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**Explaining Inflation Differentials
between Spain and the Euro Area**

Pau Rabanal

"la Caixa"

Research Department

Av. Diagonal, 629, planta 6, torre I

08028 BARCELONA

Tel. 93 404 76 82

Telefax 93 404 68 92

www.research.lacaixa.es

e-mail: publicacionesestudios@lacaixa.es

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Explaining Inflation Differentials between Spain and the Euro Area

Pau Rabanal*

Abstract:

This paper investigates the behavior of inflation differentials between Spain and the rest of the euro area member countries. Cross country studies of inflation differentials, and in particular in the EMU, have focused on three explanations: (i) the role of tradable and nontradable sector productivity improvements, and the Balassa-Samuelson effect, (ii) the role of the demand-side effects, and (iii) heterogeneity of inflationary processes inside the EMU. First, the paper documents that, during the 2002-2006 period, inflation differentials in the tradable goods sector have been driving the inflation differentials in the headline HICP inflation. Second, the paper uses the estimates of a two country, two sector Dynamic Stochastic General Equilibrium (DSGE) model with nominal rigidities in a currency union using data for Spain and the euro area, to understand the role of each feature in shaping inflation differentials. The paper finds that fluctuations in productivity improvements in the tradable sector are the most important source of headline HICP inflation differentials. Demand shocks help explain a fraction of output growth, but not of inflation dispersion. In addition, the estimated model finds no evidence that inflation dynamics are different in Spain and in the rest of the euro area.

JEL Codes: F41, F42, C51.

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

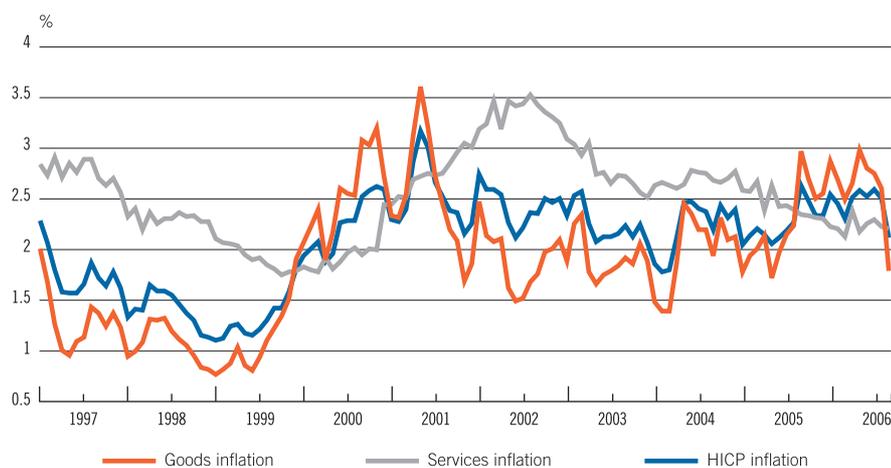
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1. Introduction

Since the launch of the common European currency, the euro, in January 1999, a topic that has received a lot of attention is the study of inflation differentials in the European Monetary Union (EMU)¹. At the time the euro and the common monetary policy were introduced, the Harmonised Index of Consumer Prices (HICP) in the EMU was at a 12-month inflation rate of 0.9 percent, with a weighted standard deviation of 1.1 percent. Seven years later, in January 2006, the HICP inflation rate was 2.4 percent, while the weighted standard deviation was 2.6 percent. This increase both in inflation and inflation dispersion can be somewhat surprising, given that in January 1999, EMU countries seemed to have achieved nominal convergence. Figure 1.1 plots the weighted standard deviation of the 12-month inflation rate, and its components (goods and services). After an all-time low in 1999, inflation dispersion has increased significantly since, albeit with some fluctuations. While most of the time there has been higher dispersion in services inflation, in two episodes (between early 2000 to mid-2001, and since late-2005) the opposite has happened, and the goods component of the HICP has in fact displayed more dispersion across EMU countries.

FIGURE 1.1 Weighted standard deviation of the 12-month inflation rate in the EMU



SOURCE: EUROSTAT and author's calculations.

Another main feature of the EMU is the persistence of inflation differentials. Even when long periods of time are considered, some member countries have consistently experienced higher inflation rates than the EMU as a whole. Table 1.1 shows the average 12-month HICP inflation rates for the January 1999 - July 2006 period, for the 12 countries of the EMU. While EMU as a whole has been at the ECB's target of 2 percent inflation on average,

1. See for instance ECB (2003), Angeloni and Erhmann (2004), López-Salido *et al.* (2005), Andrés *et al.* (2003).

there are some important cross-country differences. Some countries have been, on average, close or below the ECB target (Austria, France, Belgium, Finland and Germany); while, on the other hand, some countries have been significantly above the target: well known examples in this last group are Spain, with a seven-year average 12-month inflation rate of 3.2 percent, and Ireland, with 3.5 percent. Table 1.1 also shows that inflation in the services component of the HICP has been higher than in the goods component, and that the national pattern that we observe for the headline HICP also holds for its goods, services, and core (excluding food and energy) components.

TABLE 1.1 Average 12-month HICP inflation rates

Euro area, January 1999 - July 2006

	HICP	GOODS	SERVICES	CORE
EMU	2.07	1.92	2.28	1.71
Belgium (BE)	2.01	1.93	2.12	1.55
Germany (DE)	1.48	1.59	1.35	0.97
Greece (GR)	3.24	2.98	3.70	3.08
Spain (ES)	3.17	2.84	3.78	2.86
France (FR)	1.81	1.64	2.07	1.53
Ireland (IE)	3.50	2.37	5.01	3.36
Italy (IT)	2.35	2.12	2.69	2.19
Luxemburg (LU)	2.79	2.79	2.72	2.33
Netherlands (NL)	2.57	2.20	3.08	2.09
Austria (AT)	1.70	1.27	2.22	1.46
Portugal (PT)	3.02	2.37	4.05	2.88
Finland (FI)	1.58	1.05	2.46	1.35

SOURCE: EUROSTAT and author's calculations.

Cross country studies of inflation dynamics, and in particular in the EMU, have focused on three main explanations. The first one brings back the well-known Balassa-Samuelson effect. The second one studies the role of the demand-side effects as well as the asymmetric position of the business cycle in the economies of a currency union. The third one studies heterogeneity of inflationary processes inside the EMU, which could make inflation differentials highly persistent, even when all countries are hit by the same symmetric shocks (for instance, oil prices, or fluctuations of the euro).

Before explaining these three hypotheses in detail, it is convenient at this point to clarify a misperception that some commentators seem to have with respect to the facts presented in Figure 1.1 and Table 1.1. The behavior of services inflation, and in particular the higher rates of inflation, is often attributed to the fact that this sector faces less competition than the goods sector, which is by nature more open to international trade. From a static point of view, monopolistic or oligopolistic models of industrial organization imply that less competition in a market leads to higher prices and lower quantities than under perfect competition. However, this does not mean that the rate of price changes (i.e. inflation) should be higher in a market with less competition. From a dynamic perspective, in order

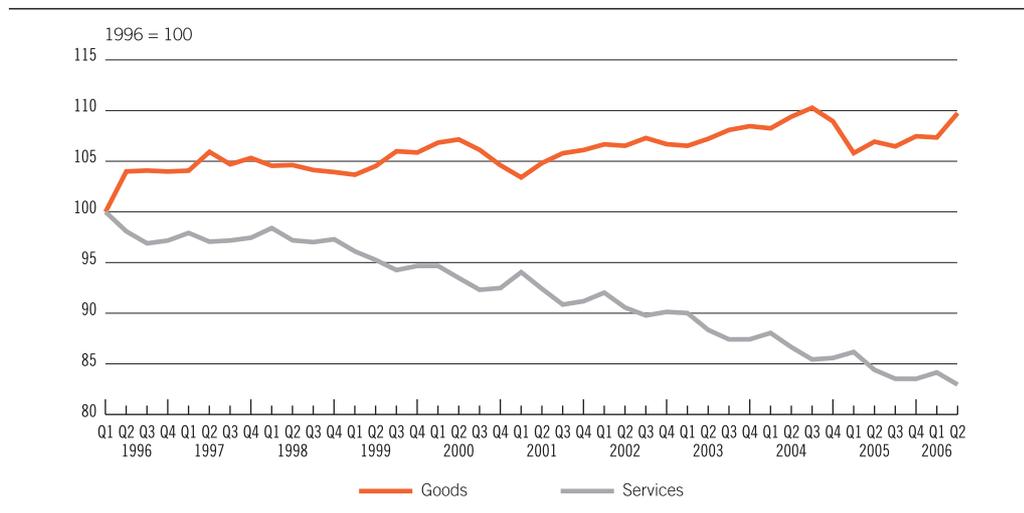
to observe persistently higher inflation in the services sector than in the goods sector, there should be declining competition in the services market with respect to the goods market. Different market structures can explain different price levels, profits and markups, but not different inflation rates.

The Balassa-Samuelson effect has become popular to explain inflation differentials for those countries experiencing a catching-up process. As the relatively poorer countries adopt new technologies and get closer to the most advanced countries, they will necessarily experience higher real GDP growth, increased wages, and higher inflation. The Balassa-Samuelson effect can be stated as follows: suppose that the sectors of an economy that are open to international trade (the “tradable” sectors) experience high productivity growth. This can happen, as in the case of the EMU, when a group of countries increase economic integration, barriers to trade fall, and hence it is easier to import more productive technologies from the more advanced countries. The higher productivity in the tradable sector increases the marginal product of labor in that sector, and therefore labor demand. This puts upward pressure on wages, which increase for the whole economy. Since prices are set as a markup over production costs, inflation increases in the sectors of the economy not open to international trade (the “nontradable” sector), that do not benefit from productivity improvements but face higher wages. The effect of productivity improvements on tradable inflation in the short term is less clear, but typically the real wage increases by less than the level of productivity, and tradable inflation declines. Therefore, the Balassa-Samuelson hypothesis could be a candidate to explain the higher inflation rate in the service sector (that does not benefit from productivity improvements) than in the goods sector, and hence leading to higher headline HICP inflation².

At first sight, this story seems to fit the EMU experience: Spain and Ireland, for instance, have experienced above-average real GDP growth and above-average inflation. In Spain, labor productivity growth has been much higher in the tradable sector than in the nontradable sector. Figure 1.2 plots labor productivity in the two sectors (defined as output per employee). In fact, productivity in the nontradable sector (that includes services and construction) has been experiencing negative growth rates in recent years. However, as López-Salido *et al.* (2005) point out, it is difficult to square the evidence on productivity and inflation with the recent growth figures in Spain. Spain has been experiencing solid growth in the recent years: during the period 1999-2006, real annual GDP growth in Spain has averaged 3.2 percent, while it has averaged 2 percent in the EMU. In addition, the nontradable sector (services and construction) has been the main engine of growth, with an average growth rate of 3.5 percent, compared to a real growth rate in the tradable sector of 2.5 percent. Therefore, supply (productivity) factors cannot be the only explanation for the evolution of the inflation differential between Spain and the EMU, because declining

2. 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.

FIGURE 1.2 Spain. Productivity in the tradable (goods) and nontradable (services and construction) sectors



NOTE: Labor productivity defined as output per employee.
SOURCE: INE and author's calculations.

productivity in the nontraded sector would imply higher inflation but lower output in this sector³. Therefore, to observe both an increase of output and prices in the nontradable sector, demand factors must have played an important role.

Finally, Angeloni and Ehrmann (2004), 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 common shocks (for instance, oil prices, or fluctuations of the euro), the response of inflation can be different across countries. Depending on the interaction between wage and price dynamics, second round effects could make inflation even more persistent.

3. Output per employee is a rough measure of productivity, since it includes other factors that cannot be attributed to productivity shocks (composition effects of employment, for instance). However, other studies that have estimated total factor productivity (TFP) measures in both sectors (Gual *et al.* 2006) have found a similar pattern.

2. Inflation Differentials between Spain and the EMU: What Drives Them?

From the policy perspective, the question to ask is to what extent are these inflation differentials (and the associated real exchange rate changes) important. Higher inflation in a country (or region) of a currency area reduces the purchasing power of its population, everything else equal. But the sources of the inflation differential are also important: while higher nontradable inflation reduces real wages for domestic households, higher inflation in the tradable sector reduces competitiveness for the same type of good, with negative implications for output growth and employment. As we show in this section, the inflation differential between Spain and the euro area in the 2002-2006 period can mostly be explained by the behavior of the relative price of traded goods: this represents a loss of competitiveness of the Spanish economy vis-à-vis its trading partners, that could potentially damage the prospects of growth.

However, Spain has been growing faster than the EMU in the recent years, and hence real exchange rate appreciation is the expected mechanism through which adjustments would occur in a currency union. Large and persistent inflationary processes need not be “bad” per se, since countries growing above potential will have a tendency to have higher inflation, while countries in recession will tend to have lower inflation. As a result, countries in recession will experience a competitiveness gain, while those countries in the peak of their business cycle will suffer a loss: altogether, the effect will be to bring all countries in a monetary union back to potential.

Finally, it is worth noting that joining a monetary union can amplify economic fluctuations: the central bank reacts to average (EMU) inflation, but countries at the peak of their business cycle need tighter monetary conditions than the union as a whole. Therefore, the real interest rate in a currency union is less countercyclical than under a country-specific inflation targeting regime, fluctuations become larger, and the mechanism that brings the union back to the steady state is by building up price differentials, as we have been observing in the recent years. The important issue is to ensure that structural rigidities in the economy do not imply a too large imbalance build-up due to inflation persistence, and hence that the adjustment occurs smoothly, rather than resulting in a painful recession.

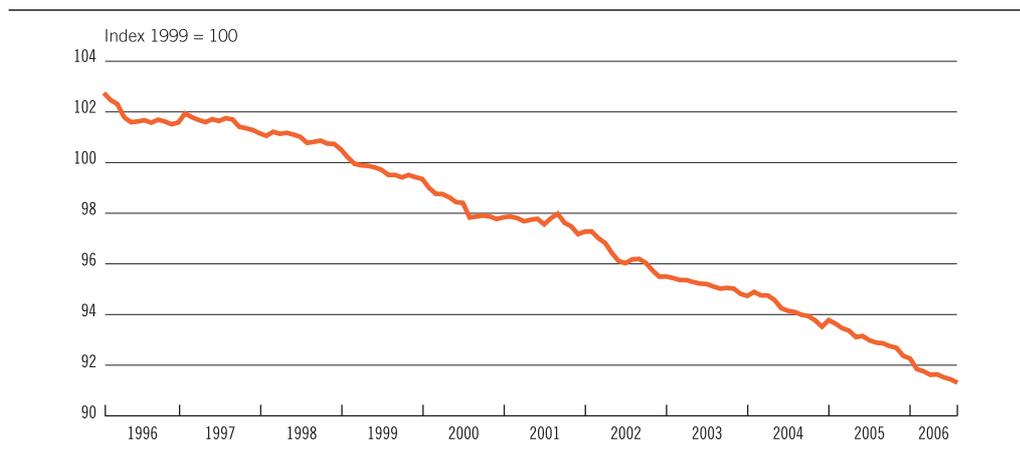
We present the evolution of the price indices between Spain and its partners in the EMU, and decompose its evolution using a simple decomposition of the traded and nontraded components of the HICP, which we proxy by the “goods” and “services” components of the HICP, taken from Eurostat. The real exchange rate between Spain and the rest of the EMU is defined as

$$RER_t = \frac{P_t^*}{P_t}$$

where P_t^* is the price level of the rest of the EMU, and P_t is the price level in Spain. Figure 2.1 plots the evolution of the RER, after seasonally adjusting the series with the TRAMO/SEATS procedure⁴. The downward trend reflects the cumulative inflation differentials between Spain and the rest of the EMU since the launch of the euro in 1999.

4. See Maravall (2002).

FIGURE 2.1 Real exchange rate between Spain and the rest of the EMU



SOURCE: EUROSTAT and author's calculations.

To understand which components of the HICP are driving this behavior of inflation, we perform a simple decomposition of the real exchange rate (see Engel, 1999; Betts and Kehoe, 2006; and Chari *et al.* 2002). First, we multiply and divide the RER by the price of tradable goods in each country, such that we get:

$$RER_t = RER_t^T * RER_t^{REL}$$

where

$$RER_t^T = \frac{P_t^{T*}}{P_t^T}$$

and

$$RER_t^{REL} = \frac{\frac{P_t^T}{P_t^N}}{\frac{P_t^{T*}}{P_t^{N*}}}$$

Further, if we assume that in each country the CPI is a geometric average of traded and nontraded goods, then we have that $P_t = (P_t^T)^\gamma (P_t^N)^{1-\gamma}$, $P_t^* = (P_t^{T*})^\gamma (P_t^{N*})^{1-\gamma}$, and the expression for RER_t^{REL} becomes:

$$RER_t^{REL} = \frac{\left(\frac{P_t^T}{P_t^N}\right)^{1-\gamma}}{\left(\frac{P_t^{T*}}{P_t^{N*}}\right)^{1-\gamma^*}}$$

where γ and γ^* denote the fraction of traded goods in each country's HICP, and P^T , P^N , P^{T*} , P^{N*} are the price levels of tradable (T) and nontradable goods (N) in both countries.

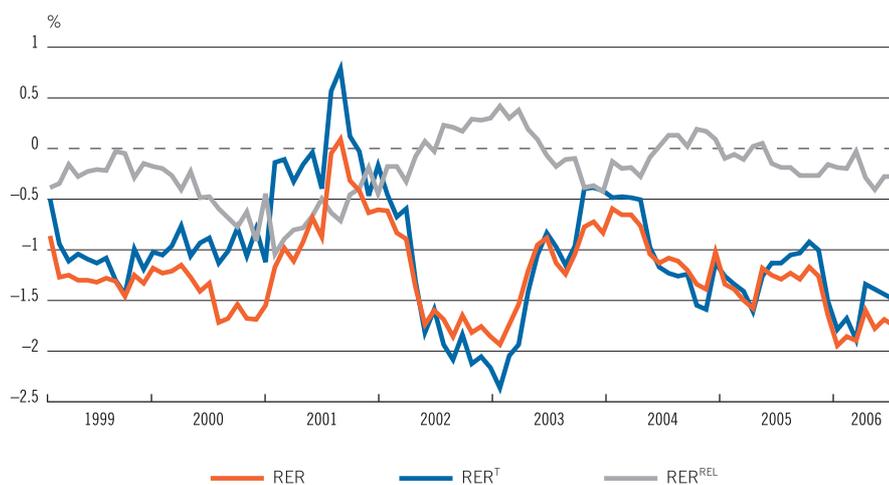
This procedure decomposes the evolution of the real exchange rate between the fluctuations of the price of traded goods in each country's CPI (RER_t^T), and the relative evolution of traded and nontraded goods prices in each country (RER_t^{REL}). The following expression holds for the change in the real exchange rate (lower case variables denote logs, and Δ is the difference operator):

$$\begin{aligned} \Delta r_{er_t} &= \Delta r_{er_t^T} + \Delta r_{er_t^{REL}} & (1) \\ &= \Delta p_t^{T*} - \Delta p_t^T + \\ &\quad + (1 - \gamma)(\Delta p_t^T - \Delta p_t^N) - (1 - \gamma^*)(\Delta p_t^{T*} - \Delta p_t^{N*}) \end{aligned}$$

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 for tradable goods, $\Delta p_t^T = \Delta p_t^T$, then fluctuations in the real exchange rate would be due to nontradable inflation only⁵. If either the consumption basket differs across countries, or there are deviations from the law of one price, or both, then fluctuations in the price of tradable goods will also matter. As we show in the following figure, this is indeed the case for Spain.

Figure 2.2 presents this decomposition using annual rates (12-month changes). This evidence is purely data-based, and does not rely on a specific functional form for price indices (arithmetic or geometric weighted averages), since by construction, $RER_t^{REL} = RER_t / RER_t^T$. Hence, we are simply trying to see how much of the change in RER can be attributed to the goods component. Clearly, there are two important subperiods since the launch of the euro that help explain inflation differentials (by definition, the evolution of the change in the real exchange rate in a currency union is the inflation differential). In the 1999-2001 period, both the relative price of goods across countries, as well as the movements of relative prices of goods and services inside each country, seemed to play a role in explaining the inflation differential. However, since 2002, virtually all the inflation differential can be explained by the evolution in the relative prices of tradable goods between Spain and the rest of the euro area. Table 2.1 confirms this analysis by presenting correlation coefficients between these three components, for the full sample 1999-2006 and for the two-subsamples. In all cases, the correlation between the aggregate inflation differential and its tradable component are always very close to one, and the correlation is highest in the 2002-2006 period, with a value of 0.92. On the contrary, the correlation between changes in the real exchange rate

FIGURE 2.2 Real exchange rate decomposition



SOURCE: EUROSTAT and author's calculations.

5. This is the case analyzed by Altissimo *et al.* (2005).

and the relative price component are mildly negative⁶. Finally, the correlation between the tradable and the relative price components is negative and high in absolute value⁷.

TABLE 2.1 Correlation coefficients

	FULL SAMPLE	1999-2001	2002-2006
$\Delta rer_t, \Delta rer_t^T$	0.88	0.87	0.92
$\Delta rer_t, \Delta rer_t^{REL}$	-0.35	-0.10	-0.42
$\Delta rer_t^T, \Delta rer_t^{REL}$	-0.75	-0.57	-0.73

SOURCE: EUROSTAT and author's calculations.

In Table 2.2, a further disaggregation is presented with the main three components of the “goods” category in the HICP. These three categories are “industrial goods excluding energy”, “energy”, and “food”. No single component seems to be a main driver of the behavior of the real exchange rate for tradable goods. Out of the three categories, the “food” component displays a zero or negative correlation with the real exchange rate for tradables, depending on the sample period. On the other hand, both the “industrial goods excluding energy” and “energy” items display a positive comovement with the tradable component. However, the correlations are not as dramatic as those presented in Table 2.1.

TABLE 2.2 Correlation coefficients

	FULL SAMPLE	1999-2001	2002-2006
$\Delta rer_t^T, \Delta rer_t^{IND}$	0.56	0.77	0.46
$\Delta rer_t^T, \Delta rer_t^{ENE}$	0.57	0.72	0.49
$\Delta rer_t^T, \Delta rer_t^{FOOD}$	-0.05	-0.50	-0.26
$\Delta rer_t^{IND}, \Delta rer_t^{ENE}$	0.10	0.31	-0.30
$\Delta rer_t^{IND}, \Delta rer_t^{FOOD}$	-0.30	-0.58	0.02
$\Delta rer_t^{ENE}, \Delta rer_t^{FOOD}$	-0.31	-0.44	-0.39

SOURCE: EUROSTAT and author's calculations.

With this evidence, in the next section we explain what type of model would be useful to study inflation differentials and the relative importance of productivity and demand shocks both in the tradable and nontradable sectors of the economy.

6. This decomposition is done in terms of the overall real exchange rate, the traded goods real exchange rate, and the residual, and follows other papers in the literature. Another way to decompose the real exchange rate would have been to focus on the real exchange for nontraded goods ($RER^N = P^N/P^M$), and a residual. In this case, the series RER and RER^N also display some strong comovement, but the evidence is not as strong as for the pair (RER, RER^T). For the full sample, the correlation between RER and RER^N is 0.47, while it increases to 0.66 for the 2002-2006 period.

7. Using a similar decomposition, Engel (1999) and Chari *et al.* (2002) found that most of the variability in the real exchange rate between the United States and main trading partners was due to traded goods. On the other hand, Betts and Kehoe (2006), and Burnstein, *et al.* (2005) suggest that the using the “goods only” component of the CPI is not a good measure of the prices of traded goods, because they include distribution, marketing, and other services that are of a nontraded nature. Using different proxies for the price of traded and nontraded goods, both papers show that the latter can explain up to 50 percent of the variability in the real exchange rate. Proxies used include the PPI for industrial goods, gross output deflators, and import and export price deflators at the dock.

3. The Model

As we explained in the introduction, three main hypotheses have been suggested to explain the persistence of inflation differentials in the EMU, which 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. In a companion paper, Rabanal (2006) 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. In this section, we briefly sketch the main ingredients of the model, and refer the reader interested in the technicalities of the model and the econometric methodology to Rabanal (2006)⁸.

3.1. Outline

The main feature of New Keynesian models is the presence of nominal rigidities: producers are not able to reset their prices whenever they find it optimal to do so. Older explanations include *menu costs*, as in Blanchard and Kiyotaki (1987), where even small fixed costs of changing prices can lead to equilibria where no price setter would want to change its price after an expansionary demand shock. Because models of monopolistic competition and menu costs can lead to multiple equilibria, macroeconomic models that try to fit the data incorporate some form of exogenous restriction on the price setting mechanism.

Due to its analytical tractability, newer generations of New Keynesian models incorporate what is known as a “Calvo-type restriction”: firms are only able to reset prices whenever they receive a stochastic signal to do so⁹. This signal arrives with constant probability every period, and is independent of the past history of signals. This modelling device allows to aggregate the price level of those producers that reset prices in a given period and those who do not in a simple way. The New Keynesian model has become now mainstream to analyze the determinants of inflation dynamics (see Galí and Gertler, 1999; and Rabanal and Rubio-Ramírez, 2005) and the role of monetary policy, but is also used to analyze other macroeconomic phenomena such as the impact of productivity improvements on hours worked (see Galí and Rabanal, 2005). In the context of international macroeconomics, models with nominal rigidities are also useful to explain the behavior of real exchange rates, and the international transmission of government (monetary and fiscal) policies.

To test for the presence and importance of Balassa-Samuelson effects, the model includes tradable and nontradable goods in both countries, and productivity shocks that affect all countries and sectors. Positive productivity shocks have the effect of improving the production frontier for each type of good, and hence cause an increase of output and a decrease of prices in that sector. In addition to country-specific productivity shocks, the model incorporates productivity shocks at the euro area level that affect either the tradable sector, or both sectors (to allow for technology spillovers across countries in the union). To understand the role of demand factors, the model incorporates demand shocks in the

8. Other DSGE-based explanations of inflation differentials using models with traded and nontraded goods include Altissimo *et al.* (2005), and López-Salido *et al.* (2005).

9. See Woodford (2003).

form of government spending in both tradable and nontradable goods. These shocks will tend to move output and prices of a given sector in the same direction, and hence are able to explain a different comovement than productivity shocks. To understand the role of monetary factors, the model incorporates a monetary policy shock which is the residual of a Taylor-type interest rate rule that targets the EMU HICP. Finally, the model allows for the possibility that the inflation dynamics equations across countries and sectors are different, and a formal test can be conducted to contrast this hypothesis. Since the model features monopolistic competition and nominal rigidities, the price of tradable goods can differ across countries due to productivity, demand, and monetary shocks.

The model is estimated using Bayesian methods. The main advantage of using this approach is that information about the model's parameters can be introduced via the prior distribution. In addition, from a computational point of view, it is helpful to identify the model's parameters (see Canova and Sala, 2006). This is particularly important when we use a relatively short sample, as is the case in the euro area. Using a likelihood-based general equilibrium approach allows us to test all the implications of the model for explaining the data.

3.2. Inflation Dynamics

To derive an equation that explains inflation dynamics, we follow the methodology in Woodford (2003). 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 a fraction φ_N in the nontradable sector, and φ_H in the tradable sector, index their price to the last period's inflation rate when they are not allowed to reoptimize.

As a result, an inflation dynamics equation of the following form arises for the nontradable sector:

$$(1 + \varphi_N)\Delta p_t^N = \varphi_N \Delta p_{t-1}^N + E_t \Delta p_{t+1}^N + \kappa^N mc_t^N - \kappa^N (p_t^N - p_t), \quad (2)$$

where $\kappa^N = \frac{(1-\theta_N)(1-\theta_N)}{\theta_N}$. Similar equations with the appropriate change of notation hold for the tradable sector in Spain, and for the tradable and nontradable sectors in the euro area. The previous equation is at the core of New Keynesian models, and it implies that inflation depends on i) expectations of future inflation ($E_t \Delta p_{t+1}^N$), which are rational, ii) lagged inflation (Δp_{t-1}^N) through the indexation of price contracts, and iii) a driving process, that we refer to as the real marginal cost of production (mc_t^N), and that we define as:

$$mc_t^N = \omega_t - x_t^N$$

Labor is the only input in the production function. Therefore, the real marginal cost of production depends positively on the real wage (ω_t), and negatively on the sector-specific productivity shock (x_t^N). Therefore, if real wages in the economy grow faster than productivity in the nontradable sector, then inflation will be higher in this sector: the model incorporates the Balassa-Samuelson effect. Finally, the Phillips Curve includes the relative price of tradables with respect to the CPI, $p_t^N - p_t$. Due to imperfect substitutability,

the prices of traded and nontraded goods can differ. However, if the price of nontradable goods is higher than the price of tradable goods, firms that produce nontradable goods will lose market share and will find it optimal to reduce their price.

3.3. Other Equilibrium Conditions

In addition to the equations that determine inflation in all countries and sectors, the model simultaneously determines:

- Consumption and savings decisions, through an equation that relates consumption and the real interest rate in each country.
- Labor supply decisions, that weight the disutility cost of supplying labor with its benefits (the real wage times the marginal utility of consumption).
- Production functions, that determine output supply in all sectors and countries.
- Aggregate demand, that includes private and public consumption for each type of good, and exports and imports across countries for tradable goods.
- Market clearing conditions, that equate in each country and sector the supply and demand of output, labor, and savings instruments, and
- Interest rates, that are set at the EMU level by the ECB, using a Taylor-type interest rate rule.

The model has 55 equations and the same number of endogenous variables.

3.4. Parameter Estimation

Denote by $\{\chi_t\}_{t=1}^T$ the set of observable variables that we wish to explain, and Θ the vector of parameters of the model (including preferences, technology, government policies, and stochastic properties of the shocks). From Bayes rule, the posterior distribution of the model's parameters is proportional to the product of the likelihood function $\mathcal{L}(\{\chi_t\}_{t=1}^T | \Theta)$ and the prior distribution $\Pi(\Theta)$:

$$P(\Theta | \{\chi_t\}_{t=1}^T) \propto \Pi(\Theta) \mathcal{L}(\{\chi_t\}_{t=1}^T | \Theta)$$

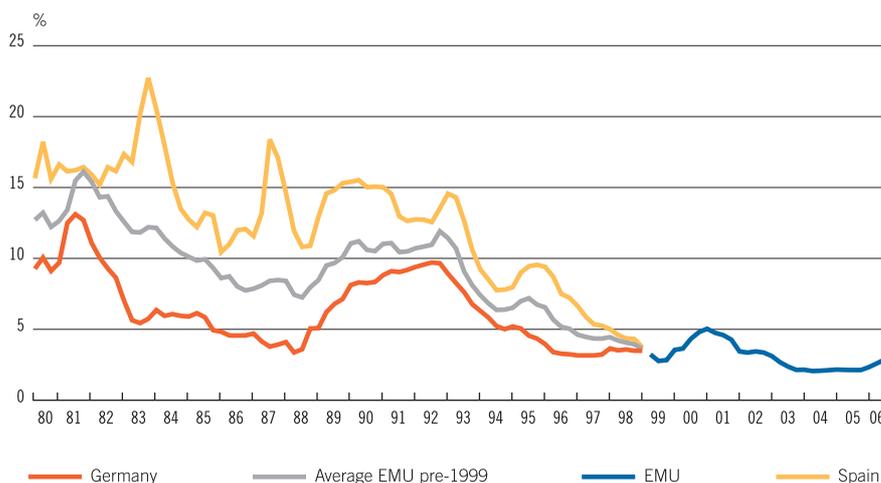
Prior information about the model's parameters is introduced in the $\Pi(\cdot)$ function. All the technical details about the estimation can be found in Rabanal (2006). An and Schorfheide (2006) also provide a comprehensive survey on the technical issues involved in estimating DSGE models with Bayesian methods.

3.5. Data

Severe data restrictions arise when estimating the model using euro area 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. At a quarterly frequency,

the sample consists of 30 observations, which represent too few observations, given that the model has a fair amount of parameters. From an econometric point of view, it is desirable to have the longest possible time series, and several papers have used the Area Wide Model (AWM) dataset of Fagan *et al.* (2001) to estimate models of the euro area as a whole¹⁰. By making this choice, one implicitly assumes that the euro area behaved like a common currency area since the beginning of the sample period (the 1970s). This can be a difficult assumption to accept, specially for those countries who joined the European Union (EU) and the European Monetary System (EMS) over the years. The assumption of a common monetary policy might be a good approximation for the countries in the “core” of the old EMS, whose monetary policies closely followed the Bundesbank in the 1980-1999 period. For instance, Pytlarczyk (2005) estimates a model of Germany inside the euro area. He does so by estimating two models at the same time: a model of a currency area like the one presented here from 1999 onwards, and a model of fixed exchange rates before the launch of the euro. In the second case he introduces risk premia to model interest rate differentials in a fixed exchange rate regime.

FIGURE 3.1 Interest Rates, 3 Month Treasury Bills



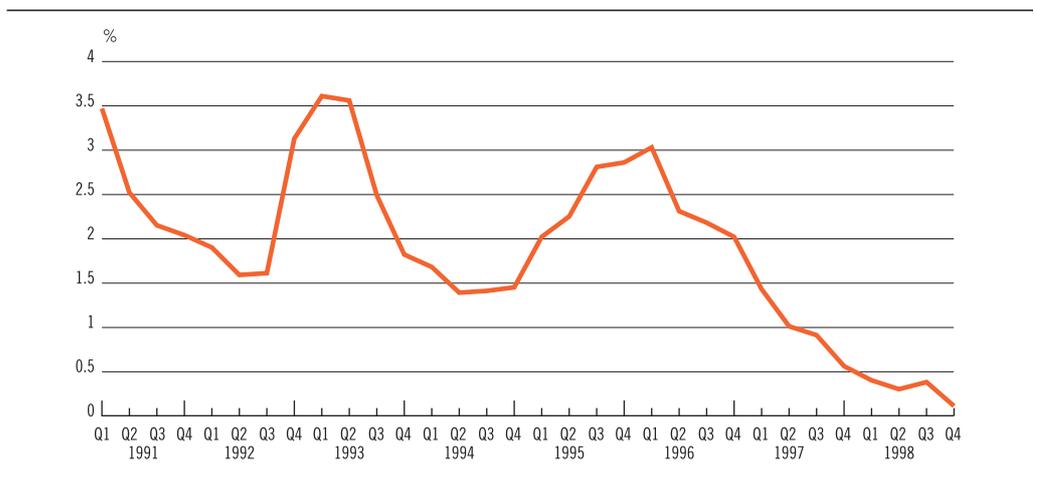
SOURCE: EUROSTAT, ECB.

Spain joined the EU in 1986, and the EMS in 1989, and it launched inflation targeting in 1995 to converge in nominal terms with the rest of countries of the euro area. Therefore, it is difficult to accept the assumption that Spain belonged to some european entity that behaved as a “synthetic” currency union, and hence this paper does not follow Pytlarczyk’s (2005) approach. The structural change for Spain of joining the EMU was a larger structural break than for Germany. Figure 3.1 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

10. This is a synthetic, nonofficial dataset maintained at the Econometric Modelling Unit of the ECB. For two examples, see Smets and Wouters (2003), and Rabanal and Tuesta (2006).

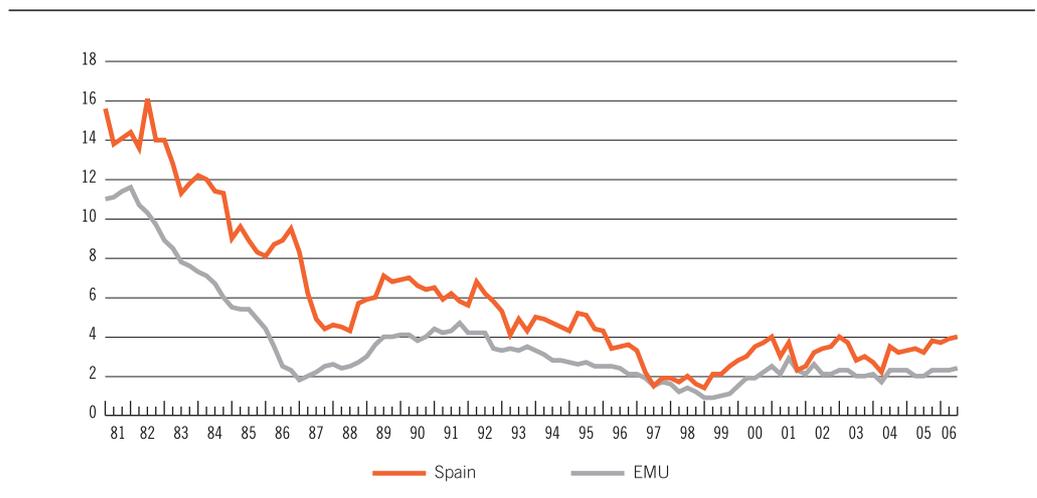
1999. Monetary policy in Spain did not follow that of the Bundesbank or a European aggregate during the 1980s and even most of the 1990s. Convergence in interest rates only seemed to happen after 1997: as Figure 3.2 shows, the spread between Spain's 3-month rates and the average of the Euro area became less than 50 basis points in the last 20 years only after the fourth quarter of 1997. Afterwards, the spread kept declining to insignificant levels, once it became clear during 1998 that Spain would enter in the EMU.

FIGURE 3.2 Spread between Spain and average EMU 3 month rates



SOURCE: EUROSTAT, ECB.

FIGURE 3.3 CPI Inflation Rates



SOURCE: EUROSTAT.

Finally, Figure 3.3 shows the 12-month CPI inflation rate. For the whole sample period, and specially in the 1980s and early 1990s Spain experienced higher inflation than the euro area. Focusing on more recent periods, average inflation in the euro area countries crossed the 4 percent threshold in 1992:03, and has stayed below that value ever since. In Spain, it took three and a half more years for inflation to fall under 4 percent (in 1996:01), after more than two decades of higher inflation rates.

For all the reasons we have explained in this subsection, and to address the fact that there was a structural change in Spain in the process of converging in nominal terms to the euro area, Rabanal (2006) estimates the model starting the sample period in 1996:01. This leaves a sample with 42 observations. Clearly, this is a short sample, and only with time we will be able to estimate the model with more observations from the EMU period.

4. Results

This section has two main parts. First, it describes the parameter estimates obtained by Rabanal (2006). Second, it presents the implications of the estimated model for explaining the data, namely impulse responses and variance decomposition analysis.

4.1. Parameter Estimates

The results of the estimated model can be summarized as follows: first, the estimated degrees of nominal rigidity across countries and sectors are similar to those obtained with survey evidence. The estimated average duration between price changes in the tradable sector is about 2 quarters both in Spain and the rest of the euro area. On the other hand, the estimated average durations range between 4 quarters in Spain and 6 quarters in the rest of the euro area for the nontradable sector. The degrees of backward looking indexation in the price setting mechanism are about one half for the Spanish tradable sector case, and roughly two-fifths for the rest of the euro area. For the nontradable sector, while the estimates point to a higher degree of nominal stickiness (less frequent price changes), the degrees of backward looking behavior are smaller, in the range of one-fourth in Spain and less than ten percent in the euro area. All these results are fully consistent with the survey evidence presented by Fabiani *et al.* (2006)¹¹.

Given that the estimated parameters are not so different across countries (at least between Spain and the rest of the euro area aggregate), Rabanal (2006) cannot reject the hypothesis that the parameters of the inflation dynamics equations are similar in Spain and the rest of the euro area. Hence, Rabanal (2006) rejects the hypothesis put forth by Angeloni and Ehrmann (2004), which suggests that different mechanisms of inflation transmission across countries in the euro area are the cause of persistent inflation differentials. However, the impact of symmetric shocks can be different due to different composition of each country's CPI (in terms of tradable and nontradable goods, and in terms of the fraction of domestically produced and imported tradable goods in the basket)¹². The estimates for the Taylor rule suggest that the ECB targets inflation with a large coefficient on the reaction of nominal interest rates to inflation, of about 1.5, with a significant degree of nominal interest rate inertia, of 0.65. These estimates are similar to other studies that have estimated Taylor rules for the euro area¹³.

4.2. Impulse Responses

In this subsection, we analyze the estimated dynamic effects of an innovation to: (i) an improvement in the euro area common component of productivity in the tradable sector, (ii) a Spain-specific improvement of productivity in the tradable sector, (iii) a Spain-specific productivity improvement in the nontradable sector, (iv) a euro area monetary policy shock, and (v) a government spending shock in the nontradable sector in Spain. The impulse-response exercise consists in introducing a one-time impulse to one of the shocks

11. This paper presents survey evidence conducted by several central banks of the euro area that asked firms how their prices are set and what is the frequency between price adjustments.

12. Outside the model, other factors such as oil dependency are likely to generate different inflation dynamics even when the estimated parameters are the same.

13. See Smets and Wouters (2003).

in the system, and then allow the shock to affect the macroeconomic variables of interest through the estimated dynamics of the system. The size of the shock is one (estimated) standard deviation.

4.2.1. Productivity Shocks

Table 4.1 presents the impact effect of the three productivity shocks on selected variables of interest, as well as the dynamics after 4, 8, and 12 quarters. In the cases of inflation and growth, the number represents accumulated year-on-year effects. In the case of the real exchange rate, we present the evolution of the level. Also, in all cases, the numbers represent deviations from long-term trend values. There are similarities and discrepancies in the reaction of main variables to these shocks. The main similarity is that, in all cases, output growth in Spain and in the euro area increase after a productivity shock. In addition, nontradable inflation in Spain always increases with a tradable sector technology shock: the Balassa-Samuelson effect is present in the estimated model, but its effect is quantitatively small. As a result, the real exchange rate always depreciates (increases) under a productivity improvement.

TABLE 4.1 Impulse Responses, Productivity Shocks

EURO AREA, TRADABLE	HORIZON			
	0	4	8	12
Spain HICP Inflation	-0.12	-0.06	-0.01	-0.004
EMU HICP Inflation	-0.11	-0.06	-0.02	-0.007
Spain HICP Services Inflation	0.02	0.00	-0.06	-0.05
EMU HICP Services Inflation	0.02	0.01	-0.06	-0.06
Spain Output Growth	0.26	0.08	-0.18	-0.09
EMU Output Growth	0.29	0.07	-0.19	-0.09
Real Exchange Rate	0.02	0.02	0.01	0.005
SPAIN, TRADABLE				
Spain HICP Inflation	-0.23	0.03	0.07	0.03
EMU HICP Inflation	-0.05	0.01	-0.003	-0.002
Spain HICP Services Inflation	0.03	0.07	-0.03	-0.05
EMU HICP Services Inflation	0.06	0.09	-0.04	-0.06
Spain Output Growth	0.30	0.23	-0.27	-0.14
EMU Output Growth	0.11	0.05	-0.10	-0.04
Real Exchange Rate	0.21	0.14	0.06	0.03
SPAIN, NONTRADABLE				
Spain HICP Inflation	-0.09	-0.06	-0.01	0.005
EMU HICP Inflation	-0.01	-0.007	-0.002	0.001
Spain HICP Services Inflation	-0.21	-0.51	-0.16	0.003
EMU HICP Services Inflation	0.06	0.12	0.05	0.01
Spain Output Growth	0.14	0.31	0.03	-0.03
EMU Output Growth	0.05	0.07	-0.02	-0.01
Real Exchange Rate	0.09	0.15	0.15	0.14

NOTE: Units expressed in percent deviations from long term values.
SOURCE: Author's estimates.

Under a euro area-wide tradable sector productivity innovation, HICP inflation declines on impact by 0.12 percent in Spain and by 0.11 percent in the euro area. Nontradable inflation increases but by very small amounts: 0.02 percent. Hence, while the Balassa-Samuelson is present, it is quantitatively small, and the behavior of headline inflation is explained mostly by the behavior of the price of tradable goods. The behavior of inflation does not display much persistence, and after 4 quarters it has returned to its long-term value (of 2 percent). Because of the similar response of headline HICP inflation in Spain and the euro area, the real exchange rate barely moves. Under this shock, growth increases by 0.26 percent in Spain and by 0.29 percent in the euro area on impact, and it exhibits some oscillating behavior (crossing the zero line) before returning to the long-term value. Overall, the effects of a euro area wide productivity shock are symmetric in both Spain and the rest of the euro area.

Under a Spain-only tradable sector technology shock, the effects are more asymmetric. The reaction of Spain variables is stronger, while the reaction of euro area variables is weaker. For the case of Spain, year-on-year inflation decreases by 0.23 percent on impact, and it takes longer for inflation to return to its long-term value. Similarly, output increases on impact by 0.3 percent above trend. Nontradable inflation increases by 0.03 percent, and it displays a hump-shaped response, since it peaks at 0.07 percent after 4 quarters. Again, the Balassa-Samuelson effect is quantitatively small and does not prevent the real exchange rate from depreciating by 0.21 percent on impact. Even though the shock is asymmetric and only affects the Spanish tradable sector, there are some spillover effects to the rest of the EMU. Since inflation in Spain declines, headline HICP inflation in the EMU declines as well. The ECB cuts rates and this boosts EMU growth to 0.11 percent above trend on impact.

The effects of a Spain-only nontradable shock are similar to those we have described for the tradable shock, except that the effect is on the nontradable sector. In this case, it is nontradable inflation that declines and displays a hump-shaped response: the impact is 0.21 percent, and after 4 quarters it is 0.51 percent below trend. As a result, the headline HICP declines, and the real exchange rate depreciates. Output growth increases in Spain by 0.14 percent, and displays some hump-shaped response. There are some small spillover effects to the rest of the EMU, because of the reaction of monetary policy.

4.2.2. Response to a Nontradable Demand Shock

The response to a nontradable demand shock is presented in the top panel of Table 4.2. The most important result is that output in Spain increases by 0.17 percent above trend on impact. 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 lose market share in the Spanish market. The effects on prices are quantitatively small. In this case, the real exchange rate appreciates, because of higher inflation in both sectors in Spain. Because this is the only shock that increases nontradable inflation, output, and causes a real appreciation at the same time, López-Salido et al. (2005) suggest that this type of shock would have to be a main ingredient in explaining the behavior of the Spanish economy in the recent years.

TABLE 4.2 Impulse Responses

SPAIN, NONTRADABLE DEMAND	HORIZON			
	0	4	8	12
Spain HICP Inflation	0.02	0.007	-0.002	-0.002
EMU HICP Inflation	0.002	0.003	0.001	0.001
Spain HICP Services Inflation	0.004	0.01	0.003	0.001
EMU HICP Services Inflation	-0.01	-0.02	-0.01	0.002
Spain Output Growth	0.17	-0.07	-0.02	-0.01
EMU Output Growth	0.007	-0.009	0.003	0.001
Real Exchange Rate	-0.02	-0.02	-0.02	-0.01
EMU, MONETARY POLICY				
Spain HICP Inflation	-0.18	-0.07	0.003	0.001
EMU HICP Inflation	-0.18	-0.08	0.003	0.001
Spain HICP Services Inflation	-0.04	-0.11	-0.05	-0.02
EMU HICP Services Inflation	0.00	-0.001	-0.001	0.00
Spain Output Growth	-0.17	0.14	0.02	0.01
EMU Output Growth	-0.19	0.16	0.02	0.01
Real Exchange Rate	0.004	0.001	0.001	0.00

NOTE: Units expressed in percent deviations from long term values.
SOURCE: Author's estimates.

4.2.3. Monetary Policy Shocks

The bottom panel of Table 4.2 shows the estimated effects of a monetary policy shock that increases the nominal interest rate by 25 basis points. Similar to the case of euro area productivity shocks, the effects of monetary policy are very similar in Spain and the euro area. This can be explained because the parameters that reflect preferences and technology across countries are assumed to be the same, while the parameters that are estimated and explain inflation dynamics turn out to be the same as well. Output declines by 0.25 percent below trend after an increase of interest rates, while nontradable inflation declines about 0.13 percent below trend on impact, and displays some hump-shaped response. The impact effect of monetary policy on headline HICP inflation is 0.18 percent below trend, which is mostly driven by the jumpy behavior of tradables inflation in both countries. Since the effect is symmetric on both price indices, the real exchange rate does not move.

4.3. What Drives Inflation Differentials?

What we have learned from the previous subsection is that shocks that affect the euro area as a whole have a symmetric effect, while Spain-only shocks seem to be necessary to explain the divergent behavior of inflation between Spain and the rest of the EMU. Moreover, a combination of shocks seems to be necessary to explain the data. For instance, a plausible explanation for the recent experience in Spain would entail a negative nontradable sector productivity change (as shown in Figure 1.2), with a positive nontradable sector demand shock. This combination could explain why inflation in services has been higher than in goods, while at the same time explaining above-trend GDP growth, specially in the nontradable sector, and real exchange rate appreciation.

While impulse response exercises are useful to understand the effects of each shock on macroeconomic variables of interest, they do not allow to measure what fraction of volatility of each variable can be attributed to each shock. To be able to answer this question, using the estimated model, we perform a variance decomposition exercise: we use the estimated model to determine which fraction of the volatility of a given variable can be attributed to each shock.

TABLE 4.3 Variance decomposition

In percent

		PRODUCTIVITY			DEMAND	MONETARY
		T	N	BOTH		
EMU	HICP Inflation	39.7	0.8	5.2	0.4	53.8
	Services HICP Inflation	16.4	71.1	0.1	4.8	7.7
	Real GDP Growth	26.8	2.2	47.6	18.5	5.0
	3 Month T-Bill	78.1	3.5	2.7	1.4	14.3
Spain	HICP Inflation	58.9	9.4	3.2	1.4	27.1
	Services HICP Inflation	6.4	88.8	0.1	0.2	4.5
	Real GDP Growth	33.6	5.2	52.9	4.4	3.8
	Services Real GDP Growth	21.7	9.7	38.5	24.8	5.5
	Inflation Differential	78.5	17.4	0.1	4	0.1

SOURCE: Author's estimates.

Table 4.3 presents the results. The model has eleven shocks. To make the exposition simpler, the shocks have been aggregated across countries for the same category. Shocks are orthogonal so their effect on each variable can be aggregated without having to worry about cross-product terms. The “Productivity, T” column includes the productivity improvements that affect the tradable sector in Spain and the rest of the euro area. The “Productivity, N” column aggregates the effect of productivity shocks in the nontradable sector in the two countries, while the “Productivity Both” includes a shock that affects both countries and both sectors at the same time. The “Demand” column aggregates the effects of government spending shocks in both countries and both sectors. This level of aggregation for demand shocks is presented because demand shocks in the tradable sectors of both countries have insignificant effects. The last column presents the effects of monetary shocks.

Several interesting results arise. First, euro area variables are mostly explained by euro area shocks, specially euro area inflation, which is mostly driven by monetary policy shocks, and euro area growth, which is driven by productivity shocks that affect the tradable sector and both sectors at the same time. About 78 percent of the volatility of nominal interest rates is driven by tradable sector productivity shocks. Second, nontradable (services) inflation both in Spain and the euro area is mostly driven by nontradable productivity shocks, while tradable sector productivity shocks have a small impact, explaining about 6 percent of nontradable inflation volatility in Spain and 16 percent in the EMU. Therefore, while the impulse responses show that there is indeed a Balassa-Samuelson effect, this turns out to be quantitatively unimportant. Third, government spending shocks turn out to be insignificant in explaining other variables than output growth. They explain about one quarter of the volatility of nontradable output in Spain, and about one fifth of the volatility

of output growth in the euro area. Indeed, most output growth in Spain and in the euro area is explained by the technology shock that affects both sectors at the same time.

Most importantly, the main result of Table 4.3 is that most of the volatility in the inflation differential turns out to be explained by tradable sector productivity shocks: their contribution is 78.5 percent of the variance of total volatility. Nontradable sector shocks explain 17.4 percent, and the rest of the shocks have marginal importance. These results are in sharp 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 1.1, where services inflation dispersion seems to be main driver of HICP inflation dispersion. In the present paper, as we have shown in Figure 2.2, differentials in tradable goods inflation is the main component 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 those obtained in the Spanish case.

Next, we offer an additional piece of evidence that supports the results of the estimated model. Real unit labor costs (that is, nominal wages adjusted for the relevant inflation faced by firms, the GDP deflator, and labor productivity) grew faster in the goods sector in Spain than in the EMU (Table 4.4). This growth is due both to higher nominal wage growth in Spain compared to the EMU, and to slower labor productivity growth. As a result, real unit labor costs faced by firms increased in Spain 1.6 percent on average, while they declined in the EMU at an annual rate of 0.6 percent during the 2000-2006 period. Hence, the evidence presented in Table 4.4 links nicely with the results of the estimation, since in the model, excessive real unit labor costs growth feeds into inflation via the Phillips Curve (equation 2). It is important to remark that due to the short sample and to restrict the number of parameters involved, Rabanal (2006) does not incorporate sticky wages in the model and nominal wage growth in the set of observable variables. Also, the set of observable variables includes real output growth but not labor productivity growth. As more data from the EMU period become available, it would be desirable to use these series as well, and look at the implications for explaining the inflation differential. Finally, Table 4.4 shows that real wages in the service sector in Spain have been declining. This could possibly be reflecting the effect of immigration. Informal evidence suggests that new immigrants have been mostly employed in the construction and services sectors, thereby depressing real wages.

TABLE 4.4 Average Annual Growth Rates, in percent, 2000-2006

	SPAIN		EMU	
	GOODS	SERVICES	GOODS	SERVICES
1. Nominal Wages	4.1	3.8	3.2	3.3
2. GDP Deflator	1.7	4.5	2.2	2.2
3. HICP Inflation	3.0	3.9	2.1	2.4
4. Labor Productivity	0.9	-1.4	1.6	0.1
5. Real Wages (1-2)	2.4	-0.8	1.0	1.1
6. Real Unit Labor Costs (1-2-3)	1.6	0.6	-0.6	0.9

SOURCES: INE, Eurostat, ECB, and author's calculations.

5. Concluding Remarks

The study of inflation differentials in a currency union has become important, specially after the observed increase in inflation dispersion and the persistence of inflation differentials in the euro area after the launch of the euro in January 1999. Several explanations have been suggested in the literature, that emphasize the role of tradable sector and nontradable sector technology shocks, demand shocks, and heterogeneous inflationary processes in the euro area. This paper has documented that the tradable goods component of the HICP is the main source of inflation differentials between Spain and the rest of the euro area for the 1999-2006 period, and specially after 2002. This paper has used the estimates of a companion paper for the case of Spain, in a two-sector, two-country DSGE model estimated with Bayesian methods.

The results can be summarized as follows: first, the estimated degrees of nominal rigidity across countries and sectors are similar to those obtained with survey evidence by Fabiani *et al.* (2006). Second, we cannot reject the hypothesis that inflation dynamics in Spain and the rest of the euro area are similar. Still, the impact of symmetric shocks can be different due to the different composition of each country's CPI. Finally, the most important explanation for the inflation differential between Spain and the euro area comes from tradable sector productivity shocks that affect either Spain, the rest of the euro area, or both. On the other hand, nontradable technology shocks have a minor contribution to explaining inflation differentials. Demand shocks are useful to explain a fraction of output growth volatility but not of inflation dispersion.

Some caveats might apply to our results. First of all, the effects of price markup shocks (that would increase the market power of firms) and productivity shocks cannot be distinguished in the context of this model. Therefore, what we are attributing as 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 is simply a labelling issue, and 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.

Second, we always need to keep in mind that the model cannot explain what it does not incorporate. As we showed in section 2, the energy component of the HICP is positively correlated with the real exchange rate for traded goods, which is in turn highly correlated with the headline inflation differential. It could well be that the importance of the tradable sector productivity shock is picking up the effect of oil price shocks, that are not included in the model. Since Spain is a highly oil dependent country, it could well be that the inflationary impact of oil prices is higher than in other countries of the euro area. Future versions of large scale models such as the one presented here should model energy prices. Finally, while the EMU is the most important trade partner of Spain, the role of trade with third countries, the role of other commodity prices and the effects of the trade-weighted euro exchange rate should be introduced in large scale macroeconomic models.

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