INTERNATIONAL REAL BUSINESS CYCLES

CAN A TWO COUNTRIES TWO SECTORS MODEL SOLVE THE QUANTITY ANOMALY?

ABSTRACT

The model that is here presented tries to solve some of the limitations of the international real business cycles literature. The *quantity anomaly* described in Backus, Kehoe and Kydland (1992) shows the problems that typical models have in getting the right international correlations order between international consumptions and international outputs. The model that is here introduced, shows that using intermediate sectors in order to get a final good can achieve the desired correlations order, although other issues are worse achieved, such as the consumption relative volatility. International calibration is used in order to compare the cyclical results of this model and a typical two countries one sector model.

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1. INTRODUCTION

In the international real business cycle literature, the today classical anomalies of quantities and prices described in Backus, Kehoe and Kydland (1992), have found several alternatives. Here I will focus on the quantities anomaly and propose one model that is more succesful than the model of Stockman and Tesar (1995). This latter model used a two final sector economy that was able to trade with one of those final sectors. It is clear that international trade concerns final goods. But it is also true that international trade concerns intermediate inputs. If the Stockman and Tesar model failed in explaining the quantities anomaly, the model that is here introduced tries to see if the technical relations among intermediate productions accounts for more cyclical characteristics than the basic model of Backucs, Kehoe and Kydland, and particularly if the quantities anomaly is solved.

Some of the main characteristics of open economies are its capabilities to trade with goods or to share capital. These movements try to get the higher possible profit. This behaviour has two consequences. The first one is the idea of consumption smoothing between countries and drives to the existence of trade deficits and surpluses. The second one is the fact that events in one country influence other countries, with which the former has commercial relations. Our research focuses in inspecting how the economic connections between countries have consequences in the transmission of aggregate fluctuations, and specially if these conditions are technical conditions related with aggregate production function of every national economy.

The initial contribution of Backus, Kehoe and Kydland (1992 and 1994), that follow the work of Dellas (1986), Stockman and Svensson (1987) and Cantor and Mark (1988), is done from the perspective of dynamic general equilibrium theory. These works, joint with those of Canova and Dellas (1990) and Baxter and Crucini (1992), have been devoted to the analysis of models in which the countries that constituted the world economy were identical. Nevertheless, other people have focused in working with a wider data set, showing how the behaviour and size of cycles is quite different between countries. Examples of this are Blackburn and Ravn (1992), Brandner and Neusser (1992), Danthine and Girardin (1989), Englund, Persson and Svensson (1992), Girardin (1991), Hassler, Lundvil, Persson and Söderlin (1992) and Kydland and Prescott (1990). Works with international comparisons are Backus, Kehoe and Kydland (1992), Blackburn and Ravn (1991), Baxter and Stockman (1989), Cooley and Ohanian (1991), Entorf (1991), Fiorito and Kollintzas (1994), Head (1991), Stockman and Tesar (1991), Ravn (1993), Zimmermann (1994) amd Ambler, Cardia and Zimmermann (1998 and 1999).

From a quantitative point of view, business cycles have been analysed in different economies in order to consider if there are regularities, such as *stylised cyclical facts*. Zimmermann (1994) analyses the cyclical behaviour of 19 countries, focusing on series related with international trade and considering also the size of the considered countries. Among the general conclusions, there can be highlighted the following ones:

1. Production: the output volatility is very different among countries and it does not depend on the country size.
2. Cross correlations between international consumptions and outputs: international consumptions cross correlations are in general lower than international outputs cross correlations.
3. Cross correlations between international investments: they are normally positive, but there are also negative ones. This correlation is usually high between neighbour and big countries, while it is smaller between the others.
4. Terms of Trade: very volatile, and very disperse among countries. It is acyclical showing a strong lead to the cycle, that is particularly important in big countries.

5. Size of net exports: its volatility depends on the degree of foreign openness of trade of every country. It is moderately countercyclical, and shows a small lag in small countries, and a lead in the big ones.

Next, in section 2 are described the cyclical characteristics of several economies and the empirical regularities in which we will focus. Then, in sections 3 and 4 are presented the models that are going to be confronted. Immediately after, in section 5 calibration is shown. Finally, in section 6, the model results compared with the data, extracting some interesting conclusions in section 7.

2. CHARACTERISING THE CICLE

In this section I will show the typical cyclical behaviour for a set of different countries and different sets of data. The aggregate data that is used is quarterly data, while sectorial data is yearly data. In the following tables are shown data from the literature for the USA, Germany, and Italy, and also data computed by me, for Spain and an aggregate of the four bigger countries of the EU (France, Germany, Italy and United Kingdom), that will be called EU4.

Table 1 presents the USA cyclical attributes of same variables of the USA economy, extracted from Cooley and Prescott (1995). Table 2 displays the same attributes, but related to the Spanish and the EU4 economies.[1] I will not repeat the typical *cyclical stylized facts* that can be found in any paper. Nevertheless, some comments can be done looking at those first two tables. The first point relates to the relative volatility of private consumption: it is more volatile than output in Europe, and less volatile in the USA. This fact has been considered by several authors, although there is not an homogeneous behaviour among all European countries. The next detail relates net exports over output in the EU4: they are not countercyclical. Many international business cycle models have tried to find this feature in their results, and, as here can be seen, perhaps it is not always so.

If we want to do an international analysis of correlations, table 3 orders the variables that have been considered. Then, capital and the terms of trade are the more correlated variables across countries (Spain and EU4). Then, output and imports, and only then follows private consumption. This particular aspect of data, that relates output and private consumption international correlations is the one that, as could not be explained by the Backus, Kehoe and Kydland model, was labeled as the quantities anomaly. Labour, investment and exports are less correlated than the former, but much more than net exports over output and labour productivity. Oil shocks are important sources of fluctuations in the considered period. It is reflected in the high positive international correlation between the terms of trade and also between imports.[2]

If we focus on sector data, tables 4 and 5 offer sectorial cyclical characteristics. Sectors are classified following Stockman and Tesar (1995). Hence, tradable sectors are agriculture, manufacturing, mining and retail and transportation sectors, and non tradable sectors include electricity, gas and water, construction, finance, insurance, and private and government services. Those tables, then, show some interesting things. The first one relates the volatility: when both sectors have a similar volatility, the aggregate is less volatile than sectors, while when both sectors have very different volatilities, the aggregate volatility lies in the middle of sectorial volatilities. Generally speaking, tradable sectors have more volatile variables than non tradable sectors. Correlations are always higher between sectorial outputs than between sectorial investment, sectorial Solow residuals, and sectorial labour productivity. By the other side, capital is more correlated across sectors than output.

[1] A description of the used data can be found in the appendix.

[2] A very interesting analysis of oil shocks effects in the business cycle can be found in *Oil Prices and the Terms of Trade,* David K. Backus and Mario J. Crucini (1998).

The international analysis of sectorial data can be done looking at table 6. In this table are shown international correlations between sectorial variables. On the average, tradable variables are more correlated across countries than non tradable variables, as could be expected. But this difference is more important in Solow residual, labour, capital and labour productivity, than in output and investment. Now, sectorial investments are less internationally correlated than the aggregate investment that was computed using quarterly data. The same happens with all variables, with the only exception of labour productivity, that is now more correlated than with aggregate quarterly data.

3. A INTERNATIONAL EXTENSION OF THE BASIC TWO COUNTRIES ONE SECTOR MODEL

The model that here is considered as *basic* is the one developed in Backus, Kehoe and Kydland (1992) and the extension is the work of Bec (1995). This model considers two countries, inhabited by an enormous number of consumers, which have the same utility function, although it can have different parameters. Firms are represented by identical technology functions for every country. Both countries produce the same kind of good. Capital is perfectly mobile and productive capital has a high degree of mobility. It does not happen with labour, that is country specific. Competitive equilibrium does exist and it means that international markets share risk.

As there is only one sector, international trade exists in order to smooth consumption and to assure that capital goes to the more productive country. World competitive equilibrium with complete markets is Pareto-efficient. Every country is inhabited by identical individuals, that live forever. Preferences are the same in every country and follow additivelly separable utility functions, such:

$$u(c_t, l_t) = \log c_t + \gamma \log l_t \,, \qquad u(c_t^*, l_t^*) = \log c_t^* + \gamma^* \log l_t^* \,,$$

where c_t is *per capita* consumption in period t and l_t is *per capita* leisure in period t, both in the home country. Variables and parameters with * are related to the foreign country. It is assumed that both γ and γ^* are positive.

Effective consumption is defined as $c_t = cp_t + \alpha g_t$, where g_t are public expenditures, cp_t is private consumption, and α is a parameter between 0 and 1. Public expenditures in every country are paid by lump sum taxes, and follow stochastic processes, defined by:

$$\log g_t = (1 - \rho_g) \log g + \rho_g \log g_{t-1} + \varepsilon_{g,t} \,,$$

where g is the average level of *per capita* public expenditures, $|\rho_g|<1$, and the innovations $\varepsilon_{g,t}$ are independent on time and have zero average and σ^2_g variance. It is also assumed that ρ_g has not to be equal to ρ^*_g and that $E[\varepsilon_{g,t}, \varepsilon^*_{g,t}]=0$.

Both countries have identical technology functions, which assume constant returns to scale. Both functions are affected by exogenous productivity shocks, a_t, that are country specific, although they can be somehow shared. The described technologies use capital, k_t, and labour, n_t. y_t refers to *per capita* output. Capital does not have to be owned by residents, while labour cannot go abroad. The production functions will have a Cobb-Douglas specification and investment is subject to adjustment costs:

$$y_t = a_t k_t^{\theta} n_t^{1-\theta} - (\phi/2)(k_{t+1} - k_t)^2 \,,$$

where $0<\theta<1$, and $\phi>0$. Both parameters can be exactly the same for both countries, but does not have to. Productivity shocks follow a multivariate stochastic process that is exogenous and stationary:

$$\begin{pmatrix} \log a_t \\ \log a_t^* \end{pmatrix} = \begin{pmatrix} r_a & r_b \\ r_b^* & r_a^* \end{pmatrix} \begin{pmatrix} \log a_{t-1} \\ \log a_{t-1}^* \end{pmatrix} + \begin{pmatrix} (1-r_a) & -r_b \\ -r_b^* & (1-r_a^*) \end{pmatrix} \begin{pmatrix} \log a \\ \log a^* \end{pmatrix} + \begin{pmatrix} e_{a,t} \\ e_{a,t}^* \end{pmatrix}$$

where the parameter matrix of the autoregresive part of the process have eigen values lower to one, in order to assure stability. $e_{a,t}, e^*_{a,t}$ are the innovations, and are characterised by 0 averages, s^2_a and s^{2*}_a variances, and $s^2_{a,a*}$ correlation. Lastly, capital cumulates following: $k_{t+1} = (1-d)k_t + i_t$, in which depreciation taxes, d and d^*, do not have to be equal.

Individual amount of time is normalised to unity, and then labour restrictions are given in every country by: $n_t + l_t \leq 1$. As it is only produced one good, total imports in the home country will be equal to total exports in the foreign country. Given p as the size of the home country, the size of the foreign country will be equal to $(1-p)$. x_t are *per capita* exports; m_t *per capita* imports; and nx_t *per capita* net exports:

$$m_t^* = \frac{p}{1-p} x_t, \qquad x_t^* = \frac{p}{1-p} m_t, \qquad nx_t^* = -\frac{p}{1-p} nx_t$$

Resources restrictions in every country will be given by:

$$p\left(y_t - cp_t - i_t - g_t - nx_t\right) = 0 \qquad (1-p)\left(y_t^* - cp_t^* - i_t^* - g_t^* + \frac{p}{1-p} nx_t\right) = 0$$

Then, variables of both countries will be related by two mechanisms: technological diffusion and foreign trade.

As it exists competitive equilibrium and as it is Pareto-efficient, the equilibrium can have a social planner problem solution. Such problem will look for the maximum of a weighted sum of national utilities, subject to former restrictions, and it is represented by the following Bellman equation:

$$V_t(k_t, k_t^*, a_t, a_t^*, g_t, g_t^*) = \max_{n_t, n_t^*, i_t, i_t^*, nx_t} \left\{ p\, u(c_t, l_t) + (1-p)\, u(c_t^*, l_t^*) + bV_{t+1} \right\},$$

subject to the laws of motion of capital. The model will be solved following King, Plosser and Rebelo (1988).

4. AN EXTENSION: A TWO COUNTRIES TWO SECTORS MODEL

The innovation of this model lies in that there is a new way of relating both countries. The already existing relation is the technological diffusion of the Solow residuals. The new relation is the fact that the foreign trade has several technical restrictions, that come from assuming a very flexible aggregate production function.

In this wider model there are also two countries, and in every country there are two intermediate productive sectors. In both countries there is one sector characterised by the fact that its whole production is used in the same country where it was produced. Meanwhile, the production of the other sector can be used both in the home country and in the foreign country. Hence, they can be labeled as non-tradable production and tradable production, respectively.

Generally speaking, country i has, as it was already explained, two sectors. First sector produces y^i_1, while the second sector produces y^i_2. The superscript relates the country where the sectorial output is produced, and subscripts denote sectors 1 and 2. It is assumed that it does not exist infinite elasticity of substitution between sectorial outputs. Armington aggregator will be used as aggregate production function. The difference between sectors 1 and 2 will be that sector 1 produces one output, that can only be used in the home country (non tradable production), while sector 2 produces a kind of output, that can be used both in the home country and in the foreign country (tradable production). Then, country i produces non tradable outputs, y^i_1, and tradable outputs, y^i_2. Tradable outputs can be commercialised in the foreign country, country j, y^i_{22}, or can be commercialised in the home country, country i, y^i_{21}. The output that have been produced and wasted in the home country will be denoted as y^i_C.

If I assume that both countries *need* imports of the foreign country, it can be understood the inelasticity of substitution that exists between domestic output and imports. It says that home resources have to be complemented with foreign production to be completely effective. Nevertheless, every country decides the ratio between foreign and home production. A control variable will be defined in order to control this level of imports: F^i_t. Hence, every country decides if imports in time t are higher that its average level or if they are lower than this level. It has to be considered that there exists a steady state level of imports in the production function. Here is where variable is F^i_t defined: weight of imports of country i over its normal level of imports: $F^i_t = \frac{y^j_{22,t}}{\bar{y}^j_{22}}$, being $\bar{y}^j_{22}$ the imports amount of the steady state.

Then a very flexible production function is defined. The Armington Aggregator is used to get in country i its final good y^i_t, composed by intermediate sectorial output, both from the home country and the foreign country:

$$y^i_t = \left[w^i_C \left\{ H^i_t \left(w^i_1 {y^i_{1,t}}^{1-r_i} + w^i_2 {y^i_{21,t}}^{1-r_i} \right)^{\frac{1}{1-r_i}} \right\}^{1-r^i_T} + w^i_F \left\{ F^i_t y^j_{22,t} \right\}^{1-r^i_T} \right]^{\frac{1}{1-r^i_T}},$$

where H^i_t is the amount of production of country i used in country i over the steady state level of production of country i used in country i, and this can be written as:

$$H^i_t = \frac{y^i_{C,t}}{\bar{y}^i_{C,t}} = \left(\frac{1}{1-PF^i} \right) + \left(\frac{-PF^i}{1-PF^i} \right) F^i_t,$$

where PF^i is the amount of imports over total production in country i: $PF^i = \frac{y^j_{22}}{y^i_1 + y^i_2}$. Parameters $1/r$ are the elasticities of substitution. In concrete, $1/r_i$ is the elasticity of substitution between domestic outputs produced in country i; and $1/r^i_T$ is the elasticity of substitution between domestic output produced in country i and output that use country i and is imported from country j. Parameters w^i_1 and w^i_2 relate the size of both sectors of country i, while w^i_C and w^i_F relate the size of home consumption in country i with imports made from country i to country j.

If I focus on tradable sector, sector 2 in any country i (i=1,2), the total amount produced, y^i_2, can be used in the home country, y^i_{21}, or can be exported, y^i_{22}. It can be written in *per capita* terms of the country of destination where this production is used, dividing by the population that live in every country: $y^i_2 = y^i_{21} + y^i_{22}\frac{\pi_j}{\pi_i}$, where π_i is the relative size of country i. The same can be expressed in normalised terms respect the total tradable production: $1 = py^i_{21} + py^i_{22}\frac{\pi_j}{\pi_i}$, where py^i_{21} is the output proportion of country i sector 2 production that is used in the same country where it was produced, while py^i_{22} is the output proportion of country i sector 2 production that is exported to the foreign country. This is another control variable for every country, as they can decide its level of exports.

Individuals in country i can use the final good in consumption, investment and public expenditure:

$$y_t^i = cp_t^i + i_t^i + g_t^i \,.$$

If I decide to write down the final good in country i, y_t^i, in terms of the production of every sector, it has to be used their *relative prices*, using one unit of consumption as nominal in every economy. Then, I can write:

$$y_{1,t}^i \frac{\partial c^i}{\partial y_{1,t}^i} + \left(y_{2,t}^i - \frac{p_1}{p_2} y_{22,t}^i \right) \frac{\partial c^i}{\partial y_{21,t}^i} - y_{22,t}^j \frac{\partial c^i}{\partial y_{22,t}^i} = y_t^i \,.$$

I define terms of trade, TOT_t^i, as the relative prices of imports respect to exports:

$$TOT_t^i = \frac{\partial c_t^i \big/ \partial y_{22,t}^j}{\partial c_t^i \big/ \partial y_{21,t}^i} = \frac{w_F^j}{w_C^i w_2^i} y_{C,t}^{i\; -\left(r^i - r_T^i\right)} \frac{y_{22,t}^{j\; -r_T^i}}{y_{21,t}^{i\; -r1}} \frac{F_t^i}{H_t^i} \,,$$

Then, international trade in country i is expressed by exports, $X_t^i = y_{22,t}^i \dfrac{p_j}{p_i}$, and imports, $M_t^i = TOT_t^i y_{22,t}^j$. Then, net exports will be: $NX_t^i = X_t^i - M_t^i$.

Every sector uses labour and capital. Labour is country specific, but is free to go to every sector. Capital used in every sector will grow with investment, and will decrease due to the effect of depreciation: $k_{j,t+1}^i = k_{j,t}^i (1 - d_j^i) + i_{j,t}^i$.

Then capital can flow from one sector to another by the flow of investment. Labour and capital use a technology, a_j^i, that can be more or less efficient, having a higher or lower level. I will use a Cobb-Douglas production function with adjustment costs in investment, in order to have similarity with the former model:

$$y_{j,t}^i = a_{j,t}^i k_{j,t}^{i\;\, q_j^i} n_{j,t}^{i\;\, 1-q_j^i} - \frac{f_j^i}{2} \left(i_{j,t}^i - d_j^i k_{j,t}^i \right)^2 ,$$

where y_j^i is the output; k_j^i is capital; n_j^i is labour; a_j^i is the level of technology; i_j^i is investment; f_j^i is the parameter of capital adjustment cost; and d_j^i is the rate of depreciation, all of them of sector j and country i.

The level of technology follows a multivariate stochastic process, exogenous and stationary:

$$\begin{bmatrix} \log a_{1,t}^1 \\ \log a_{2,t}^1 \\ \log a_{1,t}^2 \\ \log a_{2,t}^2 \end{bmatrix} = \begin{bmatrix} r_{1,1}^{1,1} & r_{1,2}^{1,1} & r_{2,1}^{1,1} & r_{2,2}^{1,1} \\ r_{1,1}^{1,2} & r_{1,2}^{1,2} & r_{2,1}^{1,2} & r_{2,2}^{1,2} \\ r_{1,1}^{2,1} & r_{1,2}^{2,1} & r_{2,1}^{2,1} & r_{2,2}^{2,1} \\ r_{1,1}^{2,2} & r_{1,2}^{2,2} & r_{2,1}^{2,2} & r_{2,2}^{2,2} \end{bmatrix} \begin{bmatrix} \log a_{1,t-1}^1 \\ \log a_{2,t-1}^1 \\ \log a_{1,t-1}^2 \\ \log a_{2,t-1}^2 \end{bmatrix} + \begin{bmatrix} 1 - r_{1,1}^{1,1} & -r_{1,2}^{1,1} & -r_{2,1}^{1,1} & -r_{2,2}^{1,1} \\ -r_{1,1}^{1,2} & 1 - r_{1,2}^{1,2} & -r_{2,1}^{1,2} & -r_{2,2}^{1,2} \\ -r_{1,1}^{2,1} & -r_{1,2}^{2,1} & 1 - r_{2,1}^{2,1} & -r_{2,2}^{2,1} \\ -r_{1,1}^{2,2} & -r_{1,2}^{2,2} & -r_{2,1}^{2,2} & 1 - r_{2,2}^{2,2} \end{bmatrix} \begin{bmatrix} \log a_1^1 \\ \log a_2^1 \\ \log a_1^2 \\ \log a_2^2 \end{bmatrix} + \begin{bmatrix} e_{1,t}^1 \\ e_{2,t}^1 \\ e_{1,t}^2 \\ e_{2,t}^2 \end{bmatrix}$$

where the parameter matrix of the autoregresive part of the process have eigen values lower to one, in order to assure stability. The sectorial shocks of every sector, $e_{j,t}^i$, are normal processes not serially autocorrelated with $s_{i,j}^2$ variances and $s_{(i,j)(l,m)}$ covariances.

The public expenditures in every country follow an autoregressive process with the same characteristics of the process of section 2. The utility function of the consumers has also the same form of the previous section.

If I assume that exists competitive equilibrium and that it is Pareto efficient, then, the equilibrium can be obtanied solving a social planner problem, represented by the following Bellman equation:

$$V_t = \max_{\substack{n_1^1, n_2^1, i_1^1, i_2^1, n_1^2, n_2^2, i_1^2, i_2^2, \\ py_{21}^1, py_{21}^2, F_t^1, F_t^2}} \left\{ p\, u(c_t^1, l_t^1) + (1-p) u(c_t^2, l_t^2) + bV_{t+1} \right\}$$

subject to the capital lows of motion.

5. CALIBRATION

The strategy that is here followed to calibrate the presented models is to take parameters from the literature in order to consider the general model behaviour. Nevertheless, in order to take into account the role of some parameters, different parameterizations are considered.

The general parameters that are chosen are those considered in Bec (1995) and in Stockman and Tesar (1995), and presented in tables 7 to 9. Then, table 7 shows the parameters of the one sector model and the parameters of its technological process. There are two different scenarios. The first one does not consider any spillovers, while the second one takes into account this possibility. Both processes are chosen in order to have similar persistence. Table 8 exhibits the two sectors model parameters. The VAR parameters of this model are shown in table 9. It is important to consider the fact that I have not included technological shocks correlations, in any of the processes of both models. This is not what is seen in the data, but it is useful to appraise the characteristics of the considered models simply using spillovers. The effect of that will be a low international correlation of all variables, but then we will see the raw characteristics of the models only considering spillovers. Elasticity of substitution will be always equal to 0,67, and, as an additional point, both countries will have the same size.

6. MODELS RESULTS

Tables 10 to 12 show the results of the models, and compare their quantitative implications with the data. Tables 10 and 11 display results of variability and national correlations of both models, using only the basic parameterization of α=0 in the one sector model, as the results are not very much different from the α=1 case. Then, the one sector models results are presented when there are spillovers (ρ_b=0,25) and when there are not (ρ_b=0). Nevertheless, table 12, that presents the international correlations, shows the results of both parameterizations of the one sector model (with α=0 and α=1), because, in that case, the international correlations are much different depending on the value of α. Data volatility is refered to Spain, EU4 and USA, and data correlations are the ones computed between Spain and EU4 and between USA and Europe.

Hence, table 10 shows the absolute and relative volatility of variables. The standard deviation of aggregate output exhibits very different results depending on the model. Hence, when we look at the one sector model, one can see how with spillovers, the output volatility is lower than without spillovers. The two sectors model considers more volatile shocks (as in the calibration of Stockman and Tesar) and then obtains a more volatile output.

Net exports over output are much less volatile with spillovers than without them in the one sector model. In the two sector model this variable has similar relative results comparing with the one sector model.

The relative volatility of private consumption is much lower than in the data in both models. This problem is worst in the two sector model than in both parameterizations of the one sector model. Labour relative volatility is similar in all sectors, while investment is more volatile in the two sectors model. In the one sector model, introducing spillovers lowers the relative volatility of investment. Looking at labour productivity, similar results are found for all models: less volatile than in data.

The results that only concerns the two sectors model show how both sectorial outputs are more volatile than the aggregate output, when data says that the tradable sector is usually the less volatile sector. Their inputs follow the volatility order of data: the tradable sector, relatively intensive in labour, has a less volatile labour (as in data) and a more volatile investment (only true in the USA data).

Exports, imports and the TOT are more volatile than output, but far from the ratios that are seen in data.

Looking at table 11, one can see the ralations of all variables with their own national aggregate output. In all considered models and parameterizations, net exports over output are countercyclical, and only in the TOT can be found a similar result. Nevertheless only in one case (one sector with spillovers) the result is significantly different from zero.

Labour and investment are very correlated with aggregate output , being always higher the labour correlation than the investment correlation. This is not what is seen in data, but the standard errors of these measurements do not allow fixing that as a model delusory result. Labour productivity is positively correlated with output, far from the heterogeneous results of data.

Private consumption is always positively correlated with output, but far from data. The two sectors model exhibits a very low contemporaneous correlation with its national aggregate output. Nevertheless, in the fourth lag this correlation is higher than the higher correlation of the one sector model (0,57 against 0,45). This result, very far from data, is very interesting considering that this kind of models, without time to build or time to plan, only used to allow one lag or lead in any variable. This numbers, and the ones of a low relative volatility of private consumption in the two sector model, say that individuals smooth a lot their consumption path along time.

Finally, exports are not correlated with output, while imports are very much correlated with output, getting a results in the middle of data sample for the latter variable.

Table 12 exhibits the international comovements of variables between countries. Looking at the international correlations of aggregate output, one can see how introducing spillovers improve general results. Nevertheless, the low values of the positives correlations, joint with the correlation of sectorial outputs in the two sector model (negative in the case of the non tradable sector) says that the model could be better calibrated with correlations between international productivity shocks. The reason for not showing them is that with the raw results of all models, their basic characteristics can be better seen.

Private consumption international correlations have a very wide range of results among models. In the one sector model with α=0, this correlation is equal to one, due to the analytical solution of one of the partial derivatives of the model. International trade allows for consumers to equal their consumption, and it is done in every period. If the definition of final consumption is wider, and then includes a portion α of government purchases, the private consumption correlations diminish. In the two sectors model, this correlation is not significantly different from zero. Nevertheless, the latter model improves the quantity anomaly: the correlations between aggregate outputs are higher than the correlations between consumptions. Introducing α=1 in the one sector model diminishes the international correlation between consumptions, but it does not change the wrong order. On the contrary, the two sectors model changes this anomaly. Their low value of international consumption correlation can be better fitted introducing international correlation among technological shocks.

Another variable that also gets a better result with the two sectors model, is labour productivity: its correlations are lower than the correlation between outputs, although the difference is not significant and, maybe, could change introducing correlations among technological shocks.

Labour and investment changes their correlation sign in the one sector model when one considers international spillovers. The difference is dramatic in the investment variable, indeed, having similar values with different sign. A more normal result is obtained in the two sector model, although the correlation is negative in investment, even though spillovers are there considered.

7. CONCLUDING COMMENTS

I conclude this paper summarizing some of the relative improvements of the proposed model. It can be said that considering two intermediate sectors allows for a better comprehension of variable international relations. It is important to note, that the more important results of the international real business cycle models can be achieved with a one sector BKK model, but considering two intermediate sectors can do a better job in solving the quantity anomaly. The Stockman and Tesar model could not solve this fact, because they considered two goods, that could be differentiated by the consumer. Here, the consumer cannot see one or the other sector. Here the sectorial difference is technical: the global economy needs sectorial output to produce a final good, which will be distributed in private consumption, investment (in any sector) or government purchases. This technical relation introduces a different source of relations in the economy, that drives the outputs to be more correlated internationally than private consumptions, partially solving the BKK quantity anomaly.

It is not clear the fact that the technical relation in the aggregate production function can do a better job than the Stockman and Tesar model of final distinction between sectors. Using sectorial intermediate outputs introduces relative prices of inputs (and their factors) to be considered, while using distinguishable goods uses the real relative prices, seen by consumers. Using a wider model with final goods and intermediate sectors perhaps could be the final solution.

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APPENDIX: DATA DESCRIPTION

I used quarterly (when possible) and yearly data in order to characterise the business cycle. For Spain, data came from the *Contabilidad Nacional Trimestral,* of *Instituto Nacional de Estadística*. In order to use per capita measures I quarterized the population serie using the Boot, Feibes y Lisman (1967) method. The quarterly measurement of labour was extracted from the *OECD Statistical Compendium, Quarterly Labor Force Statistics*. The period was 1970(I)-1998(IV). Nevertheless, I had to quarterize the first two years of the labour variable, using a method consistent with the sample characteristics of this variable. The quarter measurement of capital was computed used the perpetual inventhory method.

In order to compute the EU4 measurements, I used *OECD Statistical Compendium, National Accounts,* and *Quarterly Labor Force Statistics*. French labour had to be adjusted in the same way that I did with the Spanish labour. German data had the problem of unification. I used univariant autoregresives of order one to enlarge the initial RFA serie with the unified German serie. The enlargement was made in 1991(I).

Yearly data was used when sectorial variables were considered. Spanish data was extracted from *Instituto Nacional de Estadística* and from *Sophinet* data base, from the *BBV Foundation*, and international data came from *International Sectoral Data Base*. Tradable distinction was made following Stockman and Tesar (1995). Therefore, tradable sectors are agriculture, manufacturing, mining and retail and transportation sectors, and non tradable sectors include electricity, gas and water, construction, finance, insurance, and private and government services. I did not use *real state*, due to the fact that the capital output ratios of this variable distortionate the aggregate capital output ratio, driving it to a number far from usual. Depreciation rates were computed using this database, assuming the capital law of motion in order to calibrate the rates.

Solow residuals were computed taking into account the considered production functions, and the labour share was computed as the ratio between workers wage and output in every sector. Then, it does not consider the *European Economy* correction of this ratio.

Table 1. USA cyclical characteristics

Variable	Std. Dv.	Relative Dispersion	Cross Correlation Function with Output										
			-5	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*	*5*
Y	1,72%	1,00	0,02	0,16	0,38	0,63	0,85	1,0	0,85	0,63	0,38	0,16	-0,02
I	8,24%	4,79	0,04	0,19	0,38	0,59	0,79	0,91	0,76	0,50	0,22	-0,04	-0,24
CP	1,27%	0,74	0,25	0,42	0,57	0,72	0,82	0,83	0,67	0,46	0,22	-0,01	-0,20
G	2,04%	1,19	0,03	-0,01	-0,03	-0,01	-0,01	0,04	0,08	0,11	0,16	0,25	0,32
X	5,53%	3,22	-0,48	-0,42	-0,29	-0,10	0,15	0,37	0,50	0,54	0,54	0,52	0,44
Q	4,88%	2,84	0,11	0,19	0,31	0,45	0,62	0,72	0,71	0,52	0,28	0,04	-0,18
N	1,59%	0,92	-0,06	0,09	0,30	0,53	0,74	0,86	0,82	0,69	0,52	0,32	0,11
Y/N	0,90%	0,52	0,06	0,14	0,20	0,30	0,33	0,41	0,19	0,00	-0,18	-0,25	-0,24

Note: Y is output, I is investment, CP is private consumption, G are government purchases, X are exports, Q are imports, N is labour, and Y/N is productivity.
Source: Cooley and Prescott (1995), for HP filter detrended quarterly data, period 1954:I-1991:II.

Table 2. Spanish and UE4 cyclical characteristics

Variable	Std. Dv.	Relative Dispersion	Cross Correlation Function with Output										
			-5	*-4*	*-3*	*-2*	*-1*	*0*	*1*	*2*	*3*	*4*	*5*
Spain													
Y	1,20%	1,00	0,38	0,53	0,69	0,84	0,96	1,00	0,95	0,82	0,63	0,46	0,34
I	4,53%	3,78	0,43	0,54	0,66	0,76	0,83	0,84	0,78	0,67	0,52	0,37	0,25
CP	1,34%	1,11	0,38	0,49	0,60	0,70	0,76	0,76	0,70	0,60	0,53	0,49	0,51
G	1,18%	0,99	-0,09	-0,03	0,09	0,24	0,38	0,46	0,48	0,45	0,43	0,44	0,50
X	3,02%	2,52	0,03	0,06	0,08	0,10	0,11	0,11	0,07	-0,01	-0,12	-0,23	-0,32
Q	4,60%	3,83	0,37	0,42	0,48	0,52	0,53	0,50	0,43	0,34	0,27	0,25	0,29
NX/Y	2,56%		-0,45	-0,49	-0,53	-0,57	-0,59	-0,60	-0,59	-0,58	-0,57	-0,56	-0,55
TOT	4,17%	3,47	0,27	0,25	0,17	0,07	-0,01	-0,03	0,03	0,15	0,29	0,38	0,40
N	1,62%	1,35	0,51	0,62	0,72	0,80	0,84	0,83	0,78	0,68	0,57	0,46	0,35
K	0,87%	0,72	-0,32	-0,25	-0,15	-0,03	0,10	0,24	0,37	0,49	0,58	0,64	0,66
A	0,78%	0,65	0,15	0,19	0,25	0,29	0,30	0,24	0,10	-0,09	-0,27	-0,41	-0,48
Y/N	0,96%	0,80	-0,30	-0,32	-0,32	-0,31	-0,30	-0,30	-0,32	-0,34	-0,35	-0,35	-0,32
EU4													
Y	0,78%	1,00	0,26	0,41	0,59	0,78	0,94	1,00	0,94	0,78	0,59	0,43	0,30
I	2,49%	3,20	0,20	0,34	0,50	0,67	0,82	0,89	0,87	0,77	0,62	0,47	0,33
CP	0,84%	1,08	0,38	0,51	0,64	0,76	0,85	0,86	0,80	0,69	0,56	0,45	0,35
G	0,48%	0,62	-0,15	-0,13	-0,08	-0,01	0,05	0,10	0,13	0,13	0,15	0,19	0,25
X	2,43%	3,13	0,03	0,11	0,24	0,42	0,58	0,67	0,64	0,47	0,25	0,07	-0,05
Q	2,92%	3,75	0,13	0,24	0,39	0,56	0,72	0,81	0,80	0,67	0,49	0,31	0,17
NX/Y	1,05%		0,24	0,21	0,19	0,16	0,12	0,11	0,09	0,04	-0,01	-0,04	-0,07
TOT	2,09%	2,68	0,43	0,43	0,35	0,23	0,11	0,03	0,01	0,04	0,09	0,11	0,09
N	0,56%	0,72	0,53	0,62	0,70	0,73	0,72	0,65	0,54	0,39	0,21	0,02	-0,16
K	0,28%	0,37	-0,62	-0,58	-0,51	-0,41	-0,29	-0,14	0,02	0,18	0,33	0,46	0,55
A	0,66%	0,84	0,20	0,35	0,53	0,72	0,83	0,86	0,79	0,67	0,54	0,46	0,43
Y/N	0,96%	1,24	-0,25	-0,28	-0,30	-0,31	-0,30	-0,28	-0,26	-0,24	-0,23	-0,22	-0,19

Note: Y is output, CP is private consumption, I is investment, N is labor, G is public expenditure, X are exports, Q are imports, NX/Y are net exports over output, TOT are the terms of trade, K is capital, A is the Solow residual, and Y/N is labour productivity.
Source: *Instituto Nacional de Estadística, National Accounts (OECD Statistical Compendium)* and self made, for BK filter detrended quarterly data, period 1970:I-1998:IV.

Table 3. Spanish and UE4 international cyclical characteristics

K	0,824
TOT	0,805
Y	0,617
Q	0,603
CP	0,576
N	0,505
I	0,480
X	0,416
NX/Y	0,124
Y/N	0,077

Note: Y is output, CP is private consumption, I is investment, N is labor, G is public expenditure, X are exports, Q are imports, NX/Y are net exports over output, TOT are the terms of trade, K is capital, A is the Solow residual, and Y/N is labour productivity.
Source: *Instituto Nacional de Estadística, National Accounts (OECD Statistical Compendium)* and self made, for BK filter detrended quarterly data, period 1970:I-1998:IV.

Table 4. Literature international cyclical characteristics

	Variability (%)						Correlation
	Y	A	K	N	I	CP	$Y^{TRA}, Y^{NON\ TRA}$
Germany							
Aggregate	1,95	1,50	2,79	1,60	5,25	n.a.	0,61
Traded	2,24	1,64	2,79	1,77	6,51	n.a.	
Non Traded	1,93	1,73	3,15	1,52	5,59	n.a.	
Italy							
Aggregate	2,37	2,60	2,58	1,01	5,28	0,76	0,86
Traded	3,03	2,69	2,01	1,73	6,18	0,70	
Non Traded	1,55	2,90	3,82	0,66	6,19	0,86	
USA							
Aggregate	2,69	1,60	2,82	1,96	6,18	1,25	1,00
Traded	3,99	2,74	1,76	2,72	7,59	1,64	
Non Traded	1,47	1,94	4,07	1,26	8,83	1,21	

Note: Y is output, CP is private consumption, I is investment, N is labor, A is the Solow residual, K is capital. "n.a." means *not available.*
Source: Stockman and Tesar (1995), for yearly data, period 1970 -1986.

Table 5. Spanish and UE4 sectorial cyclical characteristics

Spain	Y	I	A	N	K	Y/N
Aggregate	1,18%	3,78%	0,63%	1,83%	0,69%	1,61%
Traded	1,47%	6,87%	0,85%	2,19%	1,07%	2,06%
Non Traded	1,23%	4,21%	0,55%	1,78%	0,53%	1,56%
Corr(Tra, Non Tra)	0,465	-0,036	0,320	0,509	0,697	0,312
EU4						
Aggregate	1,32%	2,29%	0,58%	0,66%	0,30%	0,95%
Traded	1,86%	3,26%	0,89%	0,94%	0,37%	1,43%
Non Traded	0,74%	1,78%	0,34%	0,47%	0,29%	0,61%
Corr(Tra, Non Tra)	0,805	0,622	0,601	0,600	0,795	0,494

Note: Y is output, CP is private consumption, I is investment, N is labor, A is the Solow residual, K is capital and Y/N is labour productivity.
Source: *Instituto Nacional de Estadística, International Sectorial Database (OECD Statistical Compendium)* and self made, for BK filtered year data, period 1970 -1993.

Table 6. Spanish and UE4 sectorial international cyclical characteristics

(Spain, EU4)	Trade	Non Trade
Y	0,484	0,486
I	0,274	0,236
A	0,699	0,288
N	0,352	0,144
K	0,698	0,532
Y/N	0,526	0,131

Note: Y is output, I is investment, N is labour, K is capital, A is the Solow residual, and Y/N is labour productivity.
Source: Instituto Nacional de Estadística, National Accounts (OECD Statistical Compendium) and self made, for BK filtered year data, period 1970 -1993.

Table 7. Parameters considered in calibration of the two countries one sector model

θ	δ	ϕ	β	ρ_g	σ_g	σ_a	ρ_a	ρ_b	ρ_a	ρ_b
0,42	0,025	0,05	0,988	0,97	0,02	0,009	0,95	0	0,70	0,25
θ^*	δ^*	ϕ^*	π	ρ_g^*	σ_g^*	σ_a^*	ρ_b	ρ_a^*	ρ_b	ρ_a^*
0,42	0,025	0,05	0,5	0,97	0,02	0,009	0	0,95	0,25	0,70

Table 8. Additional parameters considered in calibration of the two countries two sectors model

y^1_1/y^1 0,50	y^1_2/y^1 0,50	r^1_g 0,97	r^1 1,5	r^1_T 1,5	q^1_1 0,44	d^1_1 0,025	f^1_1 0,05	s^1_1 0,019
QPY^1 0,2		s^1_g 0,02			q^1_2 0,39	d^1_2 0,025	f^1_2 0,05	s^1_2 0,014
y^2_1/y^2 0,50	y^2_2/y^2 0,50	r^2_g 0,97	r^2 1,5	r^2_T 1,5	q^2_1 0,44	d^2_1 0,025	f^2_1 0,05	s^2_1 0,019
		s^2_g 0,02			q^2_2 0,39	d^2_2 0,025	f^2_2 0,05	s^2_2 0,014

Table 9. VAR matrix of the technological process in the two countries two sectors model

a_{11}	0,70	0,15	0	0
a_{12}	0,15	0,70	0	0,15
a_{21}	0	0	0,70	0,15
a_{22}	0	0,15	0,15	0,70

Table 10. Comparison between data and model results. Volatility

	Data (Spain)	Data (UE4)	Data (USA)	2p1s (ρ_b=0)	2p1s (ρ_b=0,25)	2p2sec
Volatility (%)						
Y	1,201%	0,779%	1,720%	1,800%	1,450%	2,530%
				0,003	*0,002*	*0,003*
NX/Y	2,558%	1,048%	1,190%	3,810%	1,370%	3,500%
				0,014	*0,002*	*0,007*
Y1	1,467%	1,857%	3,990%			3,290%
						0,004
Y2	1,234%	0,739%	1,470%			3,250%
						0,004
Relative volatility						
CP	1,115	1,078	0,740	0,318	0,310	0,265
				0,001	*0,001*	*0,001*
N	1,349	0,723	0,920	0,734	0,717	0,759
				0,002	*0,001*	*0,002*
N1	1,827	1,202	1,581			1,079
						0,003
N2	1,485	0,599	0,733			0,731
						0,002
I	3,776	3,204	4,790	4,751	2,421	5,237
				0,021	*0,007*	*0,019*
I1	5,726	4,182	4,413			3,178
						0,011
I2	3,508	2,286	5,134			8,055
						0,045
Y/N	0,803	1,238	0,520	0,376	0,379	0,340
				0,001	*0,001*	*0,001*
X	2,515	3,125	3,220			1,063
						0,004
Q	3,831	3,754	2,840			1,759
						0,005
TOT	3,475	2,679	2,140			1,474
						0,004

Note: Y is output, CP is private consumption, I is investment, N is labor, G is public expenditure, X are exports, Q are imports, NX/Y are net exports over output, TOT are the terms of trade, and Y/N is labour productivity. 1 and 2 refers to non tradable and tradable sectors, respectively. Cursive figures are the standard errors of raw statistics.

Source: USA data comes from Stockman and Tesar (1995) and Cooley and Prescott (1995), while Spanish and UE4 data is self computed.

Table 11. Comparison between data and model results. National correlations.

	Data (Spain)	Data (UE4)	Data (USA)	2p1s (ρ_b=0)	2p1s (ρ_b=0,25)	2p2sec
Correlation with own output						
NX/Y	-0,602	0,110	-0,190	-0,020	-0,385	-0,189
				0,170	*0,130*	*0,119*
CP	0,760	0,862	0,830	0,409	0,450	0,283
				0,220	*0,130*	*0,084*
N	0,830	0,654	0,860	0,950	0,951	0,962
				0,040	*0,040*	*0,012*
I	0,835	0,894	0,910	0,864	0,846	0,911
				0,040	*0,080*	*0,028*
Y/N	-0,300	-0,278	0,410	0,788	0,815	0,789
				0,130	*0,080*	*0,061*
X	0,105	0,672	0,370			0,013
						0,186
Q	0,500	0,814	0,720			0,702
						0,080
TOT	-0,034	0,027	-0,200			-0,039
						0,122

Note: Y is output, CP is private consumption, I is investment, N is labor, G is public expenditure, X are exports, Q are imports, NX/Y are net exports over output, TOT are the terms of trade, and Y/N is labour productivity. Cursive figures are the standard errors of raw statistics.
Source: USA data comes from Cooley and Prescott (1995), while Spanish and UE4 data is self computed.

Table 12. Comparison between data and model results. International correlations.

	Data (Spain, EU4)	Data (USA, Europe)	2p1s (ρ_b=0 ; α=0)	2p1s (ρ_b=0,25 ; α=0)	2p1s (ρ_b=0 ; α=1)	2p1s (ρ_b=0,25 ; α=1)	2p2sec
International Correlations							
Y	0,617	0,660	-0,413	0,209	-0,364	0,242	0,274
			0,200	*0,200*	*0,180*	*0,200*	*0,171*
NX/Y	0,489		-0,993	-0,999	-0,993	-0,999	-0,983
			0,010	*0,000*	*0,010*	*0,000*	*0,007*
Y1	0,484						-0,210
							0,167
Y2	0,486						0,788
							0,062
CP	0,576	0,510	1,000	1,000	0,524	0,457	0,068
			0,000	*0,000*	*0,160*	*0,170*	*0,308*
N	0,505	0,330	-0,672	0,035	-0,680	-0,001	0,214
			0,130	*0,210*	*0,110*	*0,210*	*0,179*
I	0,480	0,530	-0,739	0,950	-0,720	0,952	-0,210
			0,090	*0,020*	*0,080*	*0,020*	*0,166*
Y/N	0,077		0,585	0,775	0,507	0,740	0,228
			0,150	*0,080*	*0,160*	*0,100*	*0,218*

Note: Y is output, CP is private consumption, I is investment, N is labor, G is public expenditure, X are exports, Q are imports, NX/Y are net exports over output, TOT are the terms of trade, and Y/N is labour productivity. 1 and 2 refers to non tradable and tradable sectors, respectively. Cursive figures are the standard errors of raw statistics.
Source: USA data comes from Backus, Kehoe, Kydland (1995), while Spanish and UE4 data is self computed.