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Abstract

This paper studies the relationship between the Spanish real aggregate fluctuations and those of its European neighbors in the last decades. It studies the ability of alternative International Real Business Cycle models (based on Backus, Kehoe and Kydland (1994)) with different degrees of international interdependencies, to capture the observed comovement between the Spanish and European business cycles and compares the fit of those models using a probabilistic measure based on Gregory and Smith (1991, 1993) and Canova (1994, 1995). We find that (i) common shocks are important and that (ii) mechanisms of international transmission of shocks other than trade in consumption goods and services and spillovers in total factor productivity shocks are required in order to explain the joint fluctuations between Spain and its European neighbors.

1 INTRODUCTION

The internationalization of developed economies has led to the observation of increasing economic interactions across countries. Not only the foreign sector (including both the effect of international trade in goods and services and that of international capital markets) is increasingly important to explain the fluctuations of modern economies, but there is also a well documented tendency among modern economies to move together (see, among others, Danthine and Girardin (1989), Blackburn and Ravn (1991), Backus and Kehoe (1989), Ravn (1993), Christodoulakis, Dimelis and Kollintzas (1993) and Fiorito and Kollintzas (1994)).

The purpose of this paper is twofold. Firstly, we assess empirically the characteristics of and the interdependencies between the Spanish real aggregate fluctuations and those of its EU neighbors (in particular, France, Germany, Italy and the UK) over the period 1970.I-1996.IV. This will allow us to obtain an empirical reference to evaluate the convenience or viability of policies in the context of an increasing economic integration of these economies, like the ones implied by the EMU. As we know from the literature of optimal currency areas, the critical question is whether the economies involved in the integration process appear to have *similar and synchronous* responses to shocks, or whether their cycles differ in terms of their intensity, duration and timing. In the second case asymmetric policies are called for, at least when factor mobility remains less than perfect, and countries may lack incentives to adopt common policies. In the first one, common economic policies are viable since business cycle propagation mechanisms would be fairly similar across countries.

Secondly, we try to understand the mechanisms underlying the observed interdependencies: the transmission mechanisms of aggregate fluctuations and idiosyncratic shocks across countries, the response to common shocks, ... by means of standard International Real Business Cycle models.

Section 2 deals with the first aim of the paper. Standard measures of volatility, persistence and comovements with GDP of the business cycle component of main macrovariables are computed to study whether the Spanish economy responds *similarly* to shocks than the other main EU economies. It can be the case that not only the propagation mechanism of shocks within each country is similar, but also that the business cycles are *synchronous* across countries because the economies suffer symmetric shocks or are highly integrated in the sense that fluctuations in one country are transmitted fast to another. In those two cases a high degree of comovement or joint fluctuation of aggregate variables across countries would be observed. We characterize the comovements between the Spanish BC and that of a trade weighted average of France, Germany, UK and Italy (as well as with each of them) using standard cross-country correlation analysis.

Consistently with the results of Dolado, Sebastián and Vallés (1993) and Ortega (1994), among others[1], we find that the business cycle propagation mechanism inside Spain since 1970 is fairly similar to that in other EU countries, despite the differences in government consumption, exports and labor variables. We also find a strong comovement between the Spanish and European business cycles, especially in GDP, investment and net exports (which move synchronously) and private consumption (with a lag in Spain of around a year). The stronger and more synchronous relationship is found with France and Italy. The German and UK fluctuations are less correlated to the Spanish ones, although significantly, and lead by around a year many Spanish variables. Therefore, with the exception of a certain lag in some Spanish variables, we find evidence of a *similar and synchronous* business cycle in Spain and the other main European economies.

Section 3 presents alternative versions of a standard two-country two-good International Real Business Cycle model based on Backus, Kehoe and Kydland (1994), where the possible sources of aggregate fluctuations are both demand shocks (government spending shocks) and supply shocks (technology shocks), which can be idiosyncratic or common. The two countries aim to represent Spain and the trade weighted average of the other four EU countries. The transmission mechanism of these fluctuations across countries is trade in consumption goods and services as well as cross-country spillovers in supply and demand disturbances. We study four alternative models which differ in the degree of international interdependencies they include, i.e. autarky, autarky with common shocks, trade only (no common shocks)

[1]Many recent papers have measured the business cycle characteristics of the Spanish economy as well as their relationship with those of other countries using different methodologies, series or time periods. See, for example, Zimmermann (1997), Licandro and Puch (1997), Wynne and Koo (1997), Royuela and Pons (1997) and Pérez (1997). The closer to our analysis are Ortega (1994) and Borondo, González and Rodríguez (1997).

and full interdependence. We also explore whether incorporating indivisibilities in the labor supply as in Hansen (1985) yields cross-country interdependencies which are closer to the observed ones. When giving values to the deep parameters of the model, the researcher is faced with some degrees of uncertainty. We follow Canova (1994, 1995) and Canova and Ortega (1996) and account for this uncertainty by defining distributions for the model parameters based on the range of values given in the literature. Then, we present the predictions of the models in terms of the characterization of the Spanish BC and of the cross-correlations with the EU aggregate.

We find that common shocks are important in explaining the joint fluctuations between Spain and its European neighbors, but the simulation analysis identifies the need to include more mechanisms of international transmission of shocks other than trade in consumption goods and services. Some degree of market-specific shock to the labor variables should also be included to increase labor market volatilities and reduce their correlation with GDP fluctuations in order to meet the actual ones. The use of random parameters significantly improves the comovements between domestic series and confirms the insufficient modelization of the cross-country comovements. Indivisible labor does not help explain the latter although it increases cyclical volatilities as desired.

Section 4 uses a simple probabilistic approach proposed by Canova (1994, 1995), based on Gregory and Smith (1991, 1993), to evaluate the performance of a calibrated model using the uncertainty introduced by the stochastic nature of the exogenous processes and, when it is the case, by the stochastic parameters . We apply that approach to assess formally, beyond simple inspection of the model and actual data statistical properties, to which extent the different models proposed can reproduce the interdependencies observed between the Spanish and the EU real aggregate BC fluctuations. Such model evaluation confirms the conclusions of the previous section and identifies the model with both trade and common shocks and with random parameters as the closer to the observed cross-country comovements.

Section 5 summarizes and concludes.

2 CHARACTERIZATION OF THE BC FACTS

In order to characterize the Spanish business cycle and its relationship with that of other countries we first have to define what the business cycle is. In their seminal contribution to the measurement of business cycles, Burns and Mitchell (1947) specified business cycles as cyclical components of no less than 6 quarters and they found that US business cycles typically last fewer than 32 quarters. Here we follow Baxter and King (1995) who, departing from that definition, build an approximate band-pass linear filter which eliminates very slow moving (trend) components and very high frequency (irregular) components while retaining intermediate ("business cycle") stationary components from a given series.

They show that their method, a two-sided moving average very simple to implement, is an optimal approximation to the ideal band-pass filter for extracting a specified range of periodicities, but has the cost (higher the longer the maximum lag in the moving average, as in any linear filter) of loosing observations at the tails of the sample. They show how their business cycle filter is preferable to other detrending and smoothing techniques commonly used for business cycle analysis[2] like the removal of a linear trend, first-differencing or the application of the Hodrick-Prescott (HP) (1980) filter[3]. We apply their method of extracting the business cycle component both to the Spanish macrovariables and to those of the other countries to which the Spanish BC is compared.

We have chosen to focus on France, Germany, UK and Italy as the reference countries. Apart from obvious reasons as geographical, cultural and historical proximity, we have concentrated on only these four economies because they are the main trading partners for Spain and, hence, the more potentially influential on the Spanish

[2]The effects on business cycle statistics of alternative detrending methods has been documented in many pieces of the macroeconometrics and time series literature, e.g. Canova (1993b).

[3]While linear detrending would not remove the stochastic trend from many macroeconomic time series, first-differencing introduces a phase shift which alters timing relationships between variables by re-weighting strongly toward the higher frequencies and down-weighting lower frequencies. They also show that the HP filter can be a good approximation of the ideal high-pass filter which eliminates frequencies lower than the corresponding to a 32-quarter cycle without removing the higher frequency irregular variation in the series, and that it imposes substantial distortions on the cyclical components at the ends of the sample.

aggregate fluctuations.

Chart 1 displays the percentage of Spanish quarterly total trade with industrial countries (IND, upper line) and developing countries (DC) for the period 1973.I-1997.I (Source: Direction of Trade Statistics, IMF). Among the industrial countries, the joint share of France, Germany, UK and Italy (EU4) is the dominant and increased with time, especially since the entry of Spain in the EEC in 1986. The US was the largest individual country trade share at the beginning of the sample but it has continuously fallen down to the point of being surpassed by the Spanish trade with Portugal in the last 4 years (see Chart 2). The other trade partners are either oil-exporting countries (whose relationship to Spain is governed by the evolution of the oil markets rather than by their macroeconomic evolution) or developing countries with whom trade is either based on a single product (as with oil, and hence the evolution of the economy would affect the Spanish GDP depending on the evolution of that specific market) or on special linkages other than macroeconomic interdependencies (as with Latinamerican countries). Chart 2 shows that EU countries other than Germany, France, Italy and the UK have important trade relationships with Spain, of around 5% of the total Spanish trade at times (note the rise of the Portuguese share), but still substantially smaller than those four countries. Considering also that they are smaller countries and the lack of data (Belgium and Luxemburg do not have quarterly national accounts, and Portugal and the Netherlands only since 1977), we have decided not to include them in the EU4 aggregate to which to compare the Spanish BC facts.

The EU4 aggregate is a trade-weighted average of the corresponding French, German, UK and Italian series. The shares applied are each country share in total Spanish trade with the EU4 area, and are displayed in Chart 3 (left scale). It is important to note that the relative share of each of the four countries has kept very stable across time, the French and German ones being almost twice the Italian and UK ones.

2.1 Characterization of the Spanish BC

Our Spanish data set consists of quarterly real GDP (Y), private consumption (C), public consumption (G), fixed investment (FI), inventory investment (II), total investment (I=FI+II), exports (X), imports (M) and net exports (NX=X-M) of goods and services, all in thousands of pesetas per capita (dividing each series by the population between 16 and 65 years old), constant prices of 1986. The source is INE, Contabilidad Nacional Trimestral, and the sample period is 1970.I-1996.IV. French, German, UK and Italian corresponding series are obtained from OECD Quarterly National Accounts for the same period. For comparison across countries, we have transformed all series into thousands of US$ per capita dividing by each country's average US$ exchange rate of 1986. Aggregate quarterly labor series are people employed as a share of the labor force (N), average quarterly hours per worker (H), total hours worked per capita (TH=N×H) and average labor productivity (AP=Y/TH). They differ across countries in the sample size available and in the definition of h. For Spain, the sample size starting the earliest possible is 1976.III-1996.IV (Source: INE, Encuesta de Población Activa)[4]. The source for the other four countries OECD Main Economic Indicators. Full sample employment series is available for the four EU4 countries. The availability of hours series determines the sample size of H, TH and AP (1970.I-1996.IV for Germany and the UK, 1972.I-1996.IV for Italy and 1980.I-1996.IV for France)[5]. Figures 1a, 1b, 2a and 2b plot the per capita series corresponding to Spain and the EU4 aggregate, respectively[6].

[4]The source for the Spanish hours series is OECD MEI up to 1989.IV since the EPA data start only in 1990.I. The series are the original ones and have not been seasonally adjusted. This is not an inconvenience for our study when we use the Baxter and King (1995) band-pass filter to extract the business cycle component, since it excludes high-frequency fluctuations as the seasonal ones. Other filtering methods that keep short run movements (HP filter and growth rates) will reflect the lack of seasonal adjustment in the BC component they extract for the Spanish H series.

[5]The quarterly series available for each country are the following. Italy: Index of hours per worker, base 1986, which we have multiplied by 40 hours/week×13weeks/quarter to obtain the quarterly hours series. Germany: Average monthly hours in manufacturing and mining, which has been converted into an index, base 1986, and multiplied by 40 hours/week×13 weeks/quarter as in Italy. France: Average weekly hours in industry, converted into quarterly hours multiplying by 13. UK: there is no hours series available, so we have imposed 40×13 for the whole sample size.

[6]Plots of the other single country series are not reported here due to space limitations but are available from the author upon request. It is important to note that the German per capita series, including N, show a sharp decrease in 1991 due to the reunification. Given the high weight of Germany in the EU4 aggregate, we can observe the 1991 German effect also in the EU4 aggregate series.

Several studies report stylized facts of BC of several economies, among others Backus and Kehoe (1989) for ten OECD countries, the same ones as Blackburn and Ravn (1991), Fiorito and Kollintzas (1992) for the G7 and Christodoulakis, Dimelis and Kollintzas (1993) for the EU countries. As they do, we follow the standard methodology of modern Business Cycle analysis as defined in Kydland and Prescott (1991) and compute the variability (absolute percentage standard deviation, and relative to GDP), persistence (first, second and fourth order autocorrelation) and comovements of the business cycle components of the selected series (correlation of GDP with another series leading by 5 quarters, k=-5, to lagging by 5 quarters, k=5, the GDP series). We take an autocorrelation coefficient as significant if it lies outside $[-2\frac{1}{\sqrt{T}}, 2\frac{1}{\sqrt{T}}]$, T being the sample size[7]. We define a series coincident, leading or lagging by k quarters the cycle, i.e. the GDP cycle, if its maximum correlation (underlined and in bold case in the tables) with GDP occurs at lag 0, -k or k, respectively, and is significant (greater in absolute value than twice their Newey and West (1987) consistent S.E., which is marked with a star in the tables). The series is procyclical when the correlation coefficient is positive, countercyclical when negative, acyclical when not significant.

We obtain the business cycle component (in lowcase) applying the above mentioned Baxter and King (1995) optimal approximate band-pass filter to the logs of our series[8]. In particular, for quarterly series as the ones we study and for extracting the component associated to cycles 6 to 32 quarters long, they recommend a maximum lag for the two-sided filter of 12 quarters. This means loosing the first and last 3 years of data. Our sample size for Spain now is 1973.I-1993.IV (1979.III-1993.IV for labor variables) and for the EU4 aggregate it is 1973.I-1993.IV, including also n (1983.I-1993.IV for h, th and ap). Table 1 displays the BC statistics of the band-pass filtered Spanish series, Table 2 those of the EU4 aggregate and Table 3 summarizes the BC facts of France, Germany, Italy and the UK[9]. Figures 3a and 3b compare

[7]In the Spanish (EU4 aggregate) case, it is $[\frac{-2}{\sqrt{82}}, 0.221]$ for national accounts series (id., also for N) and $[\frac{-2}{\sqrt{56}}, 0.267]$ for labor series ($[\frac{-2}{\sqrt{43}}, 0.3]$).

[8]When a series can take negative values (this is the case for II and NX), output ratios of the series are taken instead of their logs (that is, II/Y and NX/Y).

[9]More complete BC statistics for France, Germany, Italy and the UK separately are not reported here due to space limitations. Similarly, we do not report the BC facts computed for HP filtered

the business cycle component of each Spanish series obtained with three filtering methods. Results for other countries are similar. It can be seen how the HP filter yields a BC component similar to the Baxter and King band-pass filter (BaxKing) but different to it the more important the short run movements are in the series, e.g. the seasonality existing in the h series[10]. The first differences of the series (Diff), where those high frequency movements are overvalued, differ substantially from both.

The basic findings about the Spanish BC are the following:

• Real GDP (y) is strongly positively autocorrelated up to lag 4th. This fact is consistent with the findings for the other countries, and for all other aggregate variables (except for ii and nx in some cases). It is generally interpreted as a sign of a strong persistence in the BC fluctuations.

• Consumption (c) is strongly procyclical and coincident with the GDP cycle, as it happens to its EU neighbors (except for France, where it leads the cycle by one quarter). It is slightly more volatile than output, contrary to the evidence reported for other countries (except the UK). In the literature, consumption is found slightly less volatile than output (as we find for France and Germany), procyclical and generally coincident. As Blackburn and Ravn (1991) point out, one should be careful in concluding from these high volatilities that there is no consumption smoothing: total private consumption includes that of durable goods[11].

• Government consumption (g) is slightly less volatile than output, procyclical and lags by 5 quarters the GDP (coincident in first differences). This policy element seems not to have been used to counterbalance the cycle but, as argued in Dolado,

series and first differences for all five countries and the EU4 aggregate. All these tables are available from the author upon request.

[10]The distortion in the tails of the sample induced by the HP filter does not affect here since we have truncated the sample size to meet the sample size from applying the band-pass filter of Baxter and King. The reason for the divergence is that the HP filter does not remove the higher frequencies.

[11]Blackburn and Ravn (1992) also find for the UK higher volatility in private consumption than in output, and show that this is caused, as one would expect, by a high variability of the consumption of durables while that of non-durables fluctuates less than output. In fact, Licandro and Puch (1997) find, for a similar period, a relative standard deviation for a measure of private consumption which includes only non-durables and the services of durables of 0.69.

Sebastián and Vallés (1993), this does not mean that government spending was not used countercyclically. Other components of government spending (e.g. subsidies or transfers) may have been used to offset the cycle. As found in any other international comparison, there is no common pattern across countries for government consumption[12].

• Investment (i) is almost four times more volatile than output, procyclical and coincident with the BC. Its two components are also very volatile. Fixed investment, fi, is 3.5 times more volatile than output, strongly procyclical and moves contemporaneously with the cycle. Since the output share of inventory investment, ii, is small, movements in the ratio can be attributed to movements in the numerator so that its volatility is particularly high. ii is procyclical and lags the cycle by one or two quarters. We find the same pattern across the EU countries studied, except for a smaller volatility in fixed investment than in Spain and the finding that for some countries fi lags by one quarter the cycle or ii is coincidental or even leading by one quarter. For different set of countries and periods of time, Fiorito and Kollintzas (1994) and Blackburn and Ravn (1991) find the same results.

• The output share of net exports (nx) is a very volatile series[13], considerably more volatile than in the other countries, clearly countercyclical (acyclical in Germany) as in the other countries and moves contemporaneously to the output cycle (leading by one quarter when looking at first differenced series). Its components are clearly more volatile than output. Imports (m) are strongly procyclical and lead the cycle by a quarter. Exports (x) are not significantly correlated with the cycle. This contrasts with other EU countries where exports are procyclical and are coincident or lead by one quarter the GDP. The concentration of Spanish exports make them more dependent on their particular competitiveness in the world market rather than on the Spanish economy. The same results we find are reported elsewhere for the main OECD countries, except for the uncorrelation of exports.

[12]Government consumption is found acyclical in France, procyclical and lagging by 1 quarter in Germany while leading by 2 quarters in Italy, countercyclical and leading by 4 or 5 quarters in the UK, and hence, acyclical in the weighted average of these four countries (EU4). Our results coincide with those reported by Fiorito and Kollintzas (1994). Again, it is difficult to draw conclusions about the role of fiscal policy from these facts.

[13]Also here, fluctuations in the ratio can be attributed to movements in the numerator (NX).

• Employment (n) is more volatile than output, strongly procyclical and coincidental. In France, Italy and the UK the volatility is found lower than output, which can be due to a more important employment effect of the two oil crisis in Spain and to other Spanish factors like industrial restructuring policies in the last decades. Employment in the other EU countries is also procyclical, and generally lags by 1 or 2 quarters, consistently with the results reported in the literature. Employment in Germany is more volatile essentially because of the effects of the 1991 reunification.
• Hours per worker (h) is found less volatile than output and acyclical, as in France, whereas more volatile and procyclical in Germany and Italy (lagging in Germany and coincidental in Italy). These series are the less homogeneous both in sample sizes and in definition, therefore comparison should be done with care. HP filtered hours per worker series (as found in Fiorito and Kollintzas (1994)), and even more first-differenced ones, display a substantially higher volatility than output since they incorporate the short run fluctuations of the original hours series, which includes its seasonality.
• Total hours (th) movements should be also interpreted with care. They are found more volatile than output, procyclical and coincidental but lagging by one quarter when looking at HP filtered series or at first differences, as in Germany and France (the latter is found less volatile than output, maybe due to data heterogeneity). In Italy, th is in phase with the output cycle.
• Average Labor Productivity (ap), in output per worked hour, is more volatile than output because of total hours volatility, countercyclical and coincidental or lagging by one quarter. Consistently with the literature, it is procyclical in France and the UK. In Germany ap is countercyclical and slightly lagging as in Spain, and acyclical in Italy.

Summarizing, we find the Spanish BC very similar to the BC in its main EU partners, especially France and Italy, displaying features common to many OECD countries in the post WWII period. Consumption, investment and employment are strongly procyclical and coincident with GDP, and net exports are counter-cyclical. We find as in the literature that there are considerable differences in government spending behavior across countries. The main differences with other EU4 countries are the higher relative volatility of consumption and employment (higher than that of output) and the behavior of exports and labor market series.

It is important to note that these results are not found very sensitive to the detrending procedure used despite the fact that the actual values of the moments may change. The main differences are the much lower autocorrelation coefficients when we look at the rates of growth of the series, as one would expect, and the decrease in absolute standard deviations and in all labor variables BC statistics, since they include high frequency movements excluded in the band-pass filter among which the strong seasonality of the hours series (which increases dramatically the volatility of h, th and ap).

This can be taken to suggest that the *BC propagation mechanism of Spain is fairly similar to that in the other main EU economies.* It can be the case that not only the propagation mechanism of shocks within each country is similar, but also that the business cycles are *synchronous* across countries because the economies suffer symmetric shocks or are highly integrated in the sense that fluctuations in one country are transmitted fast to another. In those two cases a high degree of comovement or joint fluctuation of aggregate variables across countries would be observed. Next we study this issue.

2.2 The joint fluctuation with Europe

To help the comparison of the Spanish BC and the European one, Figures 4a and 4b show jointly the business cycle components of the EU4 aggregate and the Spanish series (discontinuous line) for the whole common sample: 1973.I-1993.IV for national accounts series, 1979.III-1996.IV for employment (N) and 1983.I-1993.IV for the other labor series[14] Although the Spanish real GDP clearly lags the EU4 in the first half of the sample, the series get more synchronous towards the end reducing the lag to almost complete synchrony. This evolution is mostly happening in private consumption and investment. This is probably the effect of the *higher integration* of the member economies as the European Union was progressing. Table 4 displays the correlations of the Spanish variables with those of the EU4 aggregate and Table 5

[14]Recall that all variables are expressed in the same units: thousands of US$ of 1986 per capita for national accounts series, labor force share of employment for N, hours per worker for h and total hours worked per capita for ap.

summarizes the correlations between Spain and each country in the EU4 aggregate[15].

The basic results are:

• Spanish variables are most correlated with the French ones. The Spanish variables are strongly positively correlated to French variables (only exports and inventory investment are negatively related, and average productivity non significantly correlated). The business cycle components of both countries are synchronous for *y*, *fi*, *m* and *n* and the French cycle leads by one quarter the Spanish one in *c*, *i*, *nx* and *th*. This might reflect either the higher interdependence of these economies or the more similar structure of the two economies (in terms of institutions, response to common external influences, ...).

• *y*, *c*, *ii*, *i*, *m*, *n* and *th* are significantly and positively correlated between Spain and Germany, all of them indicating a lead of the German BC over the Spanish one of 1 to 5 quarters (GDP by 4, *c* by 5) except total investment, which fluctuates synchronously in both countries.

• The smallest relationship is found with the UK economy. Only *y*, *c*, *ii*, *n* and *th* are correlated, positively (except *ii*) and the UK variables lead the Spanish ones by around 5 quarters (except *ii*, which lags the Spanish *ii* cycle by 2 quarters).

• The Italian BC is found positively related to the Spanish one and in phase. Contemporaneous correlations are the highest, significant and positive for almost all variables. Only GDPs are not sufficiently correlated to be significant, Italian employment and government consumption lag their Spanish counterparts, while *th* and *ap* lead the Spanish series.

Summarizing, we have found that the Spanish business cycle is very related to the EU4 one, with a coincident evolution of GDP, investment, imports and net exports, and with private consumption in the EU4 leading by more than a year the Spanish one. Inventory investment in Europe lead by a quarter the Spanish ones, while the cycle in employment and total hours lead the Spanish ones by around a year. The least correlated series are government consumption (because of different national fiscal policies), exports (because of the different destinations of each coun-

[15]Cross-country correlations using filters different to the Baxter and King (1995) band-pass filter (HP filter and first differences) are not reported here due to space limitations but are available from the author upon request, as well as complete tables like Table 4 for each of the four countries in the EU4 aggregate.

try's exports) and hours series (and hence *th* and *ap*, because the hours series are the more heterogeneous across countries). The strong relationship found with the EU4 aggregate is essentially due to France and Italy, while the interdependence with the German and UK cycles is also significant and mainly characterized by the lead they have of around a year over the Spanish BC.

3 THE MODEL ECONOMIES

Section 2 has shown that the business cycle in Spain has been similar and synchronous to that of the other main EU economies in 1973.I-1993.IV, with the exception of a certain lag in some Spanish variables. This section uses several model economies in order to study to which extent the comovement observed can be a sign of (i) a transmission to Spain of fluctuations in other countries originated by their own country-specific shocks and viceversa, or of (ii) a similar response to common shocks. We explore alternative versions of a standard two-country two-good International Real Business Cycle model where one country represents Spain and the other the EU4 aggregate defined earlier. The possible sources of economic fluctuations in the model are stochastic shocks from both the demand and the supply side of the economy, either country-specific or common (i.e. contemporaneous cross-country correlation between shocks)[16]. Demand disturbances take the form of exogenous government spending shocks while supply disturbances are identified with technology shocks (exogenous total factor productivity shocks). Given the importance of trade flows between Spain and France, Germany, Italy and the UK, the specific mechanism of international transmission of shocks and fluctuations considered in the model is trade in consumption goods and services, together with cross-country spillovers in the shocks processes. We define the same economic environment for the two countries, led by similarities found in Section 2 between the internal propagation mechanisms in Spain and the EU4 aggregate.

Each country specializes in the production of a single differenciated good, in the lines of Backus, Kehoe and Kydland (BKK) (1994). Each country is populated

[16]Note that we include in the category of "common shocks" those generated in one country which have contemporaneous effects on the other country.

by a large number of utility maximizer infinitely-lived identical individuals. The representative agent sells the services of capital and labor, purchases the goods produced by the firms in order to be consumed or invested, owns all the firms and receives all the profits. There are complete financial markets within countries and free mobility of physical and financial capital across countries. However, labor is immobile internationally. All variables are expressed in per capita terms.

Each agent in country i has preferences given by the utility function

$$U_i = E_0 \sum_{t=0}^{\infty} \beta^t U_{it}(C_{it} L_{it}) \tag{1}$$

where C_{it} is consumption at time t, L_{it} is leisure and β the discount factor. The endowment of time is 1 at each period, which constrains leisure to be 1-N_{it}, i.e. to fluctuate between 0 and 1, N_{it} being the share of total time, net of sleep and personal care, each agent devotes to market activities in country i for period t. The instantaneous utility function takes the form

$$U_{it} = \frac{1}{1-\sigma}(C_{it}^{\theta} L_{it}^{1-\theta})^{1-\sigma} \ , \ for \ \sigma \neq 1 \tag{2}$$

$$U_{it} = \theta ln C_{it} + (1-\theta) ln L_{it} \ , \ for \ \sigma = 1$$

where $0 < \theta < 1$ is the share parameter for consumption in the composite commodity and σ is the risk aversion parameter.

Licandro and Puch (1997) find that incorporating indivisibilities in the labor supply à-la Hansen (1985) improves somehow the performance of the labor sector in a closed economy RBC model for Spain. Although our modeling exercise does not aim to capture the aggregate fluctuations of the Spanish labor market variables, a modelization which accounts for some idiosyncracy of the Spanish labor market (e.g. rigidities leading to a higher persistence of shocks) may help reproducing the observed relationship between the Spanish real aggregate fluctuations and that of its main EU neighbors[17]. Having that in mind, we explore the effects of incorporating indivisible labor as in Hansen (1985) into our IRBC models, which means that each

[17]There is an increasing body of literature incorporating labor market rigidities into stochastic dynamic general equilibrium models as the one described here (among others, Fève and Langot (1996) and Galí (1995)), whose application to our case we leave for further research.

agent has the choice of working a fixed number of hours at time t, say N_0, or not at all. In other words, a contract to work a share of time N_0 with probability $\frac{N_{it}}{N_0}$ and 0 hours with probability 1-$\frac{N_{it}}{N_0}$ is traded between agents and firms. With σ=1, as in Hansen (1985), this means that the instantaneous utility function takes the form:

$$U_{it} = \theta\ lnC_{it} + (1-\theta)[\frac{N_{it}}{N_0}ln(1-N_0) + (1-\frac{N_{it}}{N_0})ln(1-0)] = \theta\ lnC_{it} +$$
$$(1-\theta)\frac{ln(1-N_0)}{N_0}N_{it} = \theta\ lnC_{it} - (1-\theta)\frac{ln(1-N_0)}{N_0}L_{it} + (1-\theta)\frac{ln(1-N_0)}{N_0} \quad (3)$$

There is a representative firm operating in each country that produces output with a constant returns-to-scale production function

$$Y_{it} = A_{it}K_{it}^{1-\alpha}(X_{it}N_{it})^{\alpha}$$

where K_{it} and N_{it} are capital and total hours of work used by firms in country i and α is a parameter governing the output share of labor. X_{it} represents the labor augmenting technical progress, which grows at the exogenous constant rate γ_x-1

$$lnX_{it} = \gamma_x lnX_{it-1} \quad (4)$$

Total factor productivity, A_{it}, follows the joint process

$$\begin{bmatrix} lnA_{1t} \\ lnA_{2t} \end{bmatrix} = \begin{bmatrix} \rho_{A1} & \nu_{21} \\ \nu_{12} & \rho_{A2} \end{bmatrix} \begin{bmatrix} lnA_{1t-1} \\ lnA_{2t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \ \varepsilon_t \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{A1}^2 & cov_A \\ cov_A & \sigma_{A2}^2 \end{bmatrix} \right) \quad (5)$$

where ρ_{Ai} is the parameter that governs the persistence of the technology process within country i, ν_{ji} is the spillover parameter determining the speed at which changes in technology in country j are transmitted to country i, σ_{Ai} is the standard deviation of the exogenous technology innovation (ε_{it}) in country i, and $\psi = \frac{cov_A}{\sigma_{A1}\sigma_{A2}}$ represents the contemporaneous correlation between the innovations to technology processes in both countries, i.e. a common shock to both countries total factor productivities will be characterized by a high ψ, and the lower ψ the more country-specific is the shock.

Multiple goods are introduced by assuming that Y_{it} can be either used domestically (Y_{iit}) or exported to j (Y_{ijt}). $\Pi_i Y_{it} = \Pi_i Y_{iit} + \Pi_j Y_{ijt}$, $i \neq j$, where Π_i is the share of country i in total population (which includes population in countries 1 and 2). Hence, the production function can be rewritten as

$$A_{it}K_{it}^{1-\alpha}(X_{it}N_{it})^{\alpha} = Y_{iit} + \frac{\Pi_j}{\Pi_i}Y_{ijt} \tag{6}$$

Imports of i from j (Y_{jit}) and domestic goods are used in the production of a final good in each country, V_{it}, according to the following constant elasticity of substitution technology (see Armington (1969), or BKK (1994)):

$$V_{it} = (\omega_1 Y_{iit}^{1-\rho} + \omega_2 Y_{jit}^{1-\rho})^{\frac{1}{1-\rho}} \tag{7}$$

where $\frac{1}{\rho}$ is the elasticity of substitution between domestic and foreign goods and ω_1 and ω_2 govern the domestic and foreign content of national output, respectively. Their values depend on the import share of the economy as derived in the Appendix.

The equilibrium terms of trade (relative price of imports to exports) can be measured by

$$TOT_{it} = \frac{\partial V_{it}/\partial Y_{jit}}{\partial V_{it}/\partial Y_{iit}} = \frac{\omega_2 Y_{jit}^{-\rho}}{\omega_1 Y_{iit}^{-\rho}}$$

Domestic exports and imports are defined in terms of the domestic final good

$$Exports: \quad X_{it} = Y_{ijt}$$

$$Imports: \quad M_{it} = TOT_{it}Y_{jit}$$

We define MS as the import share in output i.e. $M_{it} = \text{MS}Y_{it}$. A value of MS of zero would mean that there is no trade between the economies (autarky). The trade balance, or net exports, in country i is then given by $NX_{it} = X_{it} - M_{it}$. There is frictionless international trade and capital markets are complete, which implies that individuals in the two countries can achieve both consumption smoothing (intertemporal transfer of consumption) and risk pooling (transfer of consumption across states of nature).

Firms accumulate capital goods according to the following law of motion

$$K_{i,t+1} = (1-\delta)K_{it} + I_{it} \tag{8}$$

where K_{it} is the stock of capital in country i, $0 < \delta < 1$ is the rate of depreciation of capital stock and I_{it} is total investment in country i.

In addition to consumers and producers, each country is endowed with a government. The government consumes domestic goods (G_{it}), taxes national final output with a proportional income tax (τ_{it}) and transfers back what remains to domestic residents (T_{it}). Alternatively, the government can issue debt that will be repaid by increases in lump-sum taxes or decreases in transfers. The infinite horizon of this economy makes Ricardian equivalence hold. The government flow budget constraint is given by

$$G_{it} + T_{it} = \tau_{it} V_{it} \tag{9}$$

which is assumed to hold on a period by period basis. Since, as in Ravn (1993), non-zero τ_{it} means that taxes are distortionary, we have to make some assumptions to solve for the competitive equilibrium. The existence of a large number of individuals allows to make the assumption that individuals take all government variables as exogenous and then solve for the competitive equilibrium along the lines of King, Plosser and Rebelo (1987), by first solving for the individual problem and then imposing the government budget constraint. To allow for balanced growth, we will assume that G_{it} and T_{it} grow along with X_{it} and that τ_{it} is constant. The percentage deviations from the steady state[18] of government spending is assumed to follow an autoregressive stochastic process of the form

$$\begin{bmatrix} \widehat{g_{1t}} \\ \widehat{g_{2t}} \end{bmatrix} = \begin{bmatrix} \rho_{G1} & \nu_{G,21} \\ \nu_{G,12} & \rho_{G2} \end{bmatrix} \begin{bmatrix} \widehat{g_{1t-1}} \\ \widehat{g_{2t-1}} \end{bmatrix} + \begin{bmatrix} \varepsilon_{G1t} \\ \varepsilon_{G2t} \end{bmatrix}, \quad \varepsilon_{Gt} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{G1}^2 & cov_G \\ cov_G & \sigma_{G2}^2 \end{bmatrix} \right) \tag{10}$$

where $\nu_{G,ji}$ controls for the spillover effect, ρ_{Gi} is the persistence parameter and σ_{Gi} is the standard deviation of the innovation to the government spending process in country i. $\psi_G = \frac{cov_G}{\sigma_{G1}\sigma_{G2}} \neq 0$ means that we allow for common fiscal policy shocks.

Finally, the aggregate resources constraint for the traded goods in the world economy is

$$\Pi_1(C_{1t} + I_{1t} + G_{1t}) + \Pi_2(C_{2t} + I_{2t} + G_{2t}) = \Pi_1 V_{1t} + \Pi_2 V_{2t} \tag{11}$$

The equilibrium solution of the model are the sequences for the endogenous variables of the model that maximize (??) subject to (4)-(??). The Appendix explains

[18] This refers to the percentage deviation of ratio of G_{it} to X_{it} with respect to its steady state value. See explanation of the solution method in te Appendix.

in detail the derivation of the equilibrium, along the lines of King, Plosser and Rebelo (1987). Once the solution is found and the "free" coefficients of the model are given values, solution paths for the variables of interest can be simulated from the model by drawing realizations from the distributions of the exogenous processes. These free coefficients are, as explained in the Appendix, [α, sg, $\overline{\tau_1}$, $\overline{\tau_2}$, σ, β, $\overline{N_1}$, $\overline{N_2}$, N_0, δ, γ_x, ρ_{A1}, ρ_{A2}, ν_{21}, ν_{12}, σ_{A1}, σ_{A2}, ψ, ρ_{G1}, ρ_{G2}, σ_{G1}, σ_{G2}, Π_1, Π_2, MS, ρ]. Next we justify their values.

3.1 Parameterization of the models

Due to the assumption of symmetric countries in the steady state (see Appendix), we assign values for the free parameters of the model according to the Spanish data and only use other European countries data to calibrate the parameters governing the country-specific shocks. Table 6 summarizes the parameter values chosen (in bold those that differ across models).

When giving values to the deep parameters of the model, the researcher is faced with some degrees of uncertainty. We follow Canova (1994, 1995) and account for this uncertainty by calibrating the parameters to a distribution rather than to a fixed value. Both the range of values and the particular distributions for model parameters have been selected based on the range of values given in the literature as well as on the values displayed in Table 6. When the literature concentrates on a narrow range around a single value for a certain parameter we tend to favour a Normal or even χ^2 distribution, sometimes truncated, whilst we take a Uniform distribution when different values within a range are equally found in the literature. The selected distributions are displayed in Table 7. Next we justify the choices of both the fixed and the random values for the model parameters.

• α = average labor share of income = 0.724. This figure corresponds to the average for the period studied (1973.I-1996.IV) of the adjusted wage share series for the Spanish economy (Source: European Economy (1997)). These are the updated series used by Bentolila and Blanchard (1990) to estimate total factor productivity in Spain. They are the share in GNP at factor cost of the compensation of employees adjusted for the share of self-employed in the occupied population. The advantage of these series is that they allow for intra-EU comparisons since they are computed for all EU members with equal criteria. The mean percentage share, i.e. mean(α), we find for the EU4 aggregate is 0.721. With a different data set and period, Licandro and Puch (1997) find an α for Spain of 0.65 (0.66 using GMM estimation). BKK and most of the literature take a value of 0.64, typically referring to the US economy. We therefore consider reasonable a uniform distribution for this parameter between 0.65 and 0.75 (U[0.65, 0.75]).

• sg = output share of government consumption = average over the period of government consumption over real GDP = 0.14. Licandro and Puch (1997) find a smaller value (sg=0.128) but the average share for the EU4 is 0.196 and other pieces of the literature suggest also higher values: King, Plosser and Rebelo (1988) suggest an sg of 30% and Baxter and King (1993) of 20% for the case of steady state balanced budget, while Aiyagari, Christiano and Eichenbaum (1992) suggest a government spending share of 17.7%. When we allow sg to be random, we choose a uniform distribution which includes these values, i.e. U[0.13, 0.30].

• $\overline{\tau_1} = \overline{\tau_1} = \tau$ = constant proportional income tax rate = average output ratio of total government revenues = 0.259, from the annual total revenues of the Administraciones Públicas reported in Marín (1997). Here we follow the same sources as for sg and choose a uniform distribution for τ which includes the values given in the literature, i.e. U[0.20, 0.30].

• σ = rate of relative risk aversion = 2, the standard value in the literature for multiplicatively separable instantaneous utility functions as the "divisible labor" one in equation (2). There is not a clear reason why σ should be 2; researchers have proposed higher values while the most common one is 2. We take a $\chi^2(2)$ distribution which makes that number the more likely and truncate it to prevent it to exceed 10. When we choose a model with indivisible labor σ takes value 1, both with fixed and with random parameters.

• β = subjective discount factor = $\frac{1}{1+r}$. r is the average real ex-post interest rate at time t for 1973.I-1996.IV, i.e. the average of the 3-month nominal interest on Spanish interbank loans at t minus the quarterly CPI inflation at t+1 (this makes r = 4.96% anually). This yields a β of 0.988, very much in line of what is used in the literature. We define a Normal distribution centered at this value N(0.988, 0.001) but truncated to the interval [0.9855, 1.002].

• $\overline{N_1} = \overline{N_2} = \overline{N}$ = steady state share of total individual time devoted to market

activities = average of the period of quarterly hours worked per person over the total possible (16 hours/day * 6 days/week * 13 weeks/quarter) times working people over the total labor force = 0.1621. Licandro and Puch (1997) obtain with a different definition and period an implicit value for $\overline{N}$ of 0.29 for Spain. The average we find for the EU4 is 0.25, so we define a U[0.15, 0.30] distribution for $\overline{N}$.
• N_0 = share of time each agent works per quarter when labor is indivisible, i.e. either work N_0 or not at all. We consider an average for the period considered of 40 hours per week, which makes N_0 = 40*13/(16*5*13) = 0.5. This value is kept fixed even with random parameters.
• $\delta = 0.022$ per quarter as computed by Licandro and Puch (1997) for the Spanish economy. A more common value in the literature is 0.025, which corresponds to a 10% depreciation per year, that is, to a total depreciation of new physical capital in 10 years time. We define a U[0.02, 0.03] distribution for δ.
• γ_x = 1 + average quarterly rate of growth of per capita real output (y_t) = 1.0037. This corresponds to a 0.37% real per capita output growth per quarter on average over the whole period, which coincides exactly with the one obtained by Licandro and Puch (1997). With random parameters, we define a Normal distribution centered at 1.0035 and with standard deviation 0.0005.
• Technology shocks: the parameters governing total factor productivity law of motion were obtained estimating a VAR(1) on the Spanish and EU4 Solow residuals, as computed in BKK or Ravn (1993). Each series was obtained by subtracting α times the log of the share of employed people in the total labor force from the log of output; the resulting series was linearly detrended after normalizing the first observation in each series to 1. Contrary to BKK and Ravn (1993), we allow α to vary over time. The estimates obtained[19] (Spain is country 1, EU4 aggregate is country 2) are:

$$\begin{bmatrix} \rho_{A1} & \nu_{21} \\ \nu_{12} & \rho_{A2} \end{bmatrix} = \begin{bmatrix} .8954\ (S.E: 0.0614) & -0.0307\ (S.E: 0.0546) \\ -0.0309\ (S.E: 0.0826) & 0.7427\ (S.E: 0.0734) \end{bmatrix}$$

It is important to note that technology disturbances are persistent in both countries, that they significantly depend on their own past while the technological

[19] The properties of the residuals are satisfactory, no autocorrelation is found although the normality assumption is not fulfilled, in particular the Spanish residuals have significant skewness.

spillovers across countries are not significantly different from zero. Typically, the ρ_A coefficients are found higher and the spillover positive (BKK define ρ_A=0.9 and $\nu_{12} = \nu_{21}$=0.088). We thus define both ρ_A with a Normal distribution centered close to our estimate for Spain but with a large standard deviation, i.e. N(0.85, 0.1). Based on the estimates obtained, the spillover parameter is defined equally for both countries as a N(0, 0.05).

The estimated standard deviations and correlation of the residuals of the VAR(1) system estimated (i.e. the technology innovations) are:

$$\begin{bmatrix} \sigma_{A1} & \psi \\ \psi & \sigma_{A2} \end{bmatrix} = \begin{bmatrix} 0.005 & 0.1334 \\ 0.1334 & 0.0067 \end{bmatrix}$$

$\psi \neq 0$ means that there is a certain contemporaneous transmission of total factor productivity shocks, which suggests the existence of common shocks hitting the two economies (Spain and the EU4 average) at the same time. Licandro and Puch (1997) find a higher σ_A for Spain (0.013) when considered a closed economy. Also BKK and related work report higher values both for the standard deviations of technology innovations and for their contemporaneous correlation (0.00852 and 0.258 respectively). We define a distribution for σ_A able to produce larger values but mostly concentrated around our estimated values: a $\chi^2(1)$ truncated to the interval [0.0045, 0.02]. We define a N(0.15, 0.03) for ψ.

• Government consumption shocks: Different national fiscal policies led to find unlikely an important comovement between government purchases in Spain and in Europe. Therefore we have imposed no spillovers between the g processes ($\nu_{G,12} = \nu_{G,21}$ = 0) nor correlated shocks to both processes (ψ_G =0). We have estimated independent AR(1) models for the business cycle components[20] of government spending in Spain and EU4, obtaining:

Spain: $g_{1t} = 0.923$ (S.E.=0.046) $g_{1t-1} + \varepsilon_{G1t}$, and $\sigma_{G1} = 0.0046$

EU4: $g_{2t} = 0.827$ (S.E.=0.065) $g_{2t-1} + \varepsilon_{G2t}$, and $\sigma_{G2} = 0.0035$

The parameterization of the model is such that there is no significant contemporaneous nor lagged transmission of country-specific fiscal policy shocks, and that they are very persistent in their country of origin. Licandro and Puch (1997) find

[20]Obtained with the Baxter and King (1995) described band-pass filter.

larger values ($\rho_G = 0.95$ and $\sigma_G = 0.011$) for Spain, while typically the literature takes even higher persistence parameters ($\rho_G = 0.97$) but standard deviations for the shocks to g are very much in line with the ones we have obtained ($\sigma_G = 0.0036$). We define a N(0.91, 0.08) for both ρ_G and a N(0.004, 0.001) truncated between 0 and 0.006 for both σ_G.

• As explained in the Appendix, $\Pi_1 = \Pi_2 = \Pi = 1/2$ since we assume symmetric counties.

• MS = output share of imports. The value of MS is the average over the period of the output share of total Spanish imports rather than Spanish imports coming from the countries included in the EU4, since we are assuming balanced world trade in the steady state and there are no other trade partners for any country (exports of one country equal imports in the other). The resulting value for MS is 0.20, which implies the following weights for the Armington aggregator according to the expressions obtained in the Appendix: $\omega_1 = (1-MS)^{\rho} = 0.716$, $\omega_2 = MS^{\rho} = 0.09$. MS in Spain has increased permanently through the period studied, 1973.I-1996.IV, and so has done the import share of the EU4, which on average is 0.224. We define a N(0.25, 0.1) distribution.

• $\frac{1}{\rho}$ = Armington aggregator's elasticity of substitution between home and foreign goods = 1.5, as in BKK. Ravn (1993) tries different values for this parameter with this same model and finds a similar qualitative performance of the model.

By modifying certain key parameters which govern the international interdependencies included in the model, we derive our four different model specifications:

(i) **Autarky**: No trade (MS=0) nor spillovers in the shock processes (ν=0) and uncorrelated shocks (no common shocks: $\psi = 0$).

(iii) Autarky with **common shocks**: No trade (MS=0) nor spillovers (ν=0) but contemporaneously correlated technology shocks ($\psi \neq 0$). We allow for common as well as country-specific shocks to closed economies.

(iii) **Trade only**: No common shocks ($\psi = 0$) nor spillover effects (ν=0) but trade in final goods and services is allowed between the two economies (MS $\neq 0$).

(iv) **Full interdependence**: common and country-specific shocks transmitted through trade and spillovers between across technology disturbances (ψ, MS and $\nu \neq 0$).

3.2 Model properties

From the system describing the equilibrium solution to the theoretical models and having given values to their deep parameters, we simulate time series by drawing realizations from the distributions of the exogenous processes. We have run 100 simulations for each model, with as many observations at each simulation as in the actual data (96 observations). We obtain the empirical implications of the alternative models by computing descriptive statistics of the business cycle components of the simulated series, using the same band-pass filter of Baxter and King (1995) as we did with the actual series in Section 2. Since we are particularly interested in the international interdependencies included in the models, we will pay particular attention to the cross-country correlations predicted by the alternative models. Casual comparison of those statistics to the ones estimated for the actual data is what the *informal evaluation of calibrated models* usually consists of. Table 8 reports the simulated relative standard deviations (std(y) is reported in absolute value) and contemporaneous correlations with respect to output as well as the cross-country contemporaneous correlations[21]. Actual data values are reported in the first column. Simulated moments are mean moments across the 100 simulations. Those with an asterisk have been found significantly different from zero[22]. Actual data correlations marked with an asterisk are significantly different from zero according to their Newey and West (1987) consistent S.E.. For each model, we report the predictions of the model both with fixed and with random parameters. Table 9 shows the results for the indivisible labor case. The last two columns of Tables 8 and 9 represent the model where both common and idiosyncratic shocks hit on both economies and when the international transmission of shocks and fluctuations can

[21] As with actual data, the simulated BC statistics for nx and ii are computed from the filtered output ratios (NX/Y and II/Y).

[22] Greater than twice their S.E.. The S.E. of the mean statistic across simulations is the standard deviation of the statistic across simulations divided by the square root of the number of simulations.

take place through spillovers in the technology shocks (although these are small as found in the estimation performed in the previous subsection) or trade in consumption goods and services ('Full Interdependence'). We take that specification with fixed parameters as our benchmark model.

The benchmark model has a hard time to reproduce the volatility of the cyclical components of actual Spanish data. In particular it generates higher volatility of investment and smaller for other variables (GDP, consumption, labor and trade variables). Trade in consumption goods and services and spillovers across technology disturbances are the only explicit transmission mechanisms in the theoretical economy. Thus, by being the variables that adjust faster to shocks, consumption and trade variables appear smoother than in the data. The contemporaneous consumption-leisure substitution effect smooths labor volatility, suggesting the lack of country-specific labor market shocks in the model. When a rigidity like the indivisibility of labor is included the std(y) rises to levels more similar to the actual one for the Spanish economy, due to a higher volatility of labor variables.The exaggerate investment volatility reflects the insufficiency of the propagation mechanisms of shocks included in the model economy (within the country and/or transmission across countries) which would cause less changing and more persistent fluctuations, as it is the case in the Spanish economy. It can also reflect an insufficient modelization of adjustment costs in investment, which would also make it less volatile.

The theoretical economy qualitatively reproduces the right comovements of the Spanish variables with GDP. It is important to note that the model reproduces the negative sign of net exports correlation with output. This countercyclicality arises, as in the data, because imports are more procyclical than exports. Quantitatively, the contemporaneous correlations with output are in general overestimated except the one of government consumption which appears non-significant as in the actual data, and net exports (significant only in the indivisible labor case). The combination of too little volatility and too high correlation with output of labor variables suggests the very much intuitive existence of non included labor market-specific shocks. Obviously, the existence or not of common international shocks ("Full Interdependence" versus "Trade Only", or "Autarky" versus "Common Shocks") does not change the picture of the domestic propagation of shocks. It is important to note that excluding trade (as in "Autarky" and "Common Shocks") results in a similar picture but for lower investment volatilities. Trade in consumption goods and services does not seem to be crucial for a better matching of observed domestic BC statistics.

The high comovements found suggest that, in order better match actual data moments, the model could be respecified in some dimensions but not in strenghthening the domestic propagation of shocks. Instead, a larger dependence on the external economy, other than through trade in consumption goods, would increase the sources of fluctuations, and hence the volatility of output and the other variables, while keeping or even reducing the comovements with output.

The main finding with respect to the cross-country correlations is that the existence of trade in consumption goods by itself does not suffice to explain the joint fluctuations observed (the "Trade Only" columns, compared to the "Autarky" ones, bring only consumption correlations closer to the data). Instead, the existence of common supply shocks is important (compare "Common Shocks" to "Autarky"): output cross-country correlation is significant because of these common shocks. This result coincides with that of Canova and Dellas (1992) and Canova (1993). The difference between the cross-country correlations with or without common shocks is very significant and is totally dependent on the ψ parameter. In fact, the corr(Y,Y*) of the "Common Shocks" model is basically of the size of ψ.

With respect to the international interdependencies, we also find that in our model economies:

• Simulated output correlation is too low, there are linkages between the Spanish and EU4 real outputs not captured by the model, that is, there are other sources of interdependence different to trade of consumption goods and services, common technology shocks or spillovers across the shocks processes.

• Private consumption is not enough correlated, especially if we eliminate trade. There is a negative cross-country investment correlation when we allow for trade, as is commonly found in these models. Government consumption is uncorrelated across countries, just as in the data.

• Imports are very little correlated in our model economies compared to actual data. Net exports correlation close to -1 is essentially imposed in the model by the assumption of balanced trade in the steady state, i.e. exports in one country are identical to imports in the other, and here the divergence with data is highest.

• Labor variables: the theoretical economy yields a too high cross-country correlation of total hours worked with respect to the actual data. The opposite occurs when including indivisible labor, since it increases country-specific volatility of labor variables. Average productivity is not correlated in most cases, as in the data.

The range of variability allowed for model parameters when we take them from the distributions defined in Table 7, instead of calibrating them to a fixed value, yields higher volatilities in the model series. Some are too high (near 4% for GDP versus 1.3% in the actual data) although others do not reach yet the levels observed [23]. However, the comovements of model variables with GDP get extremely similar to the actual ones. They are reduced with respect to the fixed parameters simulations, except for government consumption and net exports which get closer to the higher actual data ones while still unsignificant. Cross-country contemporaneous correlations worsen in general, which shows the need to improve the international propagation mechanisms of shocks and fluctuations across countries in the theoretical economy.

Summarizing, we find that common shocks are important in explaining the joint fluctuations between Spain and its European neighbors, but the simulation analysis identifies the need to include more mechanisms of international transmission of shocks other than trade in consumption goods and services, Some degree of market-specific shock to labor variables should also be included to increase labor market volatilities towards the actual ones. The use of random parameters significantly improves the comovements between domestic series and puts in evidence the insufficient modelization of the cross-country comovements.

If we want to discriminate the alternative models according to how successfully they reproduce the comovements observed between the Spanish real aggregate fluctuations and that of its European neighbors, a more formal evaluation procedure is required.

[23] With indivisible labor, some relative volatilities get extremely high, although they are not always significant.

4 EVALUATION OF CALIBRATED MODELS

In a typical calibration exercise aiming at analyzing empirically a stochastic dynamic general equilibrium model, the model is first specified given a concrete question the researcher wants to study. Then, the model is solved (usually through numerical approximation, as in our case), the free parameters of the model are given fixed values and the exogenous processes fixed distributions and finally time series for the variables of interest are generated by simulation of the model solution. The assessment of the performance of a model is typically reduced to a relatively subjective comparison of two reduced sets of summary statistics obtained from the simulated and the actual data. The model economy is considered a "good" approximation of the actual world if it can broadly reproduce the observed features of the series that it purports to model. Classical pieces in the calibration literature (e.g., Kydland and Prescott (1982) or (1991)) are typically silent on the metric one should use to evaluate the quality of the approximation of the model to the data. The approach favored by most calibrators is to glare over the exact definition of the metric used and informally assess the properties of simulated data by comparing them to the set of observed stylized facts.

Typically, a calibrator is not interested in testing the model in the strict statistical sense, i.e. verifying whether the model is the true Data Generating Process (DGP) of the actual data (the answer is already known from the outstart), but in identifying which aspects of the data a false model (in the sense of not being the true actual DGP) can replicate and whether different models give different answers because they are false in different dimensions. In this way a researcher treats the computational experiment as a measurement exercise where the task is to gauge the proportion of some observed statistics reproduced by the theoretical model. The adequacy of a particular parameterization is typically checked through sensitivity analysis, which essentially consists of computing and comparing the same statistics for different parameterizations. Comparison of competing models very seldom takes place and when it does it is typically reduced to a similarly informal subjective comparison of selected statistics.

Recent research in applied macroeconomics and time series econometrics has suggested alternatives to such informal approach to assess the fit of a model. See Canova and Ortega (1996) for a classification and comparison of those alternatives, and also Kim and Pagan (1994) for a review of recent methods for evaluating calibrated models. Here we follow a simple probabilistic approach as proposed by Canova (1994, 1995) which uses the uncertainty introduced by the stochastic nature of the exogenous processes and, when it is the case, by the stochastic parameters to evaluate the performance of a calibrated model. We apply that approach to assess formally, beyond simple inspection of the model and actual data statistical properties, to which extent the different models proposed can reproduce the interdependencies observed between the Spanish and the EU4 real aggregate fluctuations.

The evaluation of a model requires three steps: first, the selection of a set of stylized facts; second, the choice of a metric to compare functions of actual and simulated data and third, the (statistical) evaluation of the magnitude of the distance. Formally, let S_y be a set of statistics (stylized facts) of the actual data and let $S_{x^*}(z_t, \gamma)$ be the corresponding set of statistics of simulated data, given a vector of parameters γ and a vector of exogenous stochastic processes z_t. Then model evaluation consists of selecting a function $\psi(S_y, S_{x^*}(z_t, \gamma))$ that measures the distance between S_y and S_{x^*} and in assessing its magnitude.

The choice of which stylized facts one wants to match obviously depends on the question asked and on the type of model used. In our case, these are the statistics showing the degree of comovement between the Spanish and the aggregate EU4 country business cycles: the contemporaneous cross-country correlations in the bottom panels of Tables 8 and 9.

Measures of dispersion can be computed for simulated model statistics by simply changing the realization of z_t while maintaining the parameters fixed. Such measures can be used to evaluate the distance between statistics of actual and simulated data as in Gregory and Smith (1991, 1993), who construct a probabilistic metric to evaluate a model by using well known Monte Carlo techniques. To be specific, Gregory and Smith (1991, 1993) take S_y as a set of moments of the actual data and assume that they can be measured without error. Then, they construct a distribution of $S_{x^*}(z_t, \cdot\gamma)$ by drawing realizations for the z_t process from their given distribution, given γ. The metric ψ used is probabilistic, i.e. they calculate the probability $Q = P(S_{x^*} \leq S_y)$, and judge the fit of the model informally, e.g. measuring how close Q is to 0.5 i.e. how close S_y is to the median of the model moments' distribution.

This approach requires two important assumptions: that the evaluator takes the model economy as the true DGP for the data and that differences between S_y and S_{x^*} occur only because of sampling variability.

The approach of Canova (1994, 1995) allows for parameter variability when measuring the dispersion of simulated statistics, in addition to allowing the realization of the stochastic process for the exogenous variables to vary. The starting point, as discussed earlier, is that parameters are uncertain not so much because of sample variability, but because there are many estimates of the same parameter obtained in the literature, since estimation techniques, samples and frequency of the data tend to differ. If one calibrates the parameter vector to an interval, rather than to a particular value, and draws values for the parameters from the empirical distribution of parameter estimates, it is then possible to use parameter uncertainty, in addition to that of the exogenous stochastic processes, to evaluate the fit of the model. The evaluation approach used is very similar to the one of Gregory and Smith: one simulates the model repeatedly by drawing parameter vectors from their empirical "prior" distribution and realizations of the exogenous stochastic process z_t from some given distribution. Once the empirical distribution of the model statistics of interest is constructed, one can then compute the percentiles where the actual statistics lie.

Tables 10 and 11 display that percentile for each of the 9 contemporaneous cross-correlations obtained from each model (6 in the cases that international trade is not allowed). For fixed parameters we follow the approach of Gregory and Smith (1991, 1993) while for random parameters we follow that of Canova (1994, 1995). We can see that our model economies generate lower cross-country correlations than actual data: most of the simulated moments densities lie below the actual moments, yielding p-values for the actual correlation coefficients substantially greater than the ideal 0.5. The "Full Interdependence" model is the one performing better and improves when considering random parameters. Indivisible labor drives labor simulated correlations further from actual ones by reducing them substantially.

Our model economies are highly simplified representations of the Spanish and other European economies, and thus it is not surprising to find that they are rejected in a probabilistic sense (they produce p-values for the actual moments far from 0.5) as the exact Data Generation Processes of the actual cross-country correlations. What is more relevant to us is how relatively distant to the actual data each model is. The last row in Tables 10 and 11 summarizes the "success" of each model specification in reproducing the interdependencies between the Spanish BC and that of its EU4 neighbors. It displays the average p-value of the actual statistics into their corresponding simulated distributions. They provide us with a measure to rank the models. We find that the "Full Interdependence" model with divisible labor is the preferred one, once we account for the uncertainty in model parameters. The existence of common shocks is found important to explain the significant comovement observed. In fact, our measure of fit for the "Common Shocks" model with divisible labor is similar to that for the "Full Interdependence" one, but we have to take into account that the latter is evaluating the model along 9 dimensions instead of only 6.

The model evaluation methodology used confirms the conclusions drawn in Section 3 where we compared informally the model statistics to the actual ones. Common shocks are important in explaining the joint fluctuations between Spain and its European neighbors, but the simulation analysis identifies the need to include more mechanisms of international transmission of shocks other than trade in consumption goods and services in order to increase the simulated cross-country correlations.

5 SUMMARY AND CONCLUSIONS

The internationalization of developed economies has led to the observation of a tendency among the economies to move together (the so called International Business Cycle). This joint fluctuation is particularly important for the economies involved in economic integration processes such as the EMU. As we know, it is a crucial question whether these economies appear to have similar and synchronous responses to shocks, or whether their cycles differ in terms of their intensity, duration and timing.

In this paper, we have first assessed empirically the characteristics of and the interdependencies between the Spanish real aggregate fluctuations and those of the other main EU economies (in particular, France, Germany, Italy and the UK) over the period 1970.I-1996.IV. We find that the business cycle propagation mechanism inside Spain since 1970 is fairly similar to that in other EU countries, despite the differences in government consumption, exports and labor variables. We also find a strong comovement between the Spanish and European business cycles, especially in GDP, investment and net exports (which move synchronously) and private consumption (with a lag in Spain of around a year). The stronger and more synchronous relationship is found with France and Italy. The German and UK fluctuations are less correlated to the Spanish ones, although significantly, and lead by around a year many Spanish variables. Therefore, with the exception of a certain lag in some Spanish variables, we find evidence of a similar and synchronous business cycle in Spain and the other main European economies.

Then we have tried to explore the mechanisms underlying the observed interdependencies using alternative versions of a standard two-country two-good International Real Business Cycle model, based on Backus, Kehoe and Kydland (1994), where the possible sources of aggregate fluctuations are both demand shocks (government spending shocks) and supply shocks (technology shocks), which can be idiosyncratic or common, and the transmission mechanism of these fluctuations across countries is trade in consumption goods and services as well as cross-country spillovers in the exogenous disturbances. The two countries aimed to represent Spain and the trade weighted average of the other four EU economies.

We find that common shocks are important in explaining the joint fluctuations between Spain and its European neighbors, even more than trade in consumption goods and services by itself. The simulation analysis identifies the need to include more mechanisms of international transmission of shocks. Some degree of market-specific shock to the labor variables should also be included to increase labor market volatilities and reduce their correlation with GDP fluctuations in order to meet the actual ones. Incorporating indivisibilities in the labor supply as in Hansen (1985) does not help explain the latter although it increases cyclical volatilities as desired. The use of random parameters to account for the uncertainty faced by the researcher when giving values to the free parameters of the model (as in Canova (1994, 1995)) significantly improves the comovements between domestic series and confirms the insufficient modelization of the cross-country comovements.

We have applied a simple probabilistic approach, based on Gregory and Smith (1991, 1993) and Canova (1994, 1995), to assess formally, beyond simple inspection of the model and actual data statistical properties, to which extent the different models proposed can reproduce the interdependencies observed between the Spanish and the EU real aggregate BC fluctuations. Such model evaluation identifies the model with both trade and common shocks and with random parameters as the closer to the observed cross-country comovements. Common shocks are confirmed as important in explaining the joint fluctuations between Spain and its European neighbors, but the simulation analysis identifies the need to include more mechanisms of international transmission of shocks other than trade in consumption goods and services. in order to increase the simulated cross-country correlations.

In a very recent paper, Ambler, Cardia and Zimmermann (1998) introduce multiple sectors and traded intermediate goods in a two-country model as the one we have studied. They find that, despite the importance of intermediate goods trade in modern economies, introducing it in the model does not alter significantly the cross-country correlations predicted. However, going from a one-sector specification to a two-sector model leads to a more positive international transmission of the cycle (especially for the cross-country correlations of investment and employment), that they judge compatible with the US data. We leave for further research to explore the usefulness of a multiple-sector model to the Spain-Europe case. Intuitively, if we separate tradable from non tradable goods sectors, we could also explore other interesting issues of the Spanish business cycle such as e.g. the different evolution of productivity in the two sectors. Other specific mechanisms of the international transmission of business cycles interesting to include in our case could be related to international finance or monetary policy linkages.æ

References

[1] Aiyagari, R., Christiano, L. and Eichenbaum, M. (1992), 'The Output, Employment and Interest Rate Effects of Government Consumption', *Journal of Monetary Economics*, 30, 73-86.

[2] Ambler, S., Cardia, E. and Zimmermann, C. (1998), 'International Transmission of the Business Cycle in a Multi-Sectoral Model', Center for Research on Economic Fluctuations and Employment (CREFE) Working Paper No.60.

REFERENCES

[3] Armington, P. (1969), 'A Theory of Demand for Products Distinguished by Place of Production', *International Monetary Fund Staff Papers*, 27, 159-178.

[4] Backus D. and Kehoe, P. (1989), 'International Evidence on the Historical Properties of Business Cycles', Federal Reserve Bank of Minneapolis Working Paper No.402R.

[5] Backus D., Kehoe, P. and Kydland, F. (1992), 'International Real Business Cycles', *Journal of Political Economy*, 100, 745-775.

[6] Backus D., Kehoe, P. and Kydland, F. (1994), 'Dynamics of Trade Balance and the Terms of Trade: the J-Curve?', *American Economic Review*, 84(1), 84-103.

[7] Baxter, M. and King, R.G. (1993), 'Fiscal Policy in General Equilibrium', *American Economic Review*, 83(3), 315-334.

[8] Baxter, M. and King, R.G. (1995), 'Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series', NBER Working Paper No.5022.

[9] Bentolila, S. and Blanchard, O.J. (1990), 'Spanish Unemployment', *Economic Policy: a European Forum*, 10, 233-281.

[10] Blackburn K. and Ravn M.O. (1991), 'Contemporary Macroeconomic Fluctuations: an International Perspective', University of Southampton Discussion Paper No.9106.

[11] Blackburn K. and Ravn M.O. (1992), 'Business Cycles in the United Kingdom: Facts and Fictions', *Economica*, 59, 383-401.

[12] Borondo, C., González, Y. and Rodríguez, B. (1997), 'Relaciones Cíclicas de la Economía Española con los Países de la Futura UME', mimeo, Universidad de Valladolid.

[13] Burns, A.F. and Mitchell, W.C. (1947), *Measuring Business Cycles*, New York: National Bureau of Economic Research.

[14] Çanova, F. (1993), 'Sources and Propagation of International Business Cycles: Common Shocks or Transmission?', CEPR Discussion Paper No.781.

REFERENCES

[15] Canova, F. (1993b), 'Detrending and Business Cycle Facts', CEPR Discussion Paper No.782.

[16] Canova, F. (1994) 'Statistical Inference in Calibrated Models', *Journal of Applied Econometrics*, 9, S123-S144.

[17] Canova, F. (1995) 'Sensitivity Analysis and Model Evaluation in Simulated Dynamic General Equilibrium Economies', *International Economic Review*, 36, 477-501.

[18] Canova, F. and Dellas, H. (1992), 'Trade Interdependence and the International Business Cycle', *Journal of International Economics*, 34, 23-47.

[19] Canova, F. and Ortega, E. (1996), 'Testing Calibrated General Equilibrium Models', forthcoming in Mariano, R., Schuermann, T. and M. Weeks (eds.), *Simulation Based Inference in Econometrics: Methods and Applications*, Cambridge: Cambridge University Press.

[20] Christodoulakis, N., Dimelis, S.P. and Kollintzas, T. (1993), 'Comparison of Business Cycles in Greece and the EC: Idiosyncracies and Regularities', CEPR Discussion Paper No.809.

[21] Danthine, J.P. and Girardin, M. (1989), 'Business Cycles in Switzerland: A Comparative Study', *European Economic Review*, 33(1), 31-50.

[22] Dolado, J.J., Sebastián, M. and Vallés, J.J. (1993), 'Cyclical Patterns of the Spanish Economy', *Investigaciones Económicas*, 17(3), 445-473.

[23] *European Economy* (1997), No.65.

[24] Fève, P. and Langot, F. (1994), 'The RBC Models through Statistical Inference: An Application with French Data', *Journal of Applied Econometrics*, 9, S11-S37.

[25] Fiorito, R. and T. Kollintzas (1994), 'Stylized Facts of Business Cycles in the G7 from a Real Business Cycles Perspective', *European Economic Review*, 38(2), 235-269.

REFERENCES

[26] Gali, J. (1995), 'Real Business Cycles with Involuntary Unemployment', CEPR Discussion Paper No.1206.

[27] Gregory, A. and Smith, G. (1991), 'Calibration as Testing: Inference in Simulated Macro Models', *Journal of Business and Economic Statistics*, 9(3), 293-303.

[28] Gregory, A. and Smith, G. (1993), 'Calibration in Macroeconomics', in Maddala, G.S. (ed.), *Handbook of Statistics*, vol. 11, Amsterdam: North Holland.

[29] Hansen, G. (1985), 'Indivisible Labor and the Business Cycle', *Journal of Monetary Economics*, 16 (3), 309-327.

[30] Hodrick, and Prescott, E. (1980), 'Post-War U.S. Business Cycles: An Empirical Investigation', Carnegie-Mellon University Discussion Paper 451.

[31] Kim, K. and A.R. Pagan (1994), 'The Econometric Analysis of Macroeconomic Models', in H. Pesaran and Wickens, M. (eds.) *Handbook of Applied Econometrics*, Wiley & Sons.

[32] King, R.G., Plosser, C.I. and Rebelo, S.T. (1987), 'Production, Growth and Business Cycles: Technical Appendix', mimeo, University of Rochester.

[33] King, R.G., Plosser, C.I. and Rebelo, S.T. (1988), 'Production, Growth and Business Cycles I: The Basic Neoclassical Model', *Journal of Monetary Economics*, 21, 195-232.

[34] King, R.G., Plosser, C.I. and Rebelo, S.T. (1988), 'Production, Growth and Business Cycles II: Some New Developments', *Journal of Monetary Economics*, 21, 309-341.

[35] Kydland, F.E. and Prescott, E.C. (1982), 'Time to Build and Aggregate Fluctuations', *Econometrica*, 50, 1345-1370.

[36] Kydland, F.E. and Prescott, E.C. (1991), 'The Econometrics of the General Equilibrium Approach to Business Cycles', *Scandinavian Journal of Economics*, 93, 161-178.

REFERENCES

[37] Licandro, O. and Puch, L. (1997), 'Are there any Special Features in the Spanish Business Cycle?', Documentos de Trabajo FEDEA 97-06

[38] Marín, J. (1997), 'Efectos Estabilizadores de la Política Fiscal', Banco de España, Estudios Económicos No.58.

[39] Newey, W.K. and West, K.D. (1987), 'A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix', *Econometrica*, 55(3), 703-708.

[40] Ortega, E. (1994), 'Spanish Aggregate Fluctuations in the Last Two Decades and the Impact of Europe: Transmission through Trade?', mimeo, European University Institute.

[41] Pérez, P.J. (1997), 'Fuentes de Variabilidad Comunes. (¿ Existe un Ciclo Común Europeo?)', mimeo, Universidad de Valencia.

[42] Ravn, M.O. (1993), 'International Business Cycles: How Much Can Standard Theory Account for?', European University Institute Working Paper ECO 93-6.

[43] Royuela, V. and Pons, J. (1997), 'Un Análisis de Ciclo Económico Real Internacional para España y el G7', mimeo, Universitat de Barcelona.

[44] Wynne, M.A. and Koo, J. (1997), 'Business Cycles under Monetary Union: EU and US Business Cycles Compared', Federal Reserve Bank of Dallas Working Paper 97-07.

[45] Zimmermann, C. (1997), 'International trade over the Business Cycle: Stylized Facts and Remaining Puzzles', Center for Research on Economic Fluctuations and Employment Working Paper No.37.

6 APPENDIX

The equilibrium solution of the model are the sequences for the endogenous variables K_{1t}, K_{2t}, N_{1t}, N_{2t}, C_{1t}, C_{2t}, Y_{11t}, Y_{22t}, Y_{12t} and Y_{21t} that solve the following problem:

$$\text{Max} \quad E_0 \sum_{t=0}^{\infty} \beta^t U_{1t}(C_{1t}, 1 - N_{1t}) + E_0 \sum_{t=0}^{\infty} \beta^t U_{2t}(C_{2t}, 1 - N_{2t})$$

where U_{it} takes the form of equation (2) for the case of divisible labor and that of (3) for the indivisible labor case, subject to equations (4) to (11) for i=1, 2.

Since the functional forms used allow for balanced growth, all output components and the capital stock will be growing in the steady state at the common rate $\gamma_x - 1$, while hours worked and leisure will not. Then, we follow King, Plosser and Rebelo (1987) and transform the model into a stationary form by replacing all trending variables by their ratios over the permanent technology change X_{it}. The resulting "detrended" variables (in lowcase) will be constant in the steady state. The maximization problem now is

$$\text{Max} \quad E_0 \sum_{t=0}^{\infty} \beta^{*t} u_{1t}(c_{1t}, 1 - N_{1t}) + E_0 \sum_{t=0}^{\infty} \beta^{*t} u_{2t}(c_{2t}, 1 - N_{2t})$$

subject to

$$A_{1t} k_{1t}^{1-\alpha} N_{1t}^{\alpha} = y_{11t} + \frac{\Pi_2}{\Pi_1} y_{12t}, \quad A_{2t} k_{2t}^{1-\alpha} N_{2t}^{\alpha} = y_{22t} + \frac{\Pi_1}{\Pi_2} y_{21t}$$
$$v_{1t} = (\omega_1 y_{11t}^{1-\rho} + \omega_2 y_{21t}^{1-\rho})^{\frac{1}{1-\rho}}, \quad v_{2t} = (\omega_1 y_{22t}^{1-\rho} + \omega_2 y_{12t}^{1-\rho})^{\frac{1}{1-\rho}}$$
$$\gamma_x k_{1,t+1} = (1-\delta) k_{1t} + i_{1t}, \quad \gamma_x k_{2,t+1} = (1-\delta) k_{2t} + i_{2t}$$
$$g_{1t} + t_{1t} = \tau_{1t} v_{1t}, \quad g_{2t} + t_{2t} = \tau_{2t} v_{2t}$$
$$\Pi_1(c_{1t} + i_{1t} + g_{1t}) + \Pi_2(c_{2t} + i_{2t} + g_{2t}) \leq \Pi_1 v_{1t} + \Pi_2 v_{2t}$$

where $\beta^* = \beta \gamma_x^{\theta(1-\sigma)}$. The lagrangian of the maximization problem can be expressed in terms of the stationary transformations as

$$\mathcal{L}_t = u_{1t} + u_{2t} + \lambda_{1t} \Pi_1 [v_{1t} - c_{1t} - g_{1t} - (\gamma_x k_{1,t+1} - (1-\delta) k_{1t})]$$
$$+ \lambda_{2t} \Pi_2 [v_{2t} - c_{2t} - g_{2t} - (\gamma_x k_{2,t+1} - (1-\delta) k_{2t})]$$

and its first order conditions are

$$\frac{\partial \mathcal{L}_t}{\partial \lambda_{1t}} = \Pi_1[v_{1t} - c_{1t} - g_{1t} - \gamma_x k_{1,t+1} + (1-\delta)k_{1t}] = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial \lambda_{2t}} = \Pi_2[v_{2t} - c_{2t} - g_{2t} - \gamma_x k_{2,t+1} + (1-\delta)k_{2t}] = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial k_{1,t+1}} = \beta^* \lambda_{1,t+1}\Pi_1[D_1 v_{1,t+1}\frac{\partial y_{11,t+1}}{\partial k_{1,t+1}} + (1-\delta)] + \lambda_{1t}\Pi_1(-\gamma_x) = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial k_{2,t+1}} = \beta^* \lambda_{2,t+1}\Pi_2[D_1 v_{2,t+1}\frac{\partial y_{22,t+1}}{\partial k_{2,t+1}} + (1-\delta)] + \lambda_{2t}\Pi_2(-\gamma_x) = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial N_{1t}} = -D_2 u_{1t} + \lambda_{1t}\Pi_1 D_1 v_{1t}(y_{11t}, y_{21t})\frac{\partial y_{11t}}{\partial N_{1t}} = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial N_{2t}} = -D_2 u_{2t} + \lambda_{2t}\Pi_2 D_1 v_{2t}(y_{22t}, y_{12t})\frac{\partial y_{22t}}{\partial N_{2t}} = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial c_{1t}} = D_1 u_{1t}(c_{1t}, 1 - N_{1t}) - \lambda_{1t}\Pi_1 = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial c_{2t}} = D_1 u_{2t}(c_{2t}, 1 - N_{2t}) - \lambda_{2t}\Pi_2 = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial y_{11t}} = \lambda_{1t}\Pi_1 D_1 v_{1t} + \lambda_{2t}\Pi_2 D_2 v_{2t}\frac{\partial y_{12t}}{\partial y_{11t}} = 0$$
$$\frac{\partial \mathcal{L}_t}{\partial y_{22t}} = \lambda_{1t}\Pi_1 D_2 v_{1t}\frac{\partial y_{21t}}{\partial y_{22t}} + \lambda_{2t}\Pi_2 D_1 v_{2t} = 0$$

where D_n is the partial derivative of a function with respect to its nth argument. They have to be fulfilled by the equilibrium solution of the model together with the remaining constraints (which are definitions) and the transversality conditions :

$$v_{1t} = (\omega_1 y_{11t}^{1-\rho} + \omega_2 y_{21t}^{1-\rho})^{\frac{1}{1-\rho}}, \quad v_{2t} = (\omega_1 y_{22t}^{1-\rho} + \omega_2 y_{12t}^{1-\rho})^{\frac{1}{1-\rho}}$$
$$y_{11t} + \frac{\Pi_2}{\Pi_1} y_{12t} = A_{1t}k_{1t}^{1-\alpha}N_{1t}^{\alpha}, \quad y_{22t} + \frac{\Pi_1}{\Pi_2} y_{21t} = A_{2t}k_{2t}^{1-\alpha}N_{2t}^{\alpha}$$
$$\lim_{t\to\infty} \beta^{*t}\lambda_{1t}k_{1,t+1} = 0, \quad \lim_{t\to\infty} \beta^{*t}\lambda_{2t}k_{2,t+1} = 0$$

The equilibrium solution of the model is characterized by those F.O.C. together with the following definitions of the stationary transformations of some flow variables we are interested in (y_{1t}, y_{2t}, i_{1t}, i_{2t}, x_{1t}, x_{2t}, m_{1t}, m_{2t}, nx_{1t}, nx_{2t}, ap_{1t} and ap_{2t}) in terms of the solution of the above equilibrium conditions. These definitions are :

$$y_{1t} = A_{1t}k_{1t}^{1-\alpha}N_{1t}^{\alpha}, \quad y_{2t} = A_{2t}k_{2t}^{1-\alpha}N_{2t}^{\alpha}$$

$$i_{1t} = (\omega_1 y_{11t}^{1-\rho} + \omega_2 y_{21t}^{1-\rho})^{\frac{1}{1-\rho}} - c_{1t} - g_{1t}$$
$$i_{2t} = (\omega_1 y_{22t}^{1-\rho} + \omega_2 y_{12t}^{1-\rho})^{\frac{1}{1-\rho}} - c_{2t} - g_{2t}$$
$$x_{1t} = y_{12t}, \quad x_{2t} = y_{21t}$$
$$m_{1t} = \frac{\omega_2 y_{21t}^{-\rho}}{\omega_1 y_{11t}^{-\rho}} y_{21t}, \quad m_{2t} = \frac{\omega_2 y_{12t}^{-\rho}}{\omega_1 y_{22t}^{-\rho}} y_{12t}$$
$$nx_{1t} = x_{1t} - m_{1t}, \quad nx_{2t} = x_{2t} - m_{2t}$$
$$ap_{1t} = \frac{y_{1t}}{N_{1t}}, \quad ap_{2t} = \frac{y_{2t}}{N_{2t}}$$

The complexity of the optimizing conditions describing the equilibrium solution (highly nonlinear difference equation system) causes that an analytical solution cannot be obtained. Follow King, Plosser and Rebelo (1987), we log-linearize the set of first order conditions and definitions of the model, in their stationary transformation, around the steady state. This yields the approximate solution of the model which consists of a linear dynamic system expressed in percentage deviations from the steady state e.g. $\widehat{c_{1t}} = \frac{c_{1t}-\bar{c}_1}{\bar{c}_1} \simeq logc_{1t} - log\bar{c}_1$, where $\bar{c}_1$ represents the steady state value of c_{1t}[24].

The steady state of the model is the vector of values $[\overline{k_1}\ \overline{k_2}\ \overline{\lambda_1}\ \overline{\lambda_2}\ \overline{N_1}\ \overline{N_2}\ \overline{c_1}\ \overline{c_2}\ \overline{y_{11}}\ \overline{y_{22}}\ \overline{y_{21}}\ \overline{y_{12}}\ \overline{y_1}\ \overline{y_2}\ \overline{i_1}\ \overline{i_2}\ \overline{x_1}\ \overline{x_2}\ \overline{m_1}\ \overline{m_2}\ \overline{nx_1}\ \overline{nx_2}\ \overline{ap_1}\ \overline{ap_2}\ \overline{A_1}\ \overline{A_2}\ \overline{g_1}\ \overline{g_2}]$ that fulfills the previous F.O.C. and definitions when replacing each variable η_{it} by its steady state counterpart $\overline{\eta_i}$, i.e. suppressing the time subscripts. In order to perform a quantitative investigation of the properties of the equilibrium, we need to give values to the steady state vector and the deep parameters of the model. Since they are all linked through the FOCs and definitions evaluated at the steady state only a reduced number of coefficients are "free". In order to derive the expressions linking

[24]Note that the business cycle component obtained from the observed series with a filter such as the Baxter and King (1995) band-pass filter or the HP filter intends to extract precisely shorter run movements in a series than its secular trend, i.e. its short-run deviations from a stable long-run evolution. Under the assumption of balanced growth, we have converted all trending series into stationary series which have fixed values in the steady state. Therefore, deviations from those values are a proxy of the business cycle components of the series under the model assumptions. However, given the divergences between alternative BC filtering methods we will compare the model solution to the business cycle components of the observed series only after reconstructing the trending model series from the equilibrium solution (in terms of deviations from the steady state) and then applying to those trending series the same filter as to the observed data.

the rest of the coefficients, we have made the following standard assumptions (see Ravn (1993) and BKK) :

(i) Balanced trade in the steady state: exports of one of the two countries in the world economy equal the imports in the other country, i.e. $\overline{m_i} = \overline{x_j}$. Given that $m_{it} \equiv TOT_{it}y_{jit}$ and that $x_{jt} \equiv y_{jit}$, the balanced trade assumption in the steady state amounts to imposing $\overline{TOT_i}$=1, i = 1,2.

(ii) Symmetric countries: we define the same economic environment for the two countries led by the similarities found in Section 2 between the internal propagation mechanism of shocks and fluctuations in Spain and the EU4 aggregate. This amounts to defining the same functional forms to both countries and the same values for the deep parameters of the model, differing only in the parameters defining the shock processes. We also assume that both countries have equal size. Ravn (1993) found that the two-country model with asymmetric country sizes does not make theory much nearer to the data in a wide range of different cases: although elements of national business cycles change with asymmetric Π_i, the international comovements are left almost unaltered with respect to the symmetric case.

The symmetry assumption in countries with equal size means that in the steady state both countries will have equal per capita values. In light of the symmetry assumptions, in seems reasonable to make the normalization that in the steady state the output of final goods given by the Armington aggregator, $\overline{v_i}$, equals the output of good $\overline{y_i}$ (see Ravn (1993)).

(iii) $\overline{\lambda_1}$ and $\overline{\lambda_2}$ have been normalized to 1, and we have assumed that $\overline{A_1} = \overline{A_2} = 1$.

Taking these assumptions into account, the relations imposed by the FOCs and definitions evaluated at the steady state are, for i=1,2 :

• firstly, some ratios and coefficients

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial k_{i,t+1}}, \quad \frac{\overline{k_i}}{\overline{y_i}} = \frac{\beta^*(1-\alpha)(1-\overline{\tau_i})}{\gamma_x - \beta^*(1-\delta)}$$

$$\text{From } \gamma_x k_{i,t+1} = (1-\delta)k_{it} + i_{it}, \quad \frac{\overline{i_i}}{\overline{k_i}} = \gamma_x - (1-\delta)$$

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial N_{it}} \text{ and } \frac{\partial \mathcal{L}_t}{\partial c_{it}} : \text{ with divisible labor } (U_{it} \text{ as in (2)}), \ \theta = \frac{\frac{sc}{(1-\overline{\tau_i})\alpha}\frac{\overline{N_i}}{1-\overline{N_i}}}{1 + \frac{sc}{(1-\overline{\tau_i})\alpha}\frac{\overline{N_i}}{1-\overline{N_i}}}$$

with indivisible labor (U_{it} as in equation (3)) , $\theta - \dfrac{\frac{sc}{(1-\overline{\tau_i})\alpha}(\frac{-ln(1-N_0)}{N_0})\overline{N_i}}{1+\frac{sc}{(1-\overline{\tau_i})\alpha}(\frac{-ln(1-N_0)}{N_0})\overline{N_i}}$

The elasticities of u_i with respect to c or leisure (L) evaluated at the st.st., also depend on the utility function. With divisible labor: $\xi_{cc} = \theta(1-\sigma) - 1$,

$$\xi_{cL} = (1-\theta)(1-\sigma) \ , \ \xi_{LL} = (1-\theta)(1-\sigma) - 1 \ , \ \xi_{Lc} = \theta(1-\sigma)$$

with indivisible labor $\xi_{cc} = -1$, $\xi_{cL} = 0$, $\xi_{LL} = 0$, $\xi_{Lc} = 0$

From symmetry, balanced trade in the st.st. and the normalisation $\overline{v_i} = \overline{y_i}$,

$$\omega_1 = (\frac{y_{ii}}{y_i})^\rho = (1-MS)^\rho \ , \ \omega_2 = (\frac{y_{ji}}{y_i})^\rho = MS^\rho$$

- secondly, the steady state values of some variables

$$\text{From } y_{it} = A_{it}k_{it}^{1-\alpha}N_{it}^{\alpha} \ , \quad \overline{y_i} = \overline{A_i}^{\frac{1}{\alpha}}(\frac{\overline{k_i}}{\overline{y_i}})^{\frac{(1-\alpha)}{\alpha}}\overline{N_i}$$

$$\overline{i_i} = si \ \overline{y_i} = \frac{\overline{i_i}}{\overline{k_i}}\frac{\overline{k_i}}{\overline{y_i}}\overline{y_i}$$

$$\overline{k_i} = \frac{\overline{k_i}}{\overline{y_i}}\overline{y_i}$$

$$\overline{g_i} = sg \ \overline{y_i}$$

$$\text{From } i_{it} = (\omega_1 y_{iit}^{1-\rho} + \omega_2 y_{jit}^{1-\rho})^{\frac{1}{1-\rho}} - c_{it} - g_{it} \ , \quad sc = 1 - si - sg$$

$$\overline{c_i} = sc \ \overline{y_i}$$

$$\overline{m_i} \equiv \overline{TOT_i}\overline{y_{ji}} \equiv 1 \ (MS \ \overline{y_i})$$

$$\text{Under symmetry, } \overline{x_i} = \overline{x_j} \ , \quad \overline{x_i} \equiv \overline{y_{ij}} = \overline{y_{ji}}$$

$$\text{Hence, } \overline{nx_i} = 0$$

$$\text{Also under symmetry, } \overline{y_{ii}} \equiv \overline{y_i} - \frac{\Pi_j}{\Pi_i}\overline{y_{ij}} = \overline{y_i} - \overline{y_{ij}} = \overline{y_i} - \overline{y_{ji}} = (1-MS)\overline{y_i}$$

$$\overline{ap_i} \equiv \frac{\overline{y_i}}{\overline{N_i}}$$

The "free" coefficients are [α, sg, $\overline{\tau_1}$, $\overline{\tau_2}$, σ, β, $\overline{N_1}$, $\overline{N_2}$, N_0, δ, γ_x, ρ_{A1}, ρ_{A2}, ν_{21}, ν_{12}, σ_{A1}, σ_{A2}, ψ, ρ_{G1}, ρ_{G2}, σ_{G1}, σ_{G2}, Π_1, Π_2, MS, ρ]. Their values, either fixed or random, are displayed in Tables 6 and 7 and discussed in Section 3.1 in the text.

The approximate solution of the model is described by the log-linearized equations around the steady state[25]:

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial \lambda_{it}} : \ -\frac{\overline{k_i}}{\overline{y_i}}\gamma_x \widehat{k_{i,t+1}} + (1-\delta)\frac{\overline{k_i}}{\overline{y_i}}\widehat{k_{it}} = sc\ \widehat{c_{it}} - (1-MS)\widehat{y_{iit}} - MS\widehat{y_{jit}} + sg\ \widehat{g_{it}}$$

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial k_{i,t+1}} : \ \alpha \widehat{k_{i,t+1}} - \frac{\gamma_x}{\gamma_x - \beta^*(1-\delta)}\widehat{\lambda_{i,t+1}} + \frac{\gamma_x}{\gamma_x - \beta^*(1-\delta)}\widehat{\lambda_{it}}$$

$$= \alpha \widehat{N_{i,t+1}} - \rho MS\widehat{y_{ii,t+1}} + \rho MS\widehat{y_{ji,t+1}} + \widehat{A_{i,t+1}}$$

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial N_{it}} : \ \xi_{Lc}\widehat{c_{it}} - \xi_{LL}\frac{\overline{N_i}}{1-\overline{N_i}}\widehat{N_{it}}$$

$$= \widehat{\lambda_{it}} + \rho MS\widehat{y_{iit}} - \rho MS\widehat{y_{jit}} + \widehat{A_{it}} + (1-\alpha)\widehat{k_{it}} - (1-\alpha)\widehat{N_{it}}$$

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial c_{it}} : \ \xi_{cc}\widehat{c_{it}} - \xi_{cL}\widehat{N_{it}} = \widehat{\lambda_{it}}$$

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial y_{iit}} : \ -\rho MS\widehat{y_{iit}} + \rho MS\widehat{y_{jit}} + \rho(1-MS)\widehat{y_{ijt}} - \rho(1-MS)\widehat{y_{jjt}} = -\widehat{\lambda_{it}} + \widehat{\lambda_{jt}}$$

$$\text{From } \frac{\partial \mathcal{L}_t}{\partial y_{jit}} : \ \rho(1-MS)\widehat{y_{iit}} - \rho(1-MS)\widehat{y_{jit}} - \rho MS\widehat{y_{ijt}} + \rho MS\widehat{y_{jjt}} = -\widehat{\lambda_{it}} + \widehat{\lambda_{jt}}$$

$$\text{From } y_{iit} + \frac{\Pi_j}{\Pi_i}y_{ijt} = A_{it}k_{it}^{1-\alpha}N_{it}^{\alpha} \text{ and under the symmetry assumption :}$$

$$\alpha\widehat{N_{it}} - (1-MS)\widehat{y_{iit}} - MS\widehat{y_{ijt}} = -(1-\alpha)\widehat{k_{it}} - \widehat{A_{it}}$$

$$\text{From the definition of } y_{it} : \ \widehat{y_{it}} = \widehat{A_{it}} + (1-\alpha)\widehat{k_{it}} + \alpha\widehat{N_{it}}$$

$$\text{From the definition of } i_{it} : \ \widehat{y_{it}} = \frac{1-MS}{si}\widehat{y_{iit}} + \frac{MS}{si}\widehat{y_{jit}} - \frac{sc}{si}\widehat{c_{it}} - \frac{sg}{si}\widehat{g_{it}}$$

$$\text{From the definition of } x_{it} : \ \widehat{x_{it}} = \widehat{y_{ijt}}$$

$$\text{From the definition of } m_{it} : \ \widehat{m_{it}} = \rho\widehat{y_{iit}} + (1-\rho)\widehat{y_{jit}}$$

$\widehat{nx_{it}}$ is defined as the total derivative of $(\frac{nx_{it}}{y_{it}})$ evaluated at the st.st. since $\overline{nx_i} = 0$.

$$\text{Then, from the definition of } nx_{it} : \ \widehat{nx_{it}} = -\rho MS\widehat{y_{iit}} - (1-\rho)MS\widehat{y_{jit}} + MS\widehat{y_{ijt}}$$

$$\text{From the definition of } ap_{it} : \ \widehat{ap_{it}} = \widehat{A_{it}} + (1-\alpha)\widehat{k_{it}} + (\alpha-1)\widehat{N_{it}}$$

That system of equations is a linear control system with two state variables $(\widehat{k_{1t}}, \widehat{k_{2t}})$, two costates $(\widehat{\lambda_{1t}}, \widehat{\lambda_{2t}})$, eight control variables $\widehat{controls_t} = [\widehat{N_{1t}}\ \widehat{N_{2t}}\ \widehat{c_{1t}}\ \widehat{c_{2t}}\ \widehat{y_{11t}}\ \widehat{y_{22t}}\ \widehat{y_{12t}}\ \widehat{y_{21t}}]'$, twelve other flow variables $\widehat{flows_t} = [\widehat{y_{1t}}\ \widehat{y_{2t}}\ \widehat{i_{1t}}\ \widehat{i_{2t}}\ \widehat{x_{1t}}\ \widehat{x_{2t}}\ \widehat{m_{1t}}\ \widehat{m_{2t}}\ \widehat{nx_{1t}}\ \widehat{nx_{2t}}\ \widehat{ap_{1t}}\ \widehat{ap_{2t}}]'$ and four exogenous variables $\widehat{exog_t} = [\widehat{A_{1t}}\ \widehat{A_{2t}}\ \widehat{g_{1t}}\ \widehat{g_{2t}}]'$ of which

[25] The steps followed to obtain the final expressions reported here have been omitted due to space limitations but are available from the author.

we know their DGP from equations (5) and (10) in the text :

$$\begin{bmatrix} \widehat{A_{1t}} \\ \widehat{A_{2t}} \end{bmatrix} = \begin{bmatrix} \rho_{A1} & \nu_{21} \\ \nu_{12} & \rho_{A2} \end{bmatrix} \begin{bmatrix} \widehat{A_{1t-1}} \\ \widehat{A_{2t-1}} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}, \quad \varepsilon_t \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{A1} & cov_A \\ cov_A & \sigma^2_{A2} \end{bmatrix} \right)$$

$$\begin{bmatrix} \widehat{g_{1t}} \\ \widehat{g_{2t}} \end{bmatrix} = \begin{bmatrix} \rho_{G1} & \nu_{G,21} \\ \nu_{G,12} & \rho_{G2} \end{bmatrix} \begin{bmatrix} \widehat{g_{1t-1}} \\ \widehat{g_{2t-1}} \end{bmatrix} + \begin{bmatrix} \varepsilon_{G1t} \\ \varepsilon_{G2t} \end{bmatrix}, \quad \varepsilon_{Gt} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma^2_{G1} & cov_G \\ cov_G & \sigma^2_{G2} \end{bmatrix} \right)$$

The system can be expressed as

$$\left[\widehat{k_{1,t+1}}\ \widehat{k_{2,t+1}}\ \widehat{\lambda_{1,t+1}}\ \widehat{\lambda_{2,t+1}}\right]' = W\left[\widehat{k_{1t}}\ \widehat{k_{2t}}\ \widehat{\lambda_{1t}}\ \widehat{\lambda_{2t}}\right]' + R\ \widehat{exog_{t+1}} + Q\ \widehat{exog_t}$$

$$\widehat{controls_t} = Z\left[\widehat{k_{1t}}\ \widehat{k_{2t}}\ \widehat{\lambda_{1t}}\ \widehat{\lambda_{2t}}\right]' + M\ \widehat{exog_t}$$

$$\widehat{flows_t} = C\ \widehat{controls_t} + E\left[\widehat{k_{1t}}\ \widehat{k_{2t}}\ \widehat{exog_t}\right]'$$

which can be solved analytically (see King, Plosser and Rebelo (1987)).

Once the "free" coefficients of the model are given values, this approximate solution can be used for quantitative investigation of the properties of the equilibrium as it is done in Section 3.2 in the text, using e.g. Monte Carlo simulation techniques (drawing realizations from the distributions of the exogenous stochastic processes, we can simulate time series for the equilibrium solution for any other variable).æ

CHART1: % Spanish trade

1973:1-1997:1

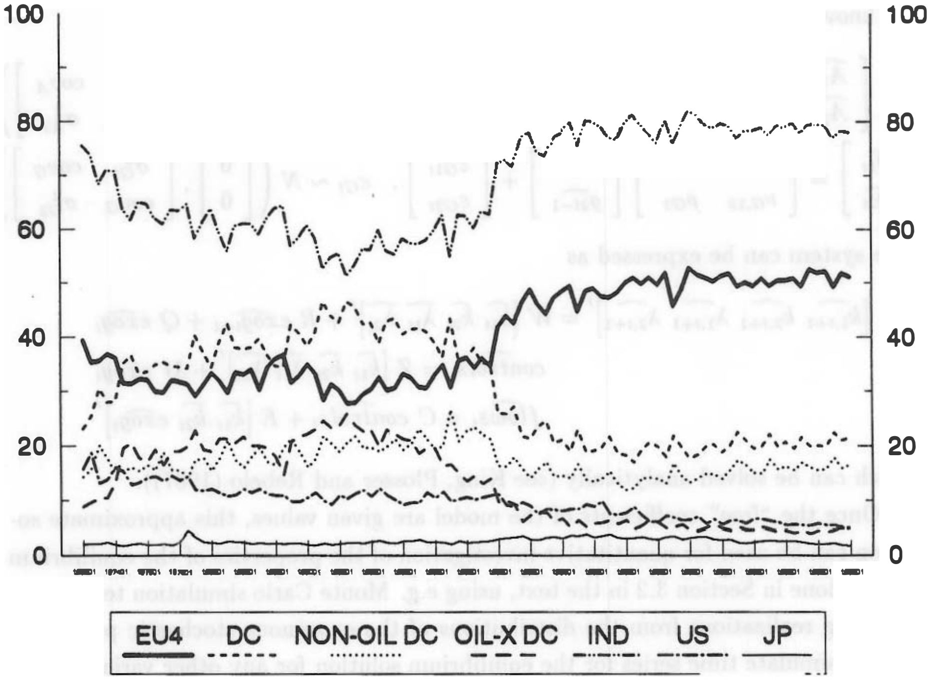


CHART2: % Spanish trade

1973:1-1997:1

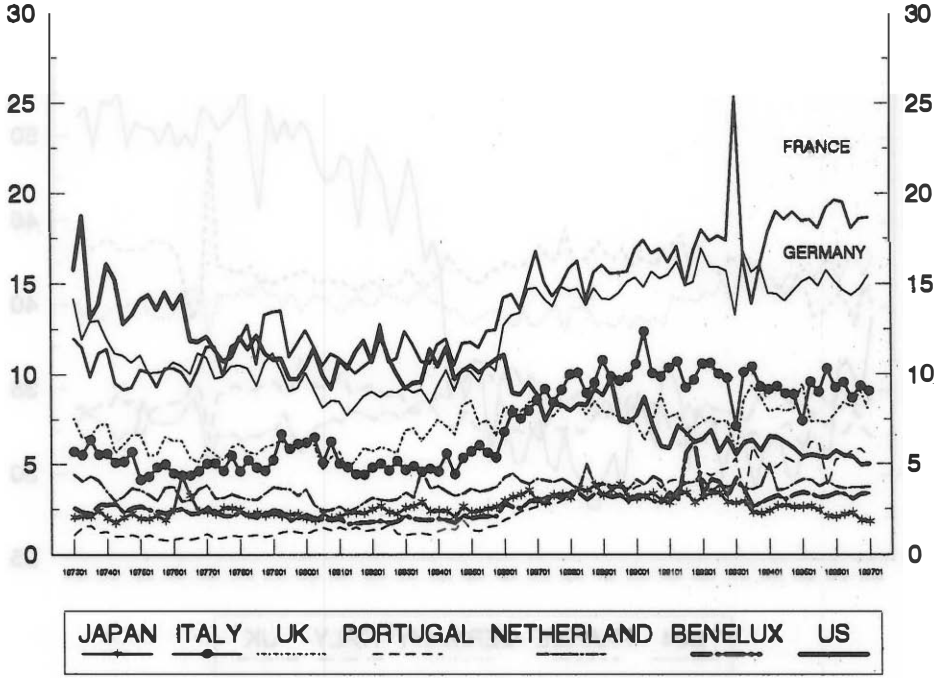
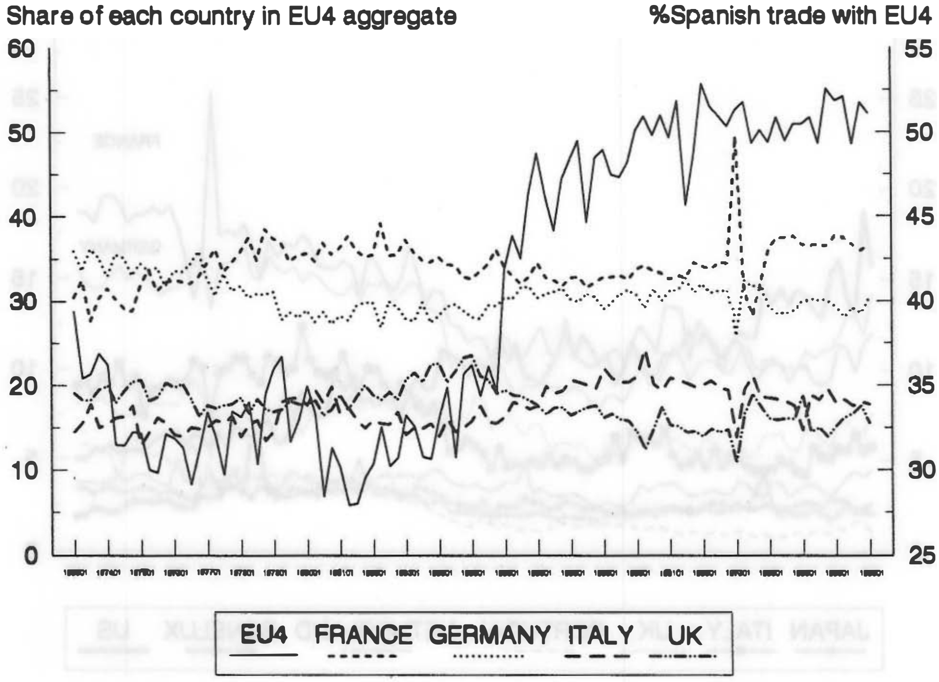


CHART3: % SHARES in EU4

1973:1-1997:1



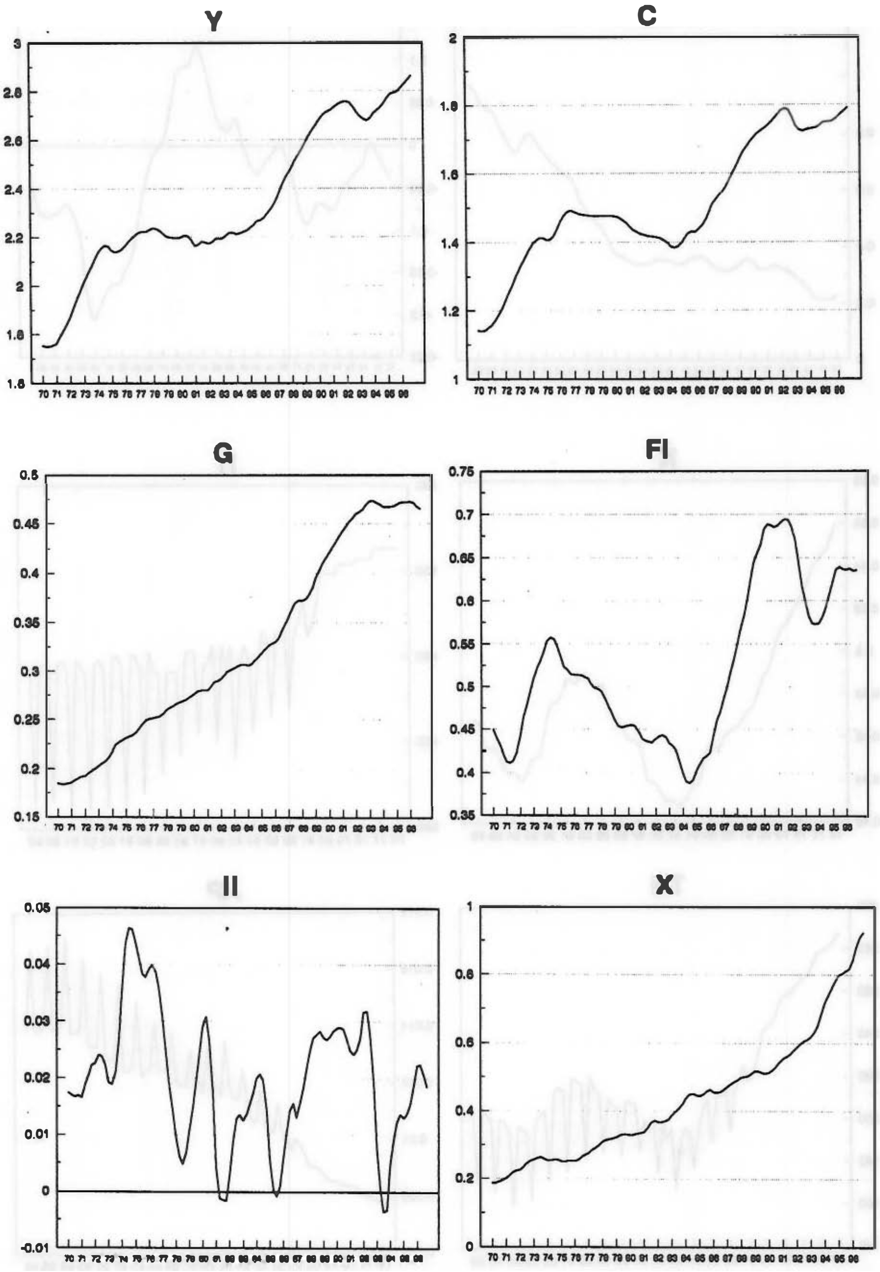


Figure 1a. Spanish original series.

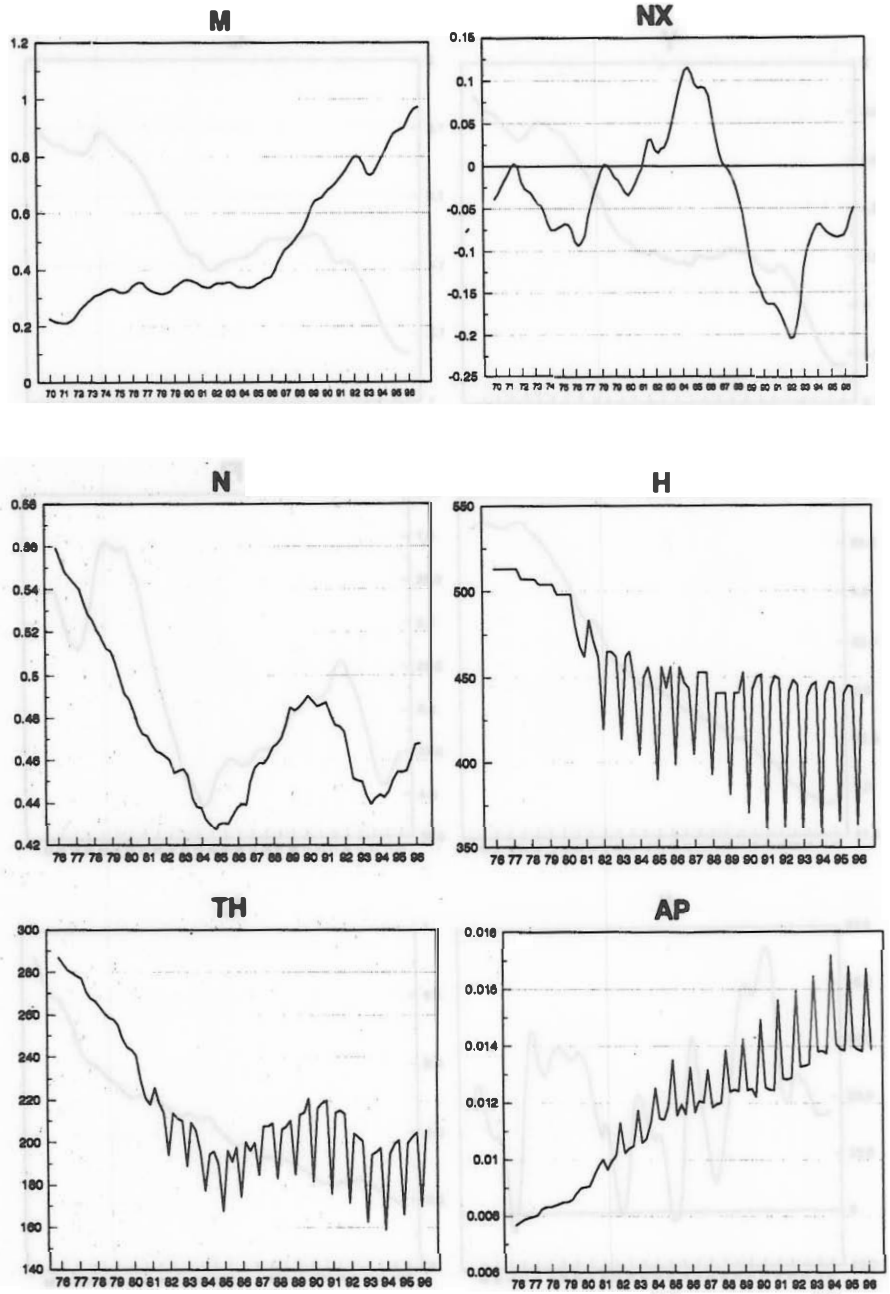


Figure 1b. Spanish original series.

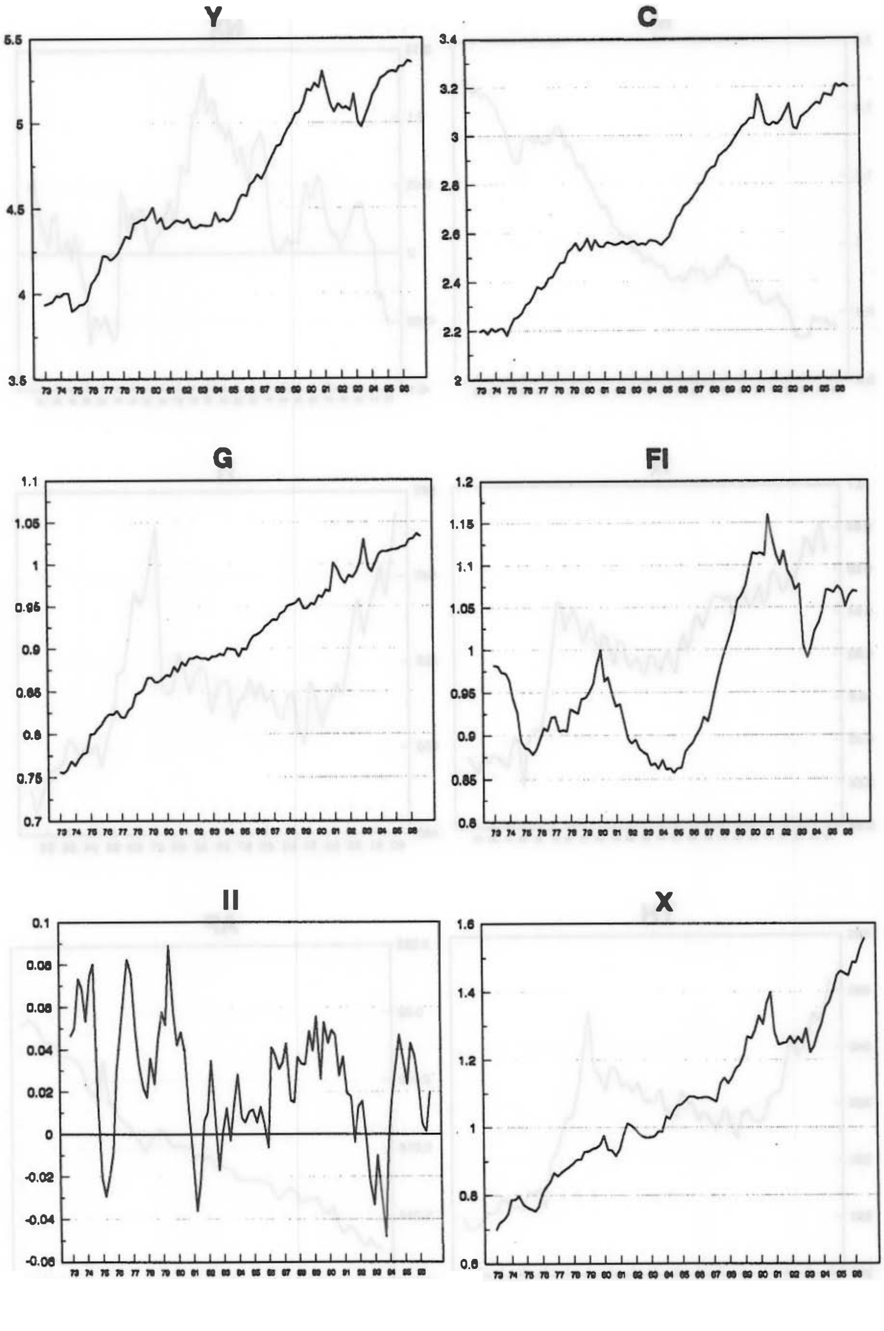


Figure 2a. EU4 aggregate series.

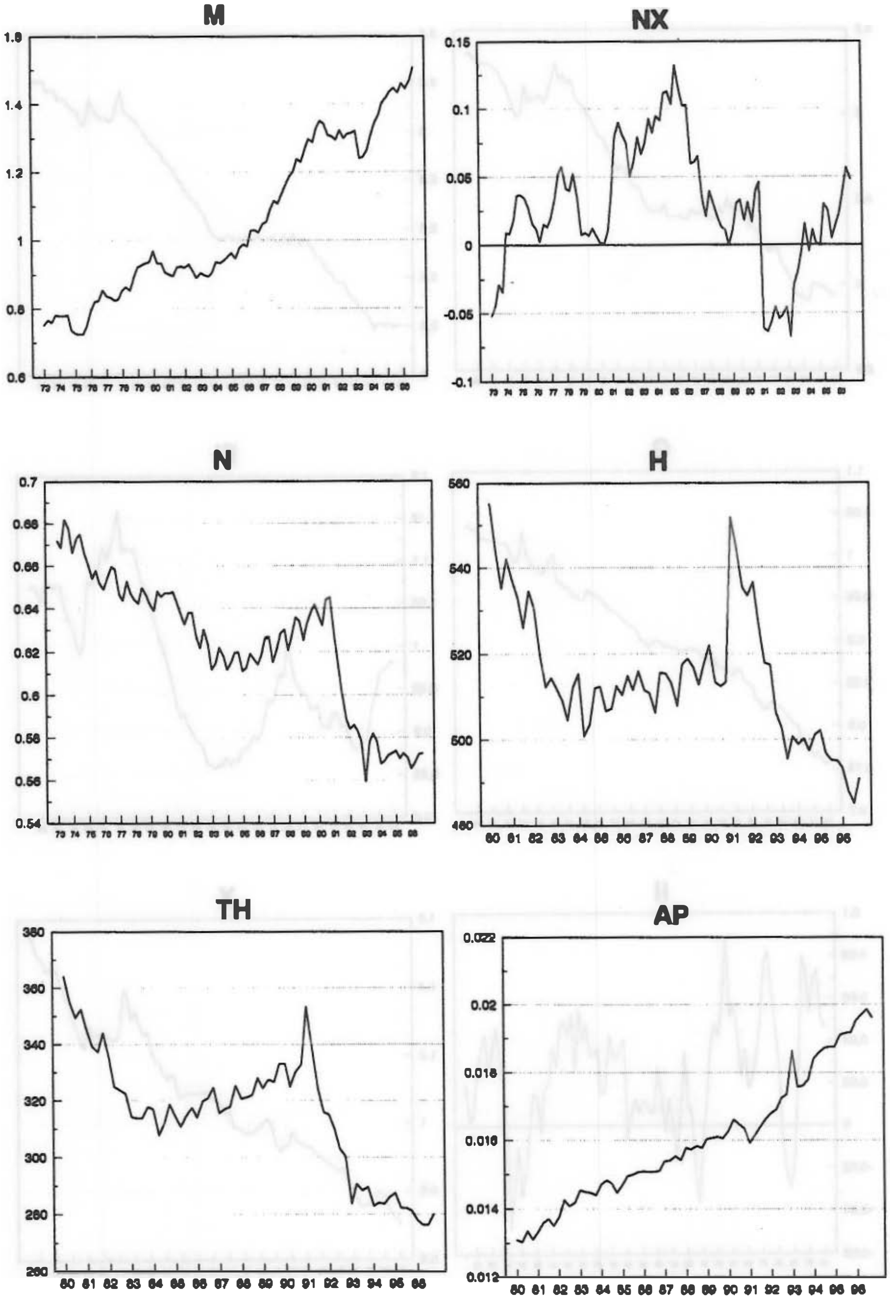


Figure 2b. EU4 aggregate series.

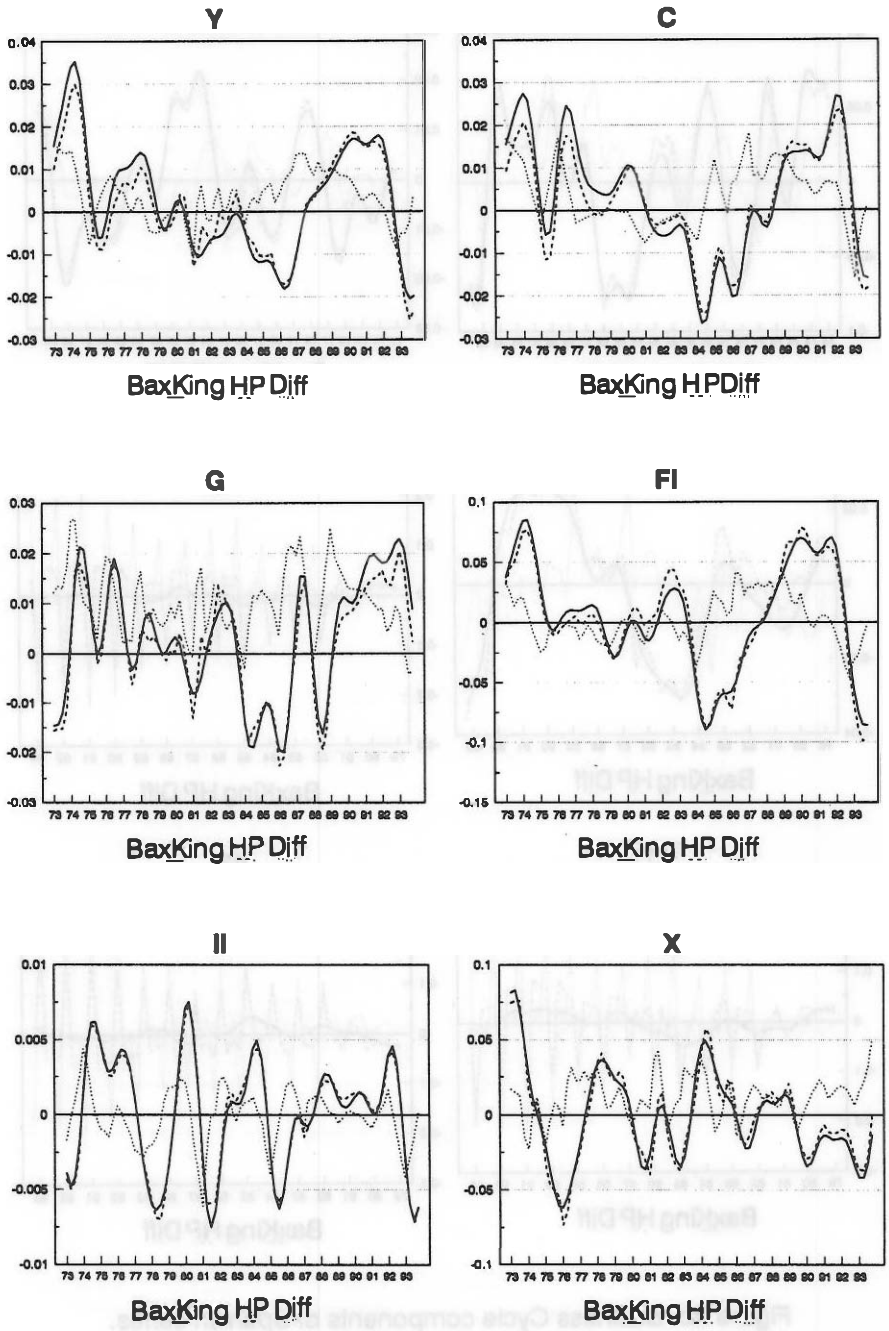


Figure 3a. Business Cycle components of Spanish series.

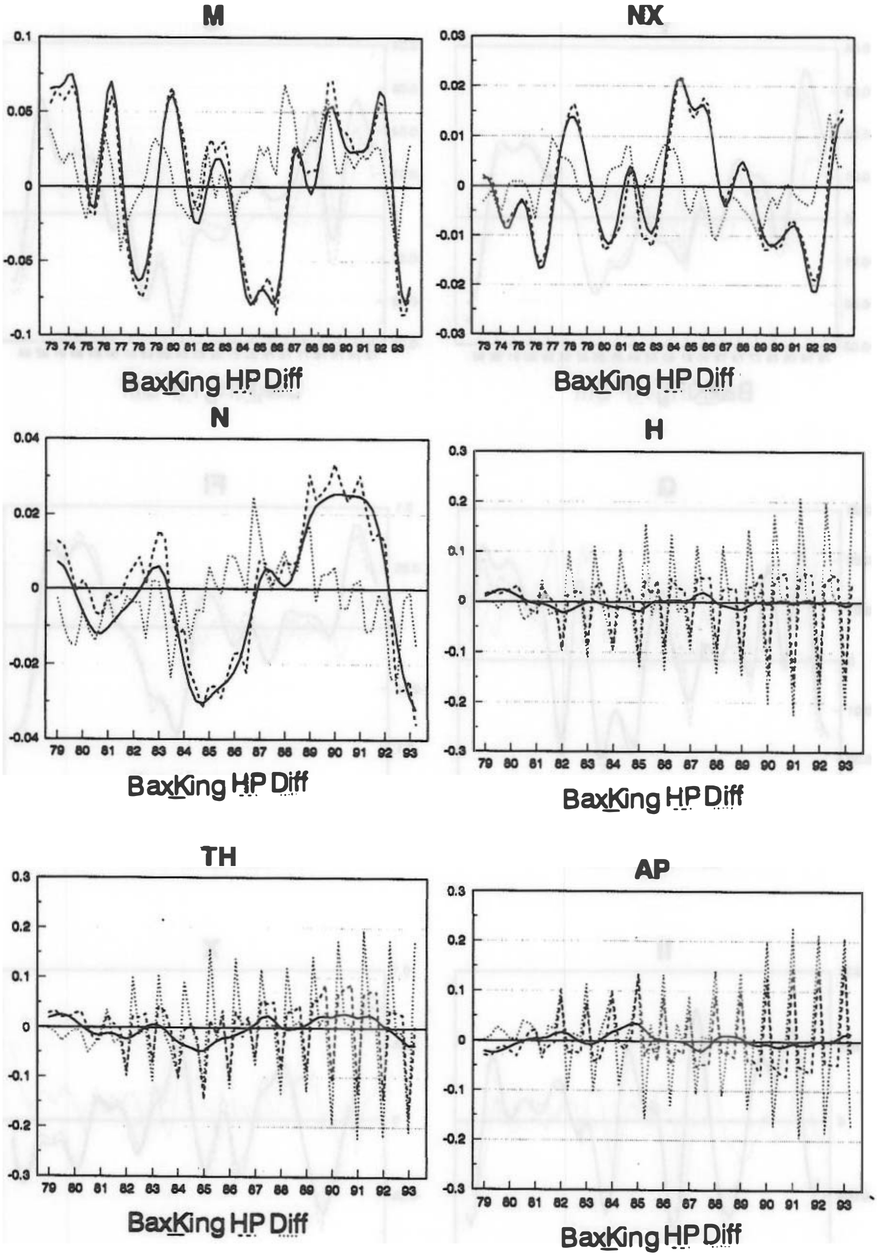


Figure 3b. Business Cycle components of Spanish series.

Table 1: **Spanish BC facts: Band-pass filtered series**

	Volatility and persistence				
	sd	sd/sd(y)	ρ_{-1}	ρ_{-2}	ρ_{-4}
y	1.30	1.00	0.96*	0.85*	0.69*
c	1.37	1.05	0.95*	0.81*	0.63*
g	1.20	0.92	0.91*	0.69*	0.42*
fi	4.53	3.48	0.96*	0.86*	0.71*
ii	0.38	0.29	0.89*	0.61*	0.22
i	5.15	3.96	0.95*	0.83*	0.64*
x	3.04	2.33	0.94*	0.77*	0.52*
m	4.66	3.58	0.93*	0.75*	0.50*
nx	1.04	0.80	0.94*	0.76*	0.53*
n	1.72	1.32	0.97*	0.87*	0.73*
h	1.01	0.77	0.88*	0.63*	0.38*
th	2.15	1.65	0.94*	0.80*	0.61*
ap	1.34	1.03	0.91*	0.67*	0.41*

	Correlations of X_{t+k} with $output_t$										
	k=-5	k=-4	k=-3	k=-2	k=-1	k=0	k=1	k=2	k=3	k=4	k=5
y	0.37	0.52*	0.69*	0.85*	0.96*	1.00*	0.96*	0.85*	0.69*	0.52*	0.37
c	0.37	0.48*	0.61*	0.73*	0.81*	0.83*	0.77*	0.67*	0.55*	0.46*	0.41
g	0.03	0.04	0.09	0.18	0.27	0.34	0.41	0.43*	0.44*	0.44*	0.47*
fi	0.45*	0.57*	0.70*	0.80*	0.87*	0.88*	0.82*	0.71*	0.56*	0.41	0.28
ii	−0.09	−0.08	−0.02	0.08	0.20	0.29*	0.33*	0.33*	0.28*	0.22	0.17
i	0.38	0.49	0.62*	0.74*	0.82*	0.85*	0.81*	0.70*	0.56*	0.41	0.28
x	0.02	0.11	0.19	0.24	0.26	0.23	0.16	0.06	−0.06	−0.18	−0.30
m	0.40	0.49*	0.59*	0.66*	0.70*	0.67*	0.58*	0.45*	0.32	0.23	0.20
nx	−0.23	−0.27	−0.33	−0.40	−0.45*	−0.47*	−0.45*	−0.39*	−0.34	−0.31	−0.32
n	0.45	0.59*	0.74*	0.86*	0.93*	0.95*	0.92*	0.84*	0.71*	0.56*	0.42
h	0.05	0.04	0.05	0.09	0.15	0.17	0.17	0.15	0.10	0.04	−0.03
th	0.37	0.48	0.61*	0.72*	0.81*	0.84*	0.82*	0.75*	0.63*	0.49*	0.35
ap	−0.23	−0.29	−0.36	−0.42*	−0.48*	−0.51*	−0.51*	−0.47*	−0.40*	−0.29	−0.17æ

Table 2: EU4 BC facts: Band-pass filtered series

	Volatility and persistence				
	sd	sd/sd(y)	ρ_{-1}	ρ_{-2}	ρ_{-4}
y	1.24	1.00	0.94*	0.78*	0.58*
c	1.05	0.85	0.93*	0.76*	0.56*
g	0.64	0.52	0.84*	0.42*	−0.04
fi	2.54	2.04	0.96*	0.84*	0.69*
ii	0.40	0.32	0.86*	0.54*	0.16
i	3.72	3.00	0.92*	0.74*	0.50*
x	2.86	2.30	0.91*	0.69*	0.41*
m	2.57	2.07	0.92*	0.72*	0.46*
nx	0.49	0.39	0.91*	0.67*	0.36*
n	1.27	1.03	0.94*	0.78*	0.57*
h	1.48	1.19	0.92*	0.69*	0.39*
th	2.30	1.86	0.95*	0.80*	0.59*
ap	1.07	0.87	0.89*	0.59*	0.22

	Correlations of X_{t+k} with $output_t$										
	k=-5	k=-4	k=-3	k=-2	k=-1	k=0	k=1	k=2	k=3	k=4	k=5
y	0.32	0.42	0.58*	0.78*	0.94*	1.00*	0.94*	0.78*	0.59*	0.42	0.32
c	0.30	0.35	0.45*	0.61*	0.78*	0.89*	0.89*	0.79*	0.63*	0.48*	0.38
g	−0.05	−0.14	−0.15	−0.06	0.09	−0.21	0.26	0.21	0.12	0.08	0.12
fi	0.10	0.19	0.33	0.51*	0.69*	0.81*	0.85*	0.83*	0.78*	0.74*	0.69*
ii	0.14	0.16	0.25*	0.40*	0.54*	0.61*	0.55*	0.43*	0.28	0.13	−0.00
i	0.14	0.22	0.36	0.56*	0.74*	0.85*	0.85*	0.77*	0.67*	0.57*	0.48*
x	0.25	0.39*	0.56*	0.72*	0.79*	0.75*	0.59*	0.39*	0.21	0.11	0.06
m	0.14	0.23	0.41	0.63*	0.82*	0.90*	0.85*	0.74*	0.60*	0.50*	0.42
nx	0.17	0.26	0.31	0.27	0.14	−0.04	−0.21	−0.35*	−0.43*	−0.44*	−0.43*
n	0.34	0.44*	0.56*	0.68*	0.77*	0.78*	0.73*	0.61*	0.46*	0.29	0.14
h	−0.30	−0.28	−0.24	−0.12	0.07	0.29	0.46*	0.61*	0.71*	0.76*	0.75*
th	0.08	0.18	0.31	0.48	0.66*	0.80*	0.90*	0.92*	0.86*	0.74*	0.58*
ap	0.21	0.16	0.12	0.07	−0.01	0.15	−0.35	−0.58*	−0.73*	−0.74*	−0.62 * æ

Table 3: **Individual countries BC facts: Band-pass filtered series**

	Spain	France	Germany	Italy	UK
	Volatility: sd(y) and sd/sd(y)				
y	1.30	1.09	2.27	1.54	1.79
c	1.05	0.80	0.83	0.86	1.07
g	0.92	0.77	0.57	0.30	0.57
fi	3.48	2.80	1.62	2.37	2.39
ii	0.29	0.62	0.23	0.51	0.38
i	3.96	4.84	2.37	3.81	3.79
x	2.33	2.43	2.41	2.18	1.35
m	3.58	3.55	1.66	2.87	2.37
nx	0.80	0.67	0.44	0.49	0.42
n	1.32	0.58	1.23	0.57	0.80
h	0.77	0.24	1.62	1.42	0.00
th	1.65	0.71	1.83	1.59	0.80
ap	1.03	0.48	1.27	1.06	0.74
	Persistence of output fluctuations				
$\rho_{-1}(y)$	0.96*	0.93*	0.92*	0.89*	0.95*
$\rho_{-4}(y)$	0.69*	0.49*	0.43*	0.24*	0.65*
	Maximum correlations of X_{t+k} with output$_t$				
c	0.83* ($k=0$)	0.79* ($k=-1$)	0.87* ($k=0$)	0.85* ($k=0$)	0.89* ($k=0$)
g	0.47* ($k=5$)	−0.32 ($k=3$)	0.56* ($k=1$)	0.35* ($k=-2$)	−0.46* ($k=-5,-4$)
fi	0.88* ($k=0$)	0.88* ($k=0$)	0.78* ($k=1$)	0.81* ($k=1$)	0.79* ($k=0,1$)
ii	0.33* ($k=1,2$)	0.74* ($k=1$)	0.63* ($k=0$)	0.78* ($k=0$)	0.67* ($k=-1$)
i	0.85* ($k=0$)	0.90* ($k=0$)	0.78* ($k=0$)	0.92* ($k=0$)	0.85* ($k=0$)
x	−0.30 ($k=5$)	0.67* ($k=0$)	0.77* ($k=0$)	0.42 ($k=-1$)	0.59* ($k=0,1$)
m	0.70* ($k=-1$)	0.86* ($k=0$)	0.93* ($k=0$)	0.87* ($k=0$)	0.78* ($k=0$)
nx	−0.47* ($k=0$)	−0.49* ($k=0$)	0.34 ($k=-2,-1$)	−0.56* ($k=1$)	−0.54* ($k=0$)
n	0.95* ($k=0$)	0.91* ($k=1$)	0.82* ($k=-1$)	0.57* ($k=1,2$)	0.86* ($k=2,3$)
h	0.17 ($k=0,1$)	0.48 ($k=2$)	0.71* ($k=3$)	0.67* ($k=0$)	0.02 ($k=4$)
th	0.84* ($k=0$)	0.90* ($k=1$)	0.89* ($k=1,2$)	0.79* ($k=0$)	0.86* ($k=2,3$)
ap	−0.51* ($k=0,1$)	0.73* ($k=0$)	−0.79* ($k=3$)	−0.41 ($k=1$)	0.73* ($k=-2$)

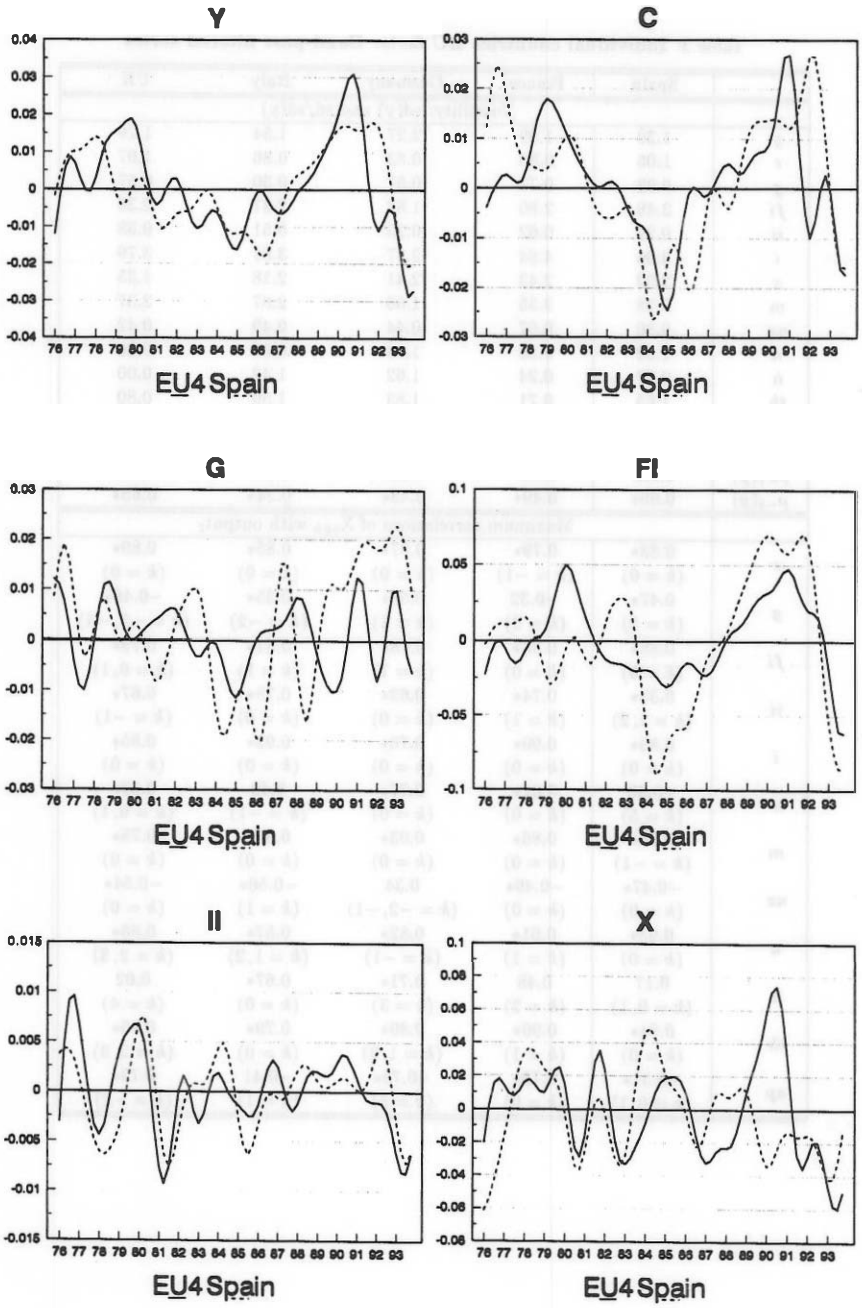


Figure 4a. Business Cycle components of EU4 and Spain.

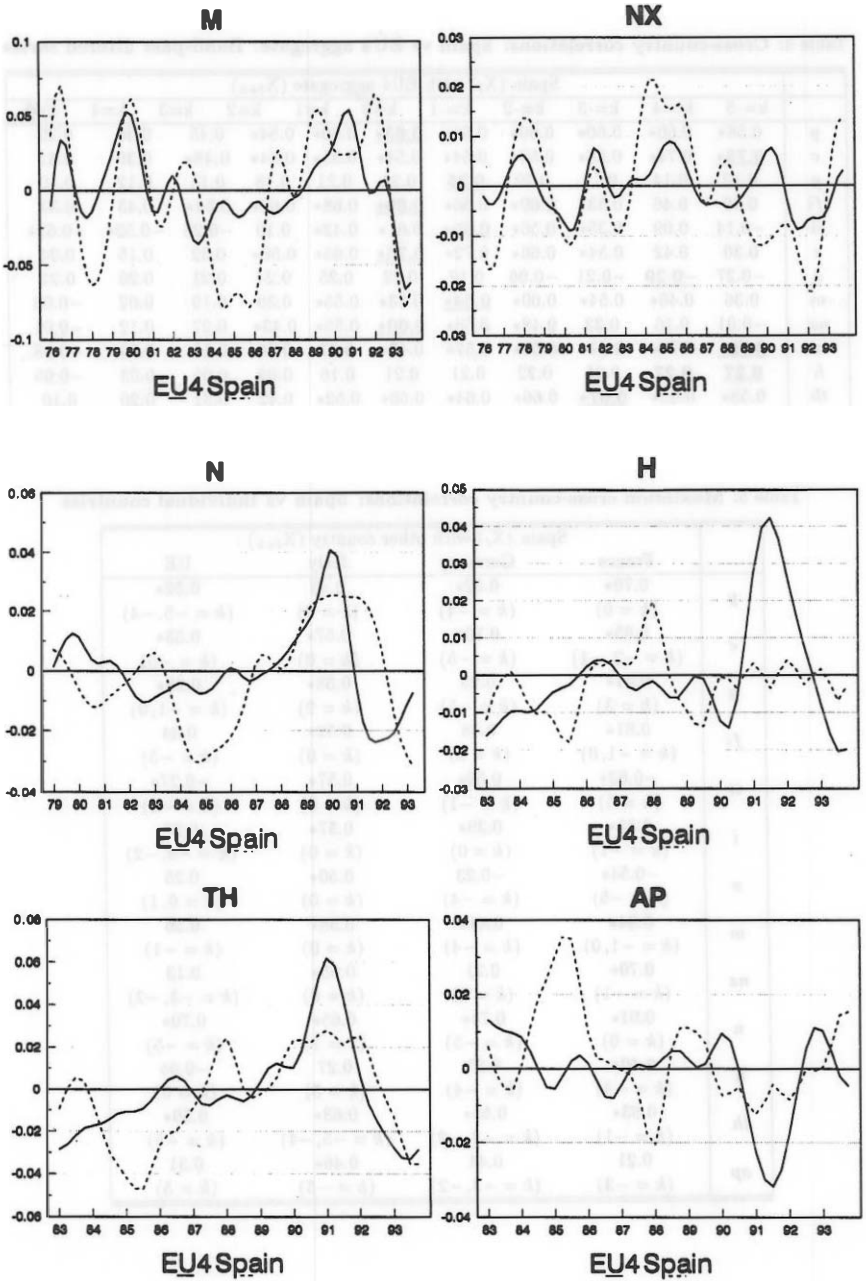


Figure 4b. Business Cycle components of EU4 and Spain.

Table 4: **Cross-country correlations: Spain vs EU4 aggregate. Band-pass filtered series**

	Spain (X_t) with EU4 aggregate (X_{t+k})										
	k=-5	k=-4	k=-3	k=-2	k=-1	k=0	k=1	k=2	k=3	k=4	k=5
y	0.58*	0.60*	0.60*	0.60*	0.61*	**0.63***	0.60*	0.54*	0.45	0.36	0.29
c	**0.76***	0.74*	0.66*	0.58*	0.54*	0.54*	0.55*	0.54*	0.48*	0.39	0.31
g	0.12	0.14	0.17	0.22	**0.25**	0.24	0.21	0.18	0.15	0.12	0.10
fi	0.40	0.46	0.53*	0.60*	0.66*	**0.69***	0.68*	0.62*	0.54*	0.43	0.33
ii	−0.14	0.09	0.35*	0.56*	**0.65***	0.61*	0.42*	0.10	−0.25	−0.52*	−0.62*
i	0.30	0.42	0.54*	0.66*	0.72*	**0.73***	0.65*	0.50*	0.32	0.15	0.04
x	−0.27	**−0.29**	−0.21	−0.06	0.10	0.22	0.25	0.24	0.21	0.20	0.21
m	0.36	0.46*	0.54*	0.60*	**0.64***	0.63*	0.55*	0.39	0.19	0.02	−0.08
nx	−0.01	0.16	0.33	0.48*	0.58*	**0.60***	0.55*	0.43*	0.27	0.12	−0.01
n	**0.79***	0.78*	0.74*	0.66*	0.57*	0.47*	0.37	0.26	0.15	0.03	−0.08
h	**0.27**	**0.27**	0.25	0.22	0.21	0.21	0.16	0.09	0.05	0.03	−0.05
th	0.58*	0.65*	**0.67***	0.66*	0.64*	0.60*	0.52*	0.42	0.31	0.20	0.10
ap	**0.32**	0.31	0.25	0.19	0.16	0.16	0.18	0.19	0.18	0.14	0.07æ

Table 5: **Maximum cross-country correlations: Spain vs Individual countries**

	Spain (X_t) with other country (X_{t+k}) :			
	France	Germany	Italy	UK
y	0.70* ($k = 0$)	0.52* ($k = -4$)	0.43 ($k = 0$)	0.52* ($k = -5, -4$)
c	0.65* ($k = -2, -1$)	0.70* ($k = -5$)	0.57* ($k = 0$)	0.53* ($k = -5$)
g	0.41* ($k = 3$)	0.25 ($k = -5$)	0.58* ($k = 2$)	0.28* ($k = -1, 0$)
fi	0.81* ($k = -1, 0$)	0.38 ($k = 2$)	0.52* ($k = 0$)	0.34 ($k = -5$)
ii	−0.63* ($k = 5$)	0.59* ($k = -1$)	0.57* ($k = 0$)	−0.27* ($k = -2$)
i	0.85* ($k = -1$)	0.39* ($k = 0$)	0.57* ($k = 0$)	0.22 ($k = -5, -2$)
x	−0.54* ($k = -5$)	−0.23 ($k = -4$)	0.50* ($k = 0$)	0.25 ($k = 0, 1$)
m	0.84* ($k = -1, 0$)	0.44* ($k = -4$)	0.58* ($k = 0$)	0.26 ($k = -1$)
nx	0.70* ($k = -1$)	0.21 ($k = 2$)	0.65* ($k = 0$)	0.13 ($k = -3, -2$)
n	0.91* ($k = 0$)	0.74* ($k = -5$)	0.65* ($k = 1$)	0.70* ($k = -5$)
h	0.40* ($k = -4$)	0.27 ($k = -4$)	0.27 ($k = 5$)	−0.05 ($k = 0$)
th	0.83* ($k = -1$)	0.58* ($k = -3, -2$)	0.63* ($k = -5, -4$)	0.59* ($k = -5$)
ap	0.21 ($k = -3$)	0.44 ($k = -3, -2$)	0.46* ($k = -5$)	0.31 ($k = 5$)

Table 6: **Parameter values for the IRBC models: FIXED PARAMETERS**

Parameter	Autarky	Common shocks	Trade only	Full Interdep.
Output Share of Labor (α)	0.724	0.724	0.724	0.724
Growth rate (γ_x)	1.0037	1.0037	1.0037	1.0037
Depr.Rate of Capital (δ)	0.022	0.022	0.022	0.22
Discount Factor (β)	0.988	0.988	0.988	0.988
Steady State hours ($\overline{N}$)	0.16	0.16	0.16	0.16
N_0, with Indivisible labor	0.5	0.5	0.5	0.5
Risk Aversion (σ)	2	2	2	2
Risk Aversion (σ) with Indivisible Labor	1	1	1	1
Share of Government Spending in Output (sg)	0.14	0.14	0.14	0.14
Tax Rate (τ)	0.26	0.26	0.26	0.26
Persistence of Tech.Disturb. (ρ_{A1})	0.89	0.89	0.89	0.89
Persistence of Tech.Disturb. (ρ_{A2})	0.74	0.74	0.74	0.74
Spillover across Technology Disturbances (ν_{21})	**0**	**0**	**0**	**-0.03**
Spillover across Technology Disturbances (ν_{12})	**0**	**0**	**0**	**-0.031**
Persistence of Gov.Sp. Dist. (ρ_{G1})	0.92	0.92	0.92	0.92
Persistence of Gov.Sp. Dist. (ρ_{G2})	0.83	0.83	0.83	0.83
S.D. of Tech.Innovations (σ_{A1})	0.005	0.005	0.005	0.005
S.D. of Tech.Innovations (σ_{A2})	0.007	0.007	0.007	0.007
Contemporaneous corr. of Technology Innovations (ψ)	**0**	**0.13**	**0**	**0.13**
S.D. of Gov.Sp.Innovations (σ_{G1})	0.0046	0.0046	0.0046	0.0046
S.D. of Gov.Sp.Innovations (σ_{G2})	0.0035	0.0035	0.0035	0.0035
Imports share (MS)	**0**	**0**	**0.2**	**0.2**
Armington parameter ($1/\rho$)	1.5	1.5	1.5	1.5
Size of each country (Π)	0.5	0.5	0.5	0.5

Table 7: **Parameter values for the IRBC models: RANDOM PARAMETERS**

Parameter	Autarky	Common shocks	Trade only	Full Interdep.
Output Share of Labor (α)	U[0.65, 0.75]	id.	id.	id.
Growth rate (γ_x)	N(1.0035, 0.0005)	id.	id.	id.
Depr.Rate of Capital (δ)	U[0.02, 0.03]	id.	id.	id.
Discount Factor (β)	N(0.988, 0.001)	id.	id.	id.
	trunc[0.9855, 1.002]	id.	id.	id.
Steady State hours ($\overline{N}$)	U[0.15, 0.30]	id.	id.	id.
N_0, with Indiv.labor	0.5	id.	id.	id.
Risk Aversion (σ)	$\chi^2(2)$ [0, 10]	id.	id.	id.
Risk Aversion (σ) with Indiv.Labor	1	id.	id.	id.
Share of Government Spending in Output (sg)	U[0.13, 0.30]	id.	id.	id.
Tax Rate (τ)	U[0.2, 0.30]	id.	id.	id.
Persistence of Tech.Disturb.(ρ_{A1})	N(0.85, 0.1)	id.	id.	id.
Persistence of Tech.Disturb.(ρ_{A2})	N(0.85, 0.1)	id.	id.	id.
Spillover across Technology Disturbances (ν_{21})	**0**	**0**	**0**	**N(0, 0.05)**
Spillover across Technology Disturbances (ν_{12})	**0**	**0**	**0**	**N(0, 0.05)**
Persistence of Gov.Sp. Dist. (ρ_{G1})	N(0.91, 0.08)	id.	id.	id.
Persistence of Gov.Sp. Dist. (ρ_{G2})	N(0.91, 0.08)	id.	id.	id.
S.D. of Tech.Innovations (σ_{A1})	$\chi^2(1)$ trunc[0.0045,0.02]	id.	id.	id.
S.D. of Tech.Innovations (σ_{A2})	$\chi^2(1)$ trunc[0.0045,0.02]	id.	id.	id.
Contemporaneous corr. of Technology Innovations (ψ)	**0**	**N(0.15, 0.03)**	**0**	**N(0.15, 0.03)**
S.D. of Gov.Sp.Innov(σ_{G1})	N(0.004,0.001) trunc[0,0.006]	id.	id.	id.
S.D. of Gov.Sp.Innov(σ_{G2})	N(0.004,0.001) trunc[0,0.006]	id.	id.	id.
Imports share (MS)	**0**	**0**	**N(0.25, 0.1)**	**N(0.25, 0.1)**
Armington parameter ($1/\rho$)	1.5	id.	id.	id.
Size of each country (Π)	0.5	id.	id.	id.

Table 8: **Moments of the model series: Divisible labor**

Moments	Actual data	Autarky		Common shocks		Trade only		Full Interdep	
		fixed	random	fixed	random	fixed	random	fixed	random
std(Y)	1.30	0.91*	3.22*	0.91*	3.38*	0.92*	3.76*	0.90*	3.99*
std(C)	1.05	0.44*	0.72*	0.44*	0.78*	0.36*	0.59*	0.36*	0.5*
std(G)	0.92	0.59*	0.62*	0.59*	0.49*	0.58*	1.63*	0.61*	0.37*
std(I)	3.96	5.24*	4.81*	5.24*	6.42*	6.04*	6.67*	5.71*	7.2*
std(X)	2.33	0	0	0	0	1.31*	1.5*	1.33*	1.52*
std(M)	3.58	0	0	0	0	0.98*	1.58*	0.94*	1.12*
std(NX)	0.80	0	0	0	0	0.28*	0.37*	0.24*	0.54*
std(TH)	1.65	0.52*	0.49*	0.52*	0.49*	0.51*	1.13*	0.52*	0.56*
std(AP)	1.03	0.52	0.76*	0.52*	0.80*	0.53*	0.72*	0.52*	0.66*
corr(C,Y)	0.83*	0.91*	0.89*	0.91*	0.88*	0.92*	0.74*	0.91*	0.75*
corr(G,Y)	0.34	0.05	0.04	0.05	0.06*	0.04	0.02	0.03	0.04
corr(I,Y)	0.85*	0.98*	0.87*	0.98*	0.80*	0.91*	0.72*	0.92*	0.78*
corr(X,Y)	0.23	0	0	0	0	0.4	0.49*	0.53*	0.51*
corr(M,Y)	0.67*	0	0	0	0	0.93*	0.82*	0.94*	0.83*
corr(NX/Y,Y)	-0.47*	0	0	0	0	-0.24	-0.17	-0.13	-0.20
corr(TH,Y)	0.84*	0.96*	0.73*	0.96*	0.64*	0.96*	0.76*	0.95*	0.83*
corr(AP,Y)	-0.51*	0.96*	0.92*	0.96*	0.91*	0.96*	0.89*	0.96*	0.85*
corr(Y,Y*)	0.63*	0.02	-0.01	0.14*	0.05	0.02	-0.07	0.16*	0.04
corr(C,C*)	0.54*	0.01	0.003	0.14*	0.09*	0.36*	0.58*	0.41*	0.69*
corr(G,G*)	0.24	-0.02	-0.002	-0.03	-0.01	-0.03	0.01	-0.04	0.0007
corr(I,I*)	0.73*	0.02	-0.01	0.14*	0.05	-0.26*	-0.30*	-0.07*	-0.19*
corr(X,X*)	0.22	0	0	0	0	0.11*	-0.10*	0.29*	0.01
corr(M,M*)	0.63*	0	0	0	0	-0.05	-0.03	0.12*	0.06
corr(NX,NX*)	0.60*	0	0	0	0	-0.99*	-0.92*	-0.99*	-0.91*
corr(TH,TH*)	0.60*	0.69*	0.58*	0.69*	0.60*	0.72*	0.48*	0.72*	0.56*
corr(AP,AP*)	0.16	0.01	-0.002	0.14*	0.09*	-0.07*	0.02	0.001	0.14*

Table 9: **Moments of the model series: Indivisible labor**

Moments	Actual data	Autarky		Common shocks		Trade only		Full Interdep	
		fixed	random	fixed	random	fixed	random	fixed	random
std(Y)	1.30	1.13*	2.50*	1.13*	3.04*	1.13*	3.25*	1.13*	4.28*
std(C)	1.05	0.38*	4.54	0.38*	1.92	0.32*	0.97*	0.32*	0.44*
std(G)	0.92	0.49*	0.47*	0.49*	0.34*	0.47*	0.29*	0.49*	0.31*
std(I)	3.96	5.72*	6.19*	5.72*	7.07*	6.49*	8.04*	6.11*	8.96*
std(X)	2.33	0	0	0	0	1.40*	1.72*	1.43*	1.33*
std(M)	3.58	0	0	0	0	0.99*	2.50*	0.96*	2.66
std(NX)	0.80	0	0	0	0	0.33*	0.48*	0.32*	0.52*
std(TH)	1.65	0.71*	0.83*	0.71*	1.73*	0.69*	1.89*	0.70*	3.42
std(AP)	1.03	0.38*	4.54*	0.38*	1.92*	0.41*	1.11*	0.40*	0.52*
corr(C,Y)	0.83*	0.84*	0.77*	0.84*	0.76*	0.84*	0.68*	0.83*	0.67*
corr(G,Y)	0.34	0.05	0.05*	0.05	0.07*	0.05	0.08	0.04	0.05
corr(I,Y)	0.85*	0.98*	0.94*	0.98*	0.91*	0.91*	0.79*	0.92*	0.79*
corr(X,Y)	0.23	0	0	0	0	0.39*	0.52*	0.54*	0.50*
corr(M,Y)	0.67*	0	0	0	0	0.93*	0.84*	0.94*	0.85*
corr(NX/Y,Y)	-0.47*	0	0	0	0	-0.23*	-0.26*	-0.09	-0.26*
corr(TH,Y)	0.84*	0.95*	0.89*	0.95*	0.80*	0.95*	0.85*	0.95*	0.87*
corr(AP,Y)	-0.51*	0.84*	0.77*	0.84*	0.76*	0.85*	0.75*	0.83*	0.74*
corr(Y,Y*)	0.63*	0.04	0.04*	0.15*	0.12*	0.09*	0.05	0.25*	0.11*
corr(C,C*)	0.54*	0.05	0.06*	0.17*	0.13*	0.36*	0.60*	0.42*	0.67*
corr(G,G*)	0.24	-0.04	0.04	-0.04	0.02	-0.03	0.04	-0.04	0
corr(I,I*)	0.73*	0.04	0.02	0.15*	0.11*	-0.19*	-0.20*	0.03	-0.13*
corr(X,X*)	0.22	0	0	0	0	0.15*	0.11*	0.35*	0.10*
corr(M,M*)	0.63*	0	0	0	0	-0.03	0.04	0.17*	0.08*
corr(NX,NX*)	0.60*	0	0	0	0	-0.99*	-0.91*	-0.99*	-0.91*
corr(TH,TH*)	0.60*	0.50*	0.38*	0.50*	0.45*	0.53*	0.46*	0.52*	0.44*
corr(AP,AP*)	0.16	0.04	0.06	0.17*	0.13*	-0.12	-0.05*	-0.06	0.06

Table 10: **Percentiles of the actual moments in the simulated distributions: Divisible labor**

Moments	Autarky		Common shocks		Trade only		Full Interdep	
	fixed	random	fixed	random	fixed	random	fixed	random
corr(Y,Y*)	1	0.99	1	0.99	1	0.91	0.98	0.96
corr(C,C*)	1	0.97	0.97	0.97	0.72	0.41	0.66	0.25
corr(G,G*)	0.81	0.81	0.81	0.86	0.81	0.84	0.88	0.79
corr(I,I*)	1	1	1	1	1	0.95	1	0.95
corr(X,X*)	–	–	–	–	0.59	0.84	0.34	0.72
corr(M,M*)	–	–	–	–	1	0.92	1	0.89
corr(NX,NX*)	–	–	–	–	1	1	1	0.99
corr(TH,TH*)	0	0.13	0	0.21	0.01	0.41	0.02	0.33
corr(AP,AP*)	0.68	0.72	0.50	0.59	0.78	0.72	0.70	0.50

Table 11: **Percentiles of the actual moments in the simulated distributions: Indivisible labor**

Moments	Autarky		Common shocks		Trade only		Full Interdep	
	fixed	random	fixed	random	fixed	random	fixed	random
corr(Y,Y*)	1	1	0.98	1	1	0.97	0.97	0.99
corr(C,C*)	0.96	0.98	0.91	0.95	0.70	0.36	0.64	0.25
corr(G,G*)	0.88	0.83	0.88	0.84	0.81	0.83	0.88	0.79
corr(I,I*)	1	1	1	1	1	0.98	1	0.97
corr(X,X*)	–	–	–	–	0.56	0.68	0.20	0.57
corr(M,M*)	–	–	–	–	1	0.97	1	0.91
corr(NX,NX*)	–	–	–	–	1	1	1	1
corr(TH,TH*)	0.97	0.68	0.97	0.82	0.89	0.60	0.90	0.70
corr(AP,AP*)	0.63	0.69	0.48	0.56	0.80	0.77	0.76	0.60

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