45- 0.60)
Δy^*	0.53	0.34	0.61 (0.57- 0.64)	0.41 (0.36- 0.46sqrt)	0.53 (0.50- 0.55)	0.38 (0.33- 0.43)
$\Delta y^{N,*}$	0.55	0.28	0.53 (0.49- 0.57)	0.48 (0.42- 0.52)	0.55 (0.52- 0.59)	0.44 (0.38- 0.53)
r	0.87	0.24	1.08 (1.00- 1.21)	0.21 (0.16- 0.23)	0.88 (0.8- 0.96)	0.21 (0.17- 0.24)
$\Delta p - \Delta p^*$	0.26	0.28	0.03 (0-0.06)	0.39 (0.34-0.44)	0.25 (0.22-0.28)	0.32 (0.27-0.36)

Note: Sample period 1996:01 to 2007:04. For each moment in the models we present the posterior mean and 90 percent interval. The restricted model uses the vector of constants $\mathcal{K}$ described in Table 2. The unrestricted model does not impose the model-consistent restrictions on $\mathcal{K}$.

The main constraint in the restricted model is that, in order to have higher inflation in one sector with respect to the EMU, productivity growth has to be lower. But lower productivity growth implies lower real GDP growth. On the contrary, Spain has had both higher inflation and higher real GDP growth (in the aggregate and in the nontradable sector) and this cannot be explained by the model, since one parameter, the productivity growth differential, needs to explain at the same time the growth differential in real variables, and the inflation differential in the nominal ones. The model with unrestricted constants does a much better job in fitting the first moments of the data, by construction, and also gets closer at replicating most second moments of the data.[16]

How could we improve the performance of the restricted model? Introducing other shocks with trends in the model is not feasible. As we have shown, preference shocks in consumption need a specific trend to be consistent with balanced growth. Labor supply shocks with a positive deterministic trend cannot help as they would imply that hours worked approach zero in the long run. The model cannot allow for different population growth rates because the weight of one country would eventually become negligible. Therefore, the restricted model needs a series of positive demand shocks to fit the Spanish data. It remains an open question if these shocks will continue to have a non-zero mean, or if Spain will be hit by zero-mean or even negative shocks in the years to come, leading to much lower output growth rates than in the recent period.

Finally, we conducted two robustness exercises. First, we studied the role of setting some of the trends of the technology shocks equal to zero in the restricted model. The case where all $\alpha' s$ are equal to zero is the case where the model assumes that all inflation rates are equal to π and all the real growth rates are equal to x. Table 7 shows that setting the trends in the tradable sector equal to zero actually results in a small improvement in model fit. This result arises from the fact that the marginal likelihood averages all possible values of the likelihood function across the parameter space, using the priors as weights, and hence it penalizes overparameterization. On the other hand, setting the trend of the nontradable sector equal to zero results in a small decrease of the likelihood function. What makes a difference is when no sector- and country-specific trends are allowed for: in this case the log-Bayes factor is 30 (which means "very decisive evidence" in the Bayesian model comparison language, see Kass and Raftery, 1995). Hence, some sector-specific differences of growth rates of technology along the balanced growth path help to fit the data better.

Second, in both models, we conducted several model comparison exercises to test the hypothesis of Angeloni and Ehrman (2007) and Andrés et al. (2004) suggesting that different inflation dynamics processes could be behind persistent inflation differentials in the EMU. As we show in Table 7, when we set the parameters of the

[16]We have also computed additional posterior second moments (correlations and autocorrelations), and the two models deliver very similar posterior means for these second moments. The results are available upon request.

Phillips Curve to be equal in the tradable sector, the value of the marginal likelihood increases, and the log-Bayes factors are around 3. What makes an important difference is to set the parameters of the Phillips Curves to be the same in the nontradable sector. The log-Bayes factor with respect to the baseline model becomes about 11 for the restricted model, and almost 40 for the unrestricted model. Hence, our results provide partial support for the Angeloni and Ehrman (2007) hypothesis in the sense that the Phillips Curves are different in the nontradable sector.

Table 7: Model Comparison, Log Marginal Likelihoods

		Restricted	Unrestricted
Baseline	-	-101.32	-
Only nontradable sector trends	$\alpha^T = \alpha^{T^*} = 0$	-100.48	-
Only tradable sector trends	$\alpha^N = \alpha^{N^*} = 0$	-103.08	-
No sector-specific trends	All $\alpha = 0$	-132.62	-
		Restricted	Unrestricted
Baseline	-	-101.32	17.61
Same coeffs. tradable sector	$\theta^H = \theta^{F^*}, \varphi^H = \varphi^{F^*}$	-98.16	21.82
Same coeffs. nontradable sector	$\theta^N = \theta^{N^*}, \varphi^N = \varphi^{N^*}$	-112.29	-26.03
Same coeffs. both sectors	All θ, φ equal	-108.09	-21.39

Note: Sample period 1996:01 to 2007:04. The restricted model uses the vector of constants κ described in Table 2. The unrestricted model does not impose the model-consistent restrictions on κ. θ is the Calvo lottery and φ is the indexation parameter in each sector

4.2 What drives inflation differentials?

In Table 8 we perform a variance decomposition exercise to understand the sources of the inflation differential volatility. We have regrouped the effects of the shocks across countries, such that the "Technology Nontradable" column includes the effects of the nontradable technology shock in Spain and in the rest of the EMU.[17] The main result of is that most of the volatility in the inflation differential turns out to be explained by tradable sector technology shocks: their contribution is 65.7 percent

[17] The variance decomposition is performed using the posterior mean of the unrestricted model, since it is the one that fits the second moments of the data best. Using the estimates from the restricted model does not change the results an an important way.

of the variance of total volatility. Nontradable sector technology shocks explain a significant size as well, 18.6 percent, while demand shocks explain 14.4 percent. Monetary policy shocks move inflation in the same direction, and hence, do not contribute to the differential.

Table 8. Variance Decomposition (in percent)

	Technology		Demand		Monetary
	Tradable	Nontradable	Tradable	Nontradable	
Δp	64.6	10.0	5.7	1.7	17.9
Δp^N	10.1	64.0	6.4	2.1	17.3
Δp^*	60.1	8.6	6.1	1.4	23.6
$\Delta p^{N,*}$	18.1	51.6	7.4	2.0	21.0
Δy	24.9	3.1	52.5	16.3	3
Δy^N	3.8	4.9	0.9	86.8	3.7
Δy^*	16.9	3.5	60.7	14.5	4.5
$\Delta y^{N,*}$	3	3.5	1.0	84.4	8
r	61.1	13.6	8.8	2.3	14
$\Delta p - \Delta p^*$	65.7	18.6	11.1	3.3	1.3

Note: variance decomposition based on the unrestricted model parameter estimates of Table 5. Observable variables description is the same as in Table 2.

Several other interesting results arise. First, nontradable inflation both in Spain and the euro area is mostly driven by nontradable technology shocks, while tradable sector technology shocks have a small impact, explaining about 18 percent of nontradable inflation volatility in the euro area and 10 percent in Spain. Therefore, this suggests that Balassa-Samuelson-type effects are quantitatively small. Headline inflation rates in both regions are mostly driven by tradable sector technology shocks (around 60 percent), and monetary policy shocks also have an important effect (about 20 percent). The demand shocks mostly explain volatility in real output growth rates, but do not explain much of the volatility in inflation rates.

Another way to look at the contribution of each shock to fluctuation of the main variables is to simulate the model using the smoothed shocks that are obtained via the Kalman filter (Hamilton, 1994). Figure 4 presents the contribution of the technology shocks in the tradable sector and in the nontradable sector in explaining

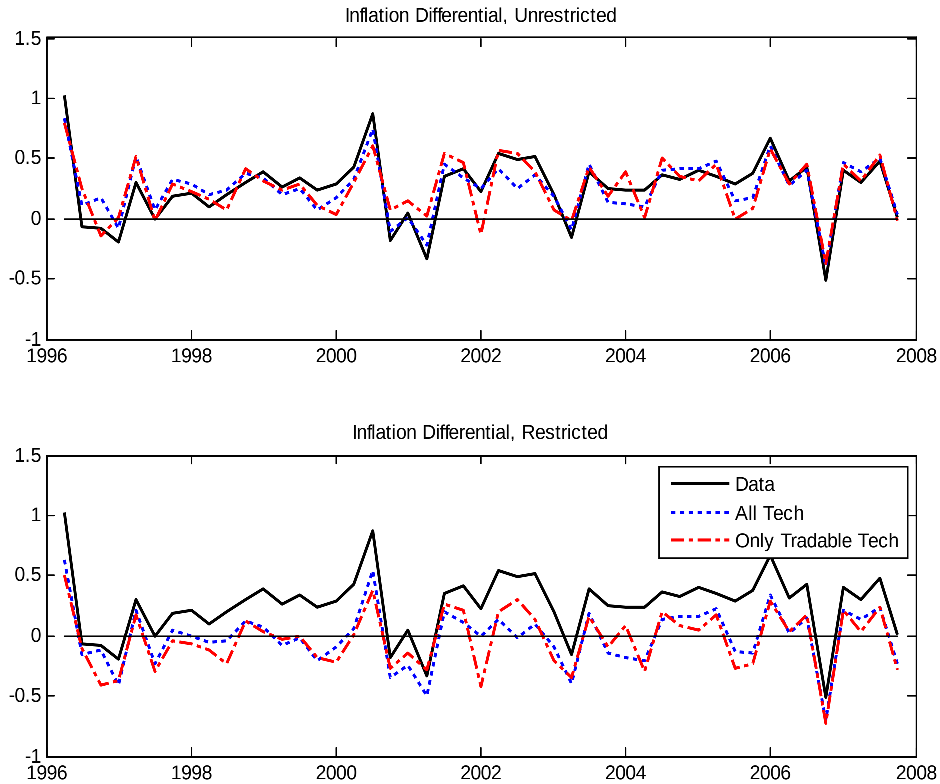

Figure 4: Decomposition of the inflation differential in the two models.

the inflation differential. In the unrestricted model, most of the inflation differential is already explained by the tradable sector technology shocks. In the restricted model, the evidence is not so striking, but still most of the fluctuations in the inflation differential, in particular the occasional spikes, are driven by both technology shocks.

These results are in stark contrast with the findings of Altissimo et al. (2005), who suggest that nontradable productivity shocks are a main driver of inflation differentials in the euro area. They base their explanation on overall inflation dispersion in the euro area and using evidence similar to Figure 1, where services inflation seems to be main driver of HICP inflation dispersion. In the present paper, as we have shown in Figure 2, differentials in the tradable goods sector inflation are the main driver of HICP inflation differentials between Spain and the EMU. Therefore, it could well be that explaining inflation differentials country by country would deliver different results than the Spanish case. It is important to remark that our results

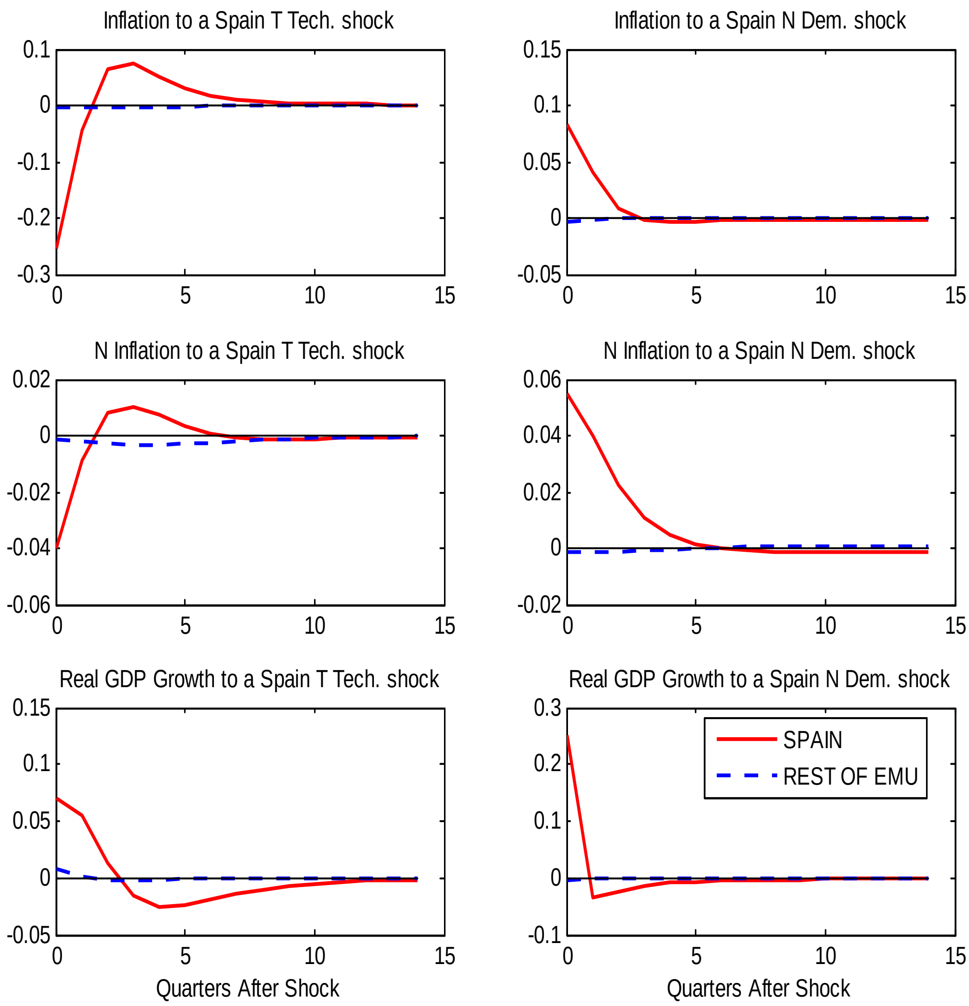

Figure 5: Impulse responses (in percent deviation from trend).

are similar to those of Duarte and Wolman (2002): their paper also finds that shocks to the tradable sector are a main driver of inflation differentials. Finally, as in the present paper, both Altissimo et al. (2005) and Duarte and Wolman (2002) find a small effect of fiscal or demand shocks on inflation differentials, while Angeloni and Ehrmann (2007) suggest that it is demand shocks that explain the behavior of inflation differentials in the EMU.

4.3 Impulse Responses

Tradable Sector Technology Shock The left column of Figure 5 displays the responses to a Spain-specific tradable sector technology shock ($\varepsilon_t^{Z,T}$). When a positive technology shock hits this sector, both headline and nontradable inflation decline in Spain. Under sticky prices, hours worked decline and consumption increases with a technology shock, and the overall result given our parameter estimates is that real wages fall. This is the reason why the Balassa-Samuelson effect fails to hold. Unit labor costs fall in both sectors, and hence inflation rates fall as well. The result is stronger in the Spanish tradable sector as it benefits from the productivity improvement. The spillover effects to the rest of the EMU are small. The same patterns arise when we analyze a euro area wide tradable sector technology shock and nontradable technology shocks in both countries (not shown to save space). In all cases the inflation rates decline, with the effect being stronger on the country/sector that received the technology improvement.

Nontradable Sector Demand Shock The response to a nontradable demand shock ($\varepsilon_t^{G,N}$) is presented in the right column of Figure 5. Real GDP growth in Spain increases by 0.25 percent above trend on impact, but displays low (and negative) serial correlation. Both nontradable and tradable inflation increase after this type of shock: the nontradable component increases because of excess demand for its product, while the tradable component increases because of the imperfect substitutability of both types of goods: tradable goods producers are able to charge higher prices and not loose market share in the Spanish market.

The conclusion of this subsection is that negative productivity shocks in both sectors (at least, relative to the EMU) together with a series of positive demand shocks in the nontradable sector are behind Spain's story of high growth and high inflation during the EMU period.

5 Concluding Remarks

Rather than repeat the results of the paper, we discuss here some caveats that could apply to our results. The most relevant one is that while the EMU is the most important trade partner of Spain (70 percent of international trade), this paper has ignored the role of external factors to the EMU in potentially explaining the inflation differential. For instance, the role of trade with third countries, the role of commodity prices and the effects of the trade-weighted euro exchange rate cannot be addressed. In order to study the role of commodity prices, we have computed the correlation between the smoothed tradable sector technology shocks, and the energy and unprocessed food (non-core) components of the HICP. We find that both the common innovation to the tradable sector technology shock (ε_t^Z), and the innovation to the technology shock in the rest of the EMU (ε_t^{Z,T^*}) display a significant correlation of around 0.5 with the energy component inflation of the HICP both in Spain and the euro area. Therefore, these two innovations (but not the innovation to the tradable sector technology shock in Spain) seem to pick up high frequency movements in the HICP due to energy prices. On the other hand, the correlation between technology shocks and the unprocessed food component is close to zero and insignificant.

Regarding the role of other external shocks, Adolfson et al. (2008b) estimate and compare a closed and a small open economy model for the euro area. Their model is more detailed than the one studied here, since it incorporates consumption and investment goods that are traded between the euro area and the rest of the world. Their main finding is that the contributions of the shocks to explaining fluctuations in the euro area change across model specifications. However, they find that the effect of foreign shocks to domestic variables in the small open economy model of the euro area is quantitatively small. Actually, in their small open economy version, Adolfson et al. (2008) find an important role for markup shocks in the imports sector. In our model, the effects of price markup shocks (that would increase the market power of firms) and productivity shocks cannot be distinguished. Therefore, what we are attributing to productivity shocks in the tradable sector could be attributed to time-varying markups, and hence the results we provide here can be seen as an upper bound to the importance of technology shocks. Note, however, that this would not change the fact that the bulk of the action to explain the inflation differential between Spain and the rest of the EMU is in the tradable sector.

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