PAPER PREPARED TO BE PRESENTED IN ETSG 2005 CONFERENCE. IN DUBLIN 8-10 SEPTEMBER

TESTING HECKSCHER-OHLIN-VANEK MODEL USING SPANISH REGIONAL DATA

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Abstract
We study the Heckscher-Ohlin-Vanek (HOV) model of trade empirically using regional data rather than country data. Our findings for the Spanish regions suggest that the HOV model performs remarkably well after relaxing the “strict” assumptions of world factor price equalisation and world identical and homothetic preferences. We also test whether Spanish regions share the same production techniques. Allowing for productivity-adjusted factor price equalisation across regions or regional-specific input-output matrices contributes very little to improve the predictive capacity of the HOV model, suggesting that the state of technology and choice of techniques is quite similar across Spanish regions.

Keywords: Heckscher-Ohlin-Vanek (HOV) model, factor content of trade, Spanish regions.

JEL Classification: F11, F14, R12.

Acknowledgements: Francisco Requena is member of INTECO (GRUPOS03/151) and is grateful for financial support from the Generalitat Valenciana, project number GV04B-070.

1. Introduction.

The Heckscher-Ohlin (HO) model is the cornerstone of international and interregional trade theory. The popularity of the HO reflects the useful insights concerning the pattern of trade as well as the income distributional consequences of trade it provides. First, trade flows are dictated by the comparative advantage arising from initial factor endowments. Second, trade volume is expected, *ceteris paribus,* to be positively correlated with the dispersion of relative factor endowments. A capital-abundant region is expected to trade more with a labour-abundant region than with another labour-abundant region. Finally, trade liberalisation raises the reward accruing to the relatively abundant factor and lowers the reward accruing to the relatively scarce one. Each of these expected results of traditional trade theory has been refuted by empirical work, as it was first found by Leontief (1953), and later studies conducted by Maskus (1985) and Bowen *et al.* (1987), amongst others. The theoretical implications of the endowment-driven theory of production and trade have stimulated a line of research orientated to find the reasons why the HO model performs so badly.

The extension by Vanek (1968) of the Heckscher-Ohlin theory of international trade to multiple factors of production, commodities and regions (the so called HOV model) establishes a relationship between factor abundances of regions, factor intensities of industries in the different regions and net trade flows: A region is expected to export the services of the factors that has in relative abundance and to import the services of the factors that are relatively scarce. This paper investigates the predictive capacity of the HOV model using regional data rather than country data. The reason for taking a regional, rather than a cross country, focus is that the regions from the same country share similar relative factor endowment, state of technology and preferences. These similarities among regions are necessary for the HOV theory to hold and, as we will establish below are supported by the data.

Davis *et al.* (1997) [DWBS] have already investigated the predictive capacity of the HOV model using regional data.[1] However, as far as we know, this is the only paper. Then more evidence is needed to corroborate their findings. One important difference with respect to DWBS is the availability of regional input-output tables in Spain to calculate the vector of net exports as the difference between net output and domestic consumption. In addition, our data allow for testing whether there are significant regional technological differences, an important assumption that has not been tested before using regional data.[2]

We follow the DWBS methodology with our Spanish regional data. First they predict the factor content of trade for Japanese regions using actual world factor endowments under the assumptions of world factor price equalisation (W-FPE) and

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[1] There are previous attempts to study the factor-endowment theory of trade using regional data (Moroney and Walker, 1966; Grimes and Prime, 1993; Horiba, 1997; Smith, 1999). However, they do not provide a "complete" test of the HOV model. See Davis *et al.* (1997) for a criticism of previous research.

[2] Davis *et al.* (1997) use different statistical sources to calculate separately net output and domestic absorption.

world identical and homothetic preferences (W-IHP). The strict HOV performs poorly and replicate Trefler´s (1995) "mystery of the missing trade". Our results corroborate their finding. Next they relax the assumptions of world factor price equalisation (W-FPE) but maintain the assumption of world identical and homothetic preferences (W-IHP). The modified HOV model performs remarkably well. However, we find no improvement using Spanish data. Finally, when they also relax the assumption of world identical and homothetic preferences, this modified version of the HOV model does not improve the predictive capacity of the HOV model. Unlike DWBS, we find that it is necessary to relax both assumptions (W-FPE and W-IHP) to achieve marked improvement in the predictive capacity of the model for the Spanish regions.

The usual caveat about using the technology of one country to evaluate the factor content of trade from other countries does not apply here since we use the Spanish technology matrix to evaluate the factor content of trade of Spanish regions. However, we feel the need to check whether the regional technological differences are important, especially after finding that relaxing world FPE was not enough to improve the predictive capacity of the HOV model. When the strict assumption of equality of region production techniques is relaxed allowing for productivity-adjusted FPE across regions or regional-specific technological matrices contributes very little to improve the predictive capacity of the HOV model. This suggests the state of technology and choice of techniques is quite similar across Spanish regions.

The remainder of the paper is organised as follows. Section 2 introduces the dataset and describes salient features of Spanish regional trade. Section 3 derives the empirical models (the "strict" HOV model vs "modified" versions of the HOV) and presents the battery of non-parametric and parametric tests of those models. Section 4 contains the empirical results. Section 5 checks whether Spanish regions share the same technology. Finally, Section 6 provides a concluding discussion of the findings.

2. Spanish regional trade.

One major contribution of this paper is the construction of a database of trade at regional level using Input-Output Tables. To test the HOV predictions we need information about all imports and exports of each region, that is, we need to know both inter-regional and international trade flows to calculate the factor content of trade.[3] We

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[3] For example, when testing the Heckscher-Ohlin theory using U.S. regional data, Smith (1999) considers only international trade flows. However, any regional empirical test of the endowment-driven theories of

have used regional input-output (IO) tables to calculate trade flows of Spanish regions around the year 1995. The data appendix contains detailed information about the construction of the database, variables and sources.

Table 1 presents a description of the Spanish regional trade, both at interregional and at international level. Column 1 shows the economic importance of the regions included in our study. We have IO tables for all regions but three of the 17 regions, Cantabria, Murcia and La Rioja. As a percentage of the Spanish GDP, the three regions have very small weight in the Spanish economy, accounting for only 4.2 % of Spanish GDP in 1995. Our dataset; therefore, incorporates the bulk of the Spanish regional trade.

Column 2 shows the openness ratio, conventionally defined as total exports and imports divided by GDP, at regional level. On average, the sum of exports and imports is greater than the regional GDP. The regions with the largest openness ratio are Aragon (180%), Navarra (167%) and Valencia Region (136%).[4] The regions with the smallest openness ratio are the two island regions, Canary Islands (59%) and Balearic Islands (71%) and the regions with less per capita income, Extremadura (62%) and Andalucia (76.5%).

An important novelty in the data set is the inclusion of the trade of services.[5] Column 3 shows the importance of tradable services. On average, tradable services represent above 10% of the total regional trade, with one particular region, Madrid, whose service trade are the 31% of total trade, three times larger than the national average. Column 4 shows that interregional trade represents a large proportion of the trade of each Spanish regions. On average the percentage is above 70%, with maximum values of 88.7% of Castilla-La Mancha and 92.4% of Extremadura. Column 5 reveals that trade of services is mainly interregional (87.6% on average), compared to the trade of goods and services (71% on average). The last four columns of Table 1 decompose the trade flows in exports and imports to check the importance of the flow direction in regional trade openness as well as to examine the role of service trade.

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trade using only international trade data will be severely biased as inter-regional trade flows account for most of the total trade of the regions. For the regions of Spain, above 60 percent of total trade is inter-regional trade.

[4] It is interesting to point out the presence of important multinacionals of the automobile industry: Ford in Valencia, Renault in Aragón and Volswagen in Navarra.

[5] Oliver (2003) has constructed an alternative database of Spanish regional trade which includes only tradable goods. In the Annex 2 (pages 229-258) of this publication there is a comparison between his database and our database. It is remarkable that there are not large differences between both databases.

[INSERT TABLE 1 ABOUT HERE]

3. Theory and tests.

Let Y be the net output, Q be the gross output and V be the factor endowment. Then $Y^r = (I - B^r)Q^r$ and $D^r(I - B^r)^{-1}Y^r = V^r$, where $D^r(I - B^r)^{-1}$ is the technology matrix or matrix of gross factor input requirements, which indicates the total (both direct and indirect) amount of each of the factors needed to produce one unit value of gross output within each of the industries, D^r is a matrix whose element (m,n) gives the average amount of factor *m* used directly to produce one unit of final output *n* in region *r*, B^r is the amount of intermediate input *m* used to produce one unit of good *n*.[6] Maintaining the assumption that all countries share the same matrix of direct factor inputs and a common input-output matrix, (the superscript S stands for Spain),

$D^r = D^S, B^r = B^S, \quad \forall r \in S$ and $D^S Q^W = V^W$

Since trade is simply the difference between production and consumption (absorption), the derivation of the HOV equation begins with the identity that a region´s net factor exports can be expressed as the difference between factors absorbed in production and factors absorbed in consumption under the assumption of full employment of factors:

$$(1) \qquad D^S(I - B^S)^{-1}T^r = V^r - D^S(I - B^S)^{-1}C^r$$

where T^r is the vector of net exports of region r (the vector has n elements, equal to the number of commodities), V^r is the vector of factor endowments of region r (the vector has m elements, equal to the number of factors) and C^r is the vector of domestic absorption of region r. We premultiply T^r and C^r by $D^r(I - B^r)^{-1}$ to convert net output for trade and consumption into total factor content of trade and consumption.

As in the traditional HOV studies, equation (1) is transformed into a testable hypothesis by making one or more of the following assumptions: (i) no measurement errors exist; (ii) commodities are freely mobile between regions while factors are immobile; (iii) technologies are the same in each region; (iv) factor prices fully equalize between regions (FPE); and, (v) identical homothetic tastes are assumed in all regions (IHP). Certainly if the HOV model is ever to be shown consistent with data, it will

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[6] Gross intensities (or direct-plus-indirect) are the appropriate measure for factor intensities since it is these that determine autarky prices (Deardoff, 1984).

plausibly be for a group of regions within a country, rather than for a sample of similar countries, where it is more likely that regions share similar factor endowments distribution, technology and preferences.[7]

In conducting empirical analysis, attention must be paid to these assumptions. While in the 2x2x2 Heckscher-Ohlin model the assumption (iv) arises as a result, the HOV model assumes factor price equalisation from the outset. If there is no full factor price equalisation then in (1) the technology matrix $D^r(I-B^r)^{-1}$ will not be the same in all regions and the vector T^r of net exports will not be the appropriate variable for measuring the factor content of trade of a region since exporting and importing industries will not produce under the same factor intensities.

There are two important requirements for assumption (iv) to be met. The first requirement is that countries are not too dissimilar in relative factor endowments. Using recent theoretical advances in trade theory by Deardoff (1994) and Xiang (2001), Debaere (2004) for the regions of UK and Japan and Aulló y Requena (2004) have showed that their relative factor endowments are not too dissimilar for Spanish regions.

The second requirement is that assumption (iii) holds, that is, the state of technology is similar across regions. The “strict” HOV model uses a single technological matrix for all countries or regions being tested. For example, James and Elmslie (1996) use the U.S. technological matrix to test the validity of the “strict” HOV model among 7 OCDE countries after showing correlations above 0.87 between the technology matrices of France, Germany, Italy, Japan, U.K. and Canada to the U.S. input-output table for 1965. However, they found weak empirical support for the “strict” HOV predictions. Recent research using international data shows that allowing for international technology differences significantly improves the predictive power of the HOV model.[8]

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[7] The measurement of the variables is also more accurate within a country since data is collected by a single statistical office, avoiding consistency problems. Finally, trade impediments are less important within a country. Finally, labour factor mobility among Spanish regions is much lower than in other countries (Mauro and Spilimbergo, 1998; Serrano, 1998).

[8] Pioneering papers testing the HOV model such as Maskus (1985) and Bowen *et al.* (1987) also utilize a single input-output table (for the U.S.) in constructing the technology matrix after imposing universal factor price equalisation. Bowen *et al.* (1987) and Trefler (1993, 1995) showed that international productivity differences explain at least part of the observed failure of the “strict” HOV model. Hakura (2001) and Davis and Weinstein (2001) used country-specific input-output tables for four EC countries and ten OCDE countries, respectively, to show that allowing for Hicks-neutral technological differences across countries greatly improves the fit of the model. More recently, Davis and Weinstein (2003) and Trefler and Zhu (2005) find that allowing for international technology differences significantly improves the predictive power of the HOV model.

DWSB (1997) and Davis and Weinstein (2001) show how to derive exact predictions for the factor content of trade in a world in which only a subset of regions share factor price equalisation. This allows us to forego the heroic assumption of universal factor price equalisation, continue to embed this in a full general equilibrium and derive exact predictions to compare with the data. We follow this strategy: for a group of regions within a country, we relax the assumptions (iv) and (v) about world factor price equalisation (W-FPE) and world identical and homothetic preferences (W-IHP). If we believe that FPE holds for the world as a whole, all countries (and their regions) use the same technology, so $D^S(I-B^S)^{-1}C^r = s^r D^S Q^W = s^r V^W$. But, if we believe that FPE fails for the world as a whole but holds for the regions of Spain, then $D^S Q^W \neq V^W$ but we still have the expression $D^S(I-B^S)^{-1}C^r = s^r D^S Q^W$, which requires to know the world gross output.

Finally, if we require identical and homothetic preferences only for the regions of Spain, rather than for the whole world, this may be expressed as $C^r = \left(s^r / s^S\right) C^S \quad \forall r \in S$. The implied factor content of absorption is $D^S(I-B^S)^{-1}C^r = \left(s^r / s^S\right) D^S(I-B^S)^{-1}C^S$ where s^r is the share in world spending for region r and s^S is the Spanish share in word spending.

Using equation (1) we can obtain three different HOV equations under three different assumptions about FPE and IHP. Under the assumptions that factor price equalisation and identical homothetic preferences hold for the world as a whole, the strict HOV model is:

(MODEL I) $D^S(I-B^S)^{-1}T^r = V^r - s^r V^W$ **(W-FPE and W-IHP)**

If we believe that FPE fails for the world as a whole but FPE still holds for the regions of Spain, the "modified" HOV model is:

(MODEL II) $D^S(I-B^S)^{-1}T^r = V^r - s^r D^S Q^W$ **(R-FPE and W-IHP)**

If we believe that FPE holds only for the regions of Spain and that IHP holds for Spain but not for the world as a whole, then the relevant equation is:

(MODEL III) $D^S(I-B^S)^{-1}T^r = V^r - \left(s^r / s^S\right) D^S(I-B^S)^{-1}C^S$ **(R-FPE and R-IHP)**

These three theoretical trade equations establish an exact link between technology, output, absorption and endowments. These exact relations are too much to hope for with real data. So we consider less exacting tests. The two sides each equation are vectors with j elements in each side. The elements of left-hand-side of the equations represent the factor content of net exports in each of the j factors in region r and the elements of the right-hand-side show the excess supply in each of the j factors in region r. A typical single-factor equation will take the form:

(MODEL I) $FT_j^r = V_j^r - s^r V_j^W$ for each region r

(MODEL II) $FT_j^r = V_j^r - s^r FQ_j^W$ for each region r

(MODEL III) $FT_j^r = V_j^r - \left(s^r / s^S\right) FC_j^S$ for each region r

where FT_j^r is the total quantity of any factor j embodied in region´s r net exports, V_j^r is the endowment of factor j in region r, V_j^W is the endowment of factor j in the world, FQ_j^W is the endowments of factor j in world gross output and FC_j^r is the endowments of factor j in Spanish absorption. The theory establishes for a given factor (region) a vector equality between what we term the *measured* [left-hand-side] and *predicted* [right-hand-side] factor content of trade for each region (factor).

For each model, three nonparametric tests of the HOV are implemented: the “sign” test, the “rank” test and the “missing trade” test. The sign test compares the signs of the values of the elements of the vectors on the two sides of equations and checks if they are the same. For a typical element,

$$sign(FT_j^r) = sign(V_j^r - s^r V_j^W) \quad r = 1,...R;\ j = 1,...,M$$

A sign match implies that the region in fact is a net exporter or importer of the factors that theory predicts. One can calculate the proportion of correct sign matches by factor (across regions), by regions (across factors), or for the matrix as a whole. With M factors and R regions, there are MR observations in total, and we are interested in what *percentage* of these has the same sign on the two sides of the equation. Notice that a completely random pattern of signs such as obtained by flipping a coin would still generate correct signs 50% of the time in a large sample. Therefore, the sign test must do considerably better than this in order to conclude that the HOV theory is successful.

The rank test compares the ranking, by factor (across regions) or by region (across factors), of the *measured* and *predicted* factor content of trade. If the corresponding cells of the matrices are supposed to be identical, then one should expect that when comparing rows (ranking of an individual factor across all regions) or columns (ranking of an individual region across factors), there should be high raw and rank correlations. An alternative way is to perform the test for each pair of elements (if we select Model I):

$$FX_k^r > FX_l^r \Leftrightarrow (V_k^r - s^r V_k^w) > (V_l^r - s^r V_l^w) \quad r = 1,...R; k,l = 1,...,M$$

This alternative rank test involves a pairwise comparison of all factors for each region, so there are M(M–1)/2 pairs for each of the R regions. If the computed factor content of one factor exceeds that of a second factor, then we check whether the relative abundance of that first factor also exceeds the relative abundance of the second factor. Again, a completely random assignment of factor abundance and relative endowments would imply that in 50% of the comparisons in a large sample, the rank test would be satisfied, so we would hope that the actual data perform considerably better than this.

A third non-parametric test, the so-called “missing trade” test, was proposed originally by Trefler (1995) and is based on calculating the ratio of the variance of the *measured* factor content of trade divided by the *predicted* factor content of trade. If the theory works, the ratio of variances should be equal to one.

Regression analysis is also performed in addition to the nonparametric tests. Regression analysis uses the HOV equations and pooled data across regions and factors. For each of the model specifications, we regress the *measured* factor content of trade against the *predicted* factor content of trade. From the regressions, we get an idea of overall performance and can control for the variation in individual factors and regions; thus, regression analysis supplements the nonparametric tests by considering pooled data and estimating the equation. If the HOV works we expect *a priori* that the sign of the coefficient on the predicted factor content of trade to be positive and statistically significant. If the HOV works exactly as the theory predicts, the value of coefficient will be equal to one.

Since these tests do not specify a clear null hypothesis, they merely give us an indication of how consistent the data is with the theory. If the model fits the data well, we conclude that relaxing the assumptions will not greatly enhance our understanding of the factor content of trade; when the model fits poorly, we conclude that there is may be substantial gains from considering alternative specifications.

4. Results.

The multiregional multifactor tests on the HOV equations are performed using data in the year 1995. The dataset contains information for 14 Spanish regions and 6 factors: agricultural land (TA), forest and wood land (TF), low-skill labour (LU), high-skill labour (LS), stock of R&D capital (RD), and stock of physical capital (K). A Data

Appendix provides more details about the construction of the variables and statistical sources.

Factors and regions must be expressed in comparable units in order to satisfy the statistical hypothesis of homoscedasticity. Following Trefler (1993, 1995), each pair region-factor observation is scale by $\sigma_f \sqrt{s^r}$ where s^r is the region´s *r* share in the Spanish GDP and σ_f is the standard error of prediction error of the model, expressed as the differences between the *measured* and *predicted* factor content of trade. [9]

Table 1 reports some standard statistics about the performance of the HOV equation. Columns 1, 2 and 3 each uses a different model specification. Row 1 shows the percentage of observations for which the *measured* factor content of trade has the same sign as the *predicted* factor content of trade. There are 84 observations (14 regions times 6 factors). Using Model I (W-FPE, W-IHP), the sign statistics are about 0.54, which is similar to those obtained by Bowen *et al.* (1987) and Trefler (1995). These authors concluded from this that the model performs about as well as a coin toss. Using Model II (R-FPE, W-IHP) does not improve the fit since the proportion of correct signs is almost the same. Using Model III (R-FPE, R-IHP), 77% of the observations have the correct sign. In addition, the p-value of the sign test is less than 0.05 which means that the probability of the *measured* and *predicted* factor content of trade randomly having the same sign more than 75% of the time is less than 5%. Column 4 uses Model III (R-FPE, R-IHP) again but now we calculate the factor content of net exports using interregional trade rather than total trade. The proportion of correct signs slightly falls when only interregional net exports are used suggesting that we are omitting an important part of trade in our calculations.

Row 2 shows the Kendall (or rank) correlations between the *measured* and *predicted* factor content of trade. The 0.56 correlation that holds when we use Model III (R-FPE and R-IHP) is a considerable improvement over the correlations of 0.27 and 0.23 that obtain using Model I (W-FPE and W-IHP) and Model II (R-FPE and W-IHP), respectively.

Row 3 reports Trefler´s (1995) "missing trade" statistic, i.e. the variance of the *measured* divided by the variance of the *predicted* factor content of trade. The result

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[9] For example, for model I, the deviations from the HOV model are $\varepsilon_f^r = FX_j^r - (V_j^r - s^r V_j^w)$ and $\sigma_j^2 = \sum_r \left(\varepsilon_f^r - \bar{\varepsilon}_f\right)^2 \Big/ R - 1$ where $\bar{\varepsilon}_j = \sum_r \varepsilon_f^r \Big/ R$.

from Model I and Model II is 0.04 and 0.07, respectively, i.e. a substantial amount of trade missing relative to the HOV predictions. Using Model III, the missing trade statistic rises more than five fold to 0.38. This is still low, but represents an order of magnitude improvement. When we calculate the factor content of interregional trade rather than total trade, the missing trade statistic falls to 0.29. This is because the omission of international trade flows deflates the amount of factors needed to produce net exports. We will use again the “missing trade” analysis in the next section to investigate the validity of the assumption of all regions sharing the same technology.

To complete the analysis, we complement the non-parametric analysis with a regression analysis. The idea is pooling the data to control for the variation in individual factors and regions. The regression results are presented in Rows 4 and 5. In all the regressions; the estimated coefficient β is small and the *p-value* in parenthesis indicates that they are different from 1. The magnitude of the coefficients and the fit of the regression for Model III is closer to the predictions of the HOV model than for Model I and II. However the magnitude of the coefficients indicates that changes in regions factor endowments have little effect on factor services exchanged through trade. The slope and the R^2 from the regressions of each of three specifications illustrate the same findings provided in rows 2 and 3.

[INSERT TABLE 2 ABOUT HERE]

Tables 3 and 4 provide additional results (*sign* and *rank* tests) by factor and by region, respectively. Each Table reports the results for Model I (W-FPE and W-IHP) and Model III (R-FPE and R-IHP). The results from Model II are omitted since they are very similar to those using Model I. The column labelled *Sign* indicates the proportions of matches between the sign of net exports of a factor and the sign of the excess of supply of the same factor, which is a comparison of the signs of the values on either side of the equality in the HOV equation. For example, in Table 3 (Model I) the proportion of sign matches is 0.29 for unskilled labour. This means that of the fourteen equations of Model I for unskilled labour, one for each region, four had signs that matched on either side of the equality. In contrast, the proportion of sign matches is 0.79 (eight out of fourteen) for K (physical capital). Table 3 (Model I) also shows that the proportion of sign matches is 0.33 for Madrid and Castilla-Leon, indicating that for each of the six factors, two had signs that matched on either side of the equality. In contrast, the proportion of sign matches is 0.83 for Vasc Country. Clearly the desired proportion of sign matches is 1. These results do not provide very much support for Model I on the basis of this sign test.[10]

When we perform *Sign* in Model III the number of matches improved significantly. Table 3 shows that the number of matches increased across regions in three out of six factors (skilled labour, arable land and forest land) and in Table 4 the number of matches increased across factors in six out of fourteen regions (Andalusia, Asturias, Castilla-La Mancha, Catalonia, Extremadura and Madrid). The results from Table 2 using pooled data are confirmed by Tables 3 and 4. When we examine the HOV under the assumptions of FPE and IHP at regional level, rather than world level, the number of sign matches increased both across regions and factors.

The rank proposition states that the order of the adjusted factor contents and the order of the adjusted resource abundance conform. The rank test labelled *Rank* shows the Kendall rank correlation between the rankings for each factor across the fourteen regions (Table 3) or each region across the six factors (Table 4). The poor match of the rankings as well as the low values of *rank* obtained for Model I in both Tables are quite disappointing. However, when we examine the rankings for Model III, the results improve significantly in both Tables. In Table 3 the Kendall´s coefficient of concordance (*rank*) for Model III are higher than in Model I in all but two factors and statistically significant for two factors (R&D stock and arable land). In Table 4 *rank* values in Model III are higher than in Model I.[11]

The results by factor and by region confirm those of Table 2. When we realx the assumption that Spanish regional consumption is proportional to world production, adopting instead the assumption that it is proportional to Spanish national consumption, we find an improvement in predictive power. That result suggests that allowing for home bias in demand contributes to an explanation of net factor trade patterns. Pons *et al.* (2001) obtained similar evidence for Spanish regions using an economic geographic framework.

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[10] We also implemented the Fisher´s exact test for the pooled sample used in *Sign* to test the null hypothesis of the independence between the signs of the values of either side of equations. We always rejected the null hypothesis at .05 significance level, suggesting that it is coincidental the observed sign matches.

[11] Most values are below 0.5 for Model I in Tables 3 and 4, suggesting no support for HOV under the assumptions of W-FPE and W-IHP. In Model III, there are five regions (Andalucia, Canary Islands, Castilla-Mancha, Valencian Region and Vasc Country) with statistically significant Kendall´s coefficients.

[INSERT TABLE 3 ABOUT HERE]
[INSERT TABLE 4 ABOUT HERE]

5.- Testing for regional technology differences.

In the previous section we find support for the HOV predictions under the assumptions of regional factor price equalisation and regional identical and homothetic preferences. But we have still assumed that all Spanish regions share the same technology. In this section we check the validity of this assumption. We follow two different approaches. The first approach is to use the Trefler´s (1993) productivity-equivalent transformation. This approach uses per capita GDP differences between regions as a proxy for productivity differences to re-calculate the *predicted* factor content of trade such that relative factor endowments are expressed in efficiency units rather than physical units. An alternative approach, based on the availability of input-output matrices, is to use region-specific technology matrices to calculate the *measured* factor content of trade and absorption. The first approach has been used by Trefler (1995) and Davis and Weinstein (2001), while the second approach has been implemented by Horiba (2001), Davis and Weinstein (2003) and Trefler and Zhu (2005). All those papers use country-level data and find that there is a dramatic improvement in the predictive capacity of the HOV model.

Using Spanish regional data, we test both Hicks-neutral technology differences and input-output technology choice differences across regions. Following Trefler (1995), we graph the net factor trade residuals against the *predicted* factor content of trade. Theory tells us that this should be a horizontal line at zero. Instead, if this is close to having a slope of minus one, indicates that the *measured* factor content of trade is small relative to the *predicted* factor content of trade. [12]

Figure 1 illustrates the "missing trade" in Spanish regional data for Model I and Model III. As we have seen in Table 2, when we relax the assumptions of world FPE and world IHP, the "missing trade" tends to reduce but it does not disappear. Focusing on Model III, the specification that fits better the data, we relax the assumption that different regions share the same technology. First we use the difference in per capita

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[12] We adopt this graph approach for consistency with the paper mentioned above.

GDP between a region and Spanish average to proxy for Hicks neutral productivity differences, π_r . The productivity-adjusted version of Model III can be rewritten as:

$$FT_j^r = \pi_r V_j^r - \sum_r \left(s^r / s^S\right) \pi_r FC_j^r$$

The new equation simply requires premultiplying a region´s endowment and consumption by its productivity measure. (The factor content of trade does not have to be adjusted since the Spanish technology matrix was used to calculate them for all the regions). Second, we calculate the *measured* factor content of trade using $D^S (I - B^r)^{-1}$ rather than $D^S (I - B^S)^{-1}$, that is, we use the intermediate input-output matrices from each region to calculate regional-specific technology matrices.(The factor content of Spanish consumption does not been adjusted).

Figure 2 illustrates the "missing trade" in Spanish regional data for Model III when we allow for technology differences. As it can be observed, relaxing the assumption about identical techniques does not improve the predictive capacity of Model III as the problem of "missing trade" is not alleviated. Therefore, factor price equalisation holds for the Spanish regions.

7.- Conclusions

The Heckshen-Ohlin model continues being the cornerstone of international trade theory to explain the pattern of inter-industry flows between regions. Trade is explained by comparative advantage that emerges from differences in relative factor endowments. The generally poor empirical results from the Hecksher-Ohlin in both its Vanek and non-Vanek forms have motivated the need to find why.

The current paper builds on previous tests of HOV by giving careful consideration to the assumptions underlying the theory. Specifically we restrict our HOV tests to regional data, which are expected to be similar in terms of relative endowments, technology and tastes. We believe that this test provides a "best case" scenario for HOV to hold empirically because of the restriction of similarity between regions. The discussion of results reveals the importance for empirical studies of HOV to be conducted in settings where the assumptions underlying the model can reasonably be expected to be achieved. Indeed, it is likely that the failure to adequately consider the assumptions of same technology, factor price equalisation and identical preferences across countries is a partial explanation for the generally poor empirical results that have been generated using the Hecksher-Ohlin model.

The results of our study show poor support for the HOV model in its strict setting, that is, under world factor price equalisation and world identical, homothetic preferences. When we allow a more realistic setting, where factor price equalisation and identical homothetic preferences hold only at regional level, the HOV model performs significantly better. Our findings are consistent with DWBS (1997) examination of the Japanese regions. However we find that relaxing only the assumption of regional factor price equalisation while maintaining the assumption of world identical homothetic preferences is not enough to improve the predictive capacity of the HOV model for the Spanish regions; home bias in consumption arises as an important determinant of regional trade flows.

We also examine the “strict” assumption of equality of region production techniques. Allowing for productivity-adjusted FPE across regions contributed very little to improve the predictive capacity of the HOV model, suggesting that the state of technology and choice of techniques is quite similar across Spanish regions.

Our results suggest that the approach taken here of allowing the assumptions of the model determine the empirical testing that is done improves the concordance of the theory to the data. In particular, the predictive capacity of the HOV model improves ones we use data for a group of “homogeneous” geographic units (in our case, the regions of Spain) and we relax some of the assumptions of the model to hold at regional level rather than at world level (in our case, both factor price equalisation and identical homothetic preferences).

Data appendix

Data are collected for trade flows, factor endowments and factor intensities, the three variables of the HOV equations for which independent observations are required in a complete test. The sources of the data used on trade flows, domestic net output and absorption, world gross output, the direct factors matrix (D) and the technology matrix (B) refer to 1995 while data on factor endowments for both the Spanish regions and the OCDE countries refer to 1990.

Table A.1 lists the Spanish regions included in the sample and the year for which the regional input-output table is available. The excluded regions are Cantabria, Murcia and La Rioja due to lack of input-output tables. The 19 OECD countries used to calculate the vector of world endowment ("the *World*") are USA, Canada, Japan, Australia, New Zealand, Norway, Sweden, Austria, Germany, France, Italy, UK, Netherlands, Belgium, Denmark, Greece, Ireland, Portugal and Spain.

Data on consumption, gross and net production and trade are available for 23 sectors of the economy including agriculture, industry and services. The sectors are listed in Table A.2 with the Spanish Input-Output Table and NACE industry numbers to which they correspond. The concordance of sectors for the Spanish regions is available on request.

Data on international levels of production came from the OECD Input-Output Database (2002), which contains the gross production of the 23 sectors of the Spanish Input-Output Table around 1995 for 20 countries: Australia, Brazil, Canada, China, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Japan, Hungary, Korea, Netherlands, Norway, Poland, Spain, UK and USA. We have added two additional IO tables for Portugal and Russia.

Data for the Spanish factor endowments was collected from the following sources: *Contabilidad Regional de España,1990* (INE) for total labour; Encuesta de Salarios de la Industria y Servicios, 1990 (INE) for participation of skilled and unskilled labour in labour force, *Anuario de Estadística* (INE) for land endowments; *Encuesta de I+D* (INE) for stock de I+D; Fundación BBVA-IVIE *(1998)* for stock of physical capital.

Data for the OCDE factor endowments was collected from the following sources: International Labour Office (1990) *Year Book of Labour Statistics* for skilled and unskilled labour endowments; Statistical Appendix of Coe and Helpman (1995)

“International R&D Spillovers“ (*European Economic Review*, 39, 859-887) for stock of physical capital and stock of R&D; FAO (1991) *Production Yearbook* for land endowments. The variables are expressed in thousand of euros (physical capital, R&D stock, GDP), units (skilled labour and unskilled labour) and hectares (arable land and forests).

Trade flows were obtained directly from the regional input-output tables. Imports and exports include both interregional trade (exchange of goods and services with other Spanish regions) and international trade (exchange of goods and services with the rest of the world). Interregional trade represents above 70 percent of total regional trade and trade with OECD countries (“the *World*”) accounts for nearly 90 percent of international Spanish trade.

The technological matrix or matrix of indirect input requirements was constructed using the Spanish Input-Output Table (1995), published by INE. The direct factor requirement for labour, R&D and physical capital in each sector was obtained as the ratio between net output and the factor employed in the sector. Factor intensities for types of land are calculated as proportional to the output of the corresponding input-output sector, following the methodology suggested in Hakura (2001).

Table A.3 presents the database. The first six rows contain the net trade factor content for the Spanish regions. For example, all regions are net importers of physical capital except Madrid. The next six rows contain the factor content of each regional domestic demand while the last six rows contain the factor endowment.

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Tables of results

Table 1: Description of Spanish regional trade

	OUTPUT	TRADE				EXPORTS		IMPORTS	
Comunidad Autónoma	Porcentage GDP $_{1995}$ (a)	Openness Ratio (b)	Weight of services in total trade (c)	Inter-regional trade (d)		Porcentage inter-regional exports (e)		Porcentage inter-regional imports (e)	
	All sectors	All sectors	Service sectors only	All sectors	Service sectors only	All sectors	Service sectors only	All sectors	Service sectors only
Andalusia	13.4	76.5	11.0	72.2	80.9	64.4	80.3	77.0	81.7
Aragon	3.3	180.2	11.2	60.9	80.7	57.7	81.3	64.0	80.3
Asturias	2.4	103.6	12.0	76.3	89.7	78.6	83.9	74.3	96.8
Balearic Islands	2.3	71.0	7.0	82.4	81.3	47.5	77.5	89.8	83.3
Canary Islands	2.9	59.2	5.0	70.3	97.2	71.4	97.0	57.5	100.0
Castilla-León	6.1	94.7	5.4	65.6	81.7	65.2	78.6	66.0	93.9
Castilla-La Mancha	3.5	120.8	9.3	88.7	92.1	90.0	81.7	87.5	95.1
Catalonia	18.5	124.4	12.6	66.5	86.6	75.1	84.0	57.4	89.8
Valencia	9.5	136.4	12.3	67.8	75.4	62.6	65.0	72.4	85.7
Extremadura	1.6	62.6	6.2	92.4	96.3	91.9	83.4	92.8	100.0
Galicia	6.6	114.7	6.6	71.6	99.7	66.3	100.0	74.8	99.5
Madrid	16.8	90.5	31.4	60.9	78.7	76.2	85.9	44.0	29.7
Navarra	1.7	167.1	5.6	66.2	97.7	54.6	84.2	78.1	99.0
Vasc Country	6.3	121.0	13.4	62.3	88.4	59.0	77.6	65.6	97.0
Cantabria	1.2	na	na	na	na	na	na	na	na
Murcia	2.3	na	na	na	na	na	na	na	na
Rioja (La)	0.8	na	na	na	na	na	na	na	na
Average		**108.8**	**10.6**	**71.7**	**87.6**	**68.6**	**82.9**	**71.5**	**88.0**

Note: na: no available . X: Exports, M: Imports, GDP: Gross Domestic Output. (a): regional GDP / Spanish GDP. (b): (X total + M total) / GDP. (c): Services trade / Total trade. (d): (X interregional + M interregional) / (X total + M total). (e): X interregional / X total. (f): M interregional / M total. Source: Own elaboration using regional IO Tables.

Table 2: Main results. Pooling data.

	(1) Strict HOV (W-FPE, W-IHP) Total trade	(2) Modified HOV (R-FPE, W-IHP) Total trade	(3) Modified HOV (R-FPE, R-IHP) Total trade	(4) Modified HOV (R-FPE, R-IHP) Interregional trade
Sign Test	0.54	0.48	0.77	0.73
	(0.23)	(0.25)	(0.03)	(0.05)
Rank Test	0.27	0.23	0.56	0.54
	(0.22)	(0.22)	(0.08)	(0.08)
Missing Trade Test	0.04	0.07	0.38	0.29
Slope β	0.033	0.038	0.101	0.114
	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.04	0.07	0.21	0.21

Nota: 86 observations (14 regions x 6 factors). Sign test is the percentage of observations for which the *measured* and *predicted* factor content of trade have the same sign. Rank test is the Kendall correlation statistic between the *measured* and *predicted* factor content of trade. The “missing trade” test is the variance of the *measured* divided by the variance of the *predicted* factor content of trade. The slope β and the R^2 are obtained from the regression of the *measured* factor content of trade against the and *predicted* factor content of trade. Total trade means a region´s trade with the world. Interregional trade means trade with other Spanish regions

Table 3. Sign and rank tests, factor by factor.

Model I: W-FPE and W-IHP

		AND	ARA	AST	BAL	CAN	CLE	CMA	CAT	CV	EXT	GAL	MAD	NAV	PVS	Sign	Rank
K	F.C.	12	11	2	13	8	3	7	5	10	4	14	1	9	6		
	F.E.	13	6	1	7	8	9	4	12	2	3	10	14	5	11	**0.64**	**0.27**
LS	F.C.	11	12	4	13	7	3	6	2	10	5	14	1	9	8		
	F.E.	2	11	8	6	3	14	5	10	7	4	1	9	13	12	**0.64**	**0.23**
LU	F.C.	12	10	5	13	11	3	4	2	8	7	14	1	9	6		
	F.E.	4	7	13	14	9	2	6	8	3	5	1	10	11	12	**0.29**	**0.09**
RD	F.C.	14	6	4	10	9	8	11	2	12	5	13	1	7	3		
	F.E.	13	5	3	4	6	10	7	14	11	2	9	8	1	12	**0.64**	**0.07**
TA	F.C.	2	6	9	14	10	3	1	7	11	5	8	13	4	12		
	F.E.	11	3	6	7	8	4	2	14	12	1	9	13	5	10	**0.64**	**0.36**
TF	F.C.	13	12	6	9	11	8	7	3	4	5	10	14	2	1		
	F.E.	11	8	3	9	10	5	6	12	13	2	1	14	7	4	**0.41**	**0.23**

Model III: R-FPE and R-IHP

		AND	ARA	AST	BAL	CAN	CLE	CMA	CAT	PVL	EXT	GAL	MAD	NAV	PVS	Sign	Rank
K	F.C.	12	11	2	13	8	3	7	5	10	4	14	1	9	6		
	F.E.	14	6	1	11	9	8	3	5	12	4	10	13	7	2	**0.93**	**0.41**
LS	F.C.	11	12	4	13	7	3	6	2	10	5	14	1	9	8		
	F.E.	11	12	4	13	3	2	6	14	10	1	5	8	7	9	**0.79**	**0.69**
LU	F.C.	12	10	5	13	11	3	4	2	8	7	14	1	9	6		
	F.E.	6	7	14	13	9	2	5	12	3	4	10	1	8	11	**0.50**	**0.41**
RD	F.C.	14	6	4	10	9	8	11	2	12	5	13	1	7	3		
	F.E.	13	5	6	12	10	8	14	2	11	7	9	1	3	4	**0.85**	**0,69**
TA	F.C.	2	6	9	14	10	3	1	7	11	5	8	13	4	12		
	F.E.	5	4	8	9	11	2	1	13	10	3	7	14	6	12	**0.79**	**0,64**
TF	F.C.	13	12	6	9	11	8	7	3	4	5	10	14	2	1		
	F.E.	12	8	3	9	10	5	7	13	11	2	4	14	6	1	**0.50**	**0.27**

Notes: F.C. factor content measure ranking; F.E. factor endowment measure ranking. There are six factors, physical capital (K), R&D (RD), skilled labour (LS), unskilled labour (LU), land for arable and pasture (TA) and forest land (TF). Rank is the value of the Kendall´s coefficient of concordance [0, 1]. Sign is the proportion of sign matches based on one-by-one comparisons.

Table 4. Sign and rank tests, region by region.

Model I: W-FPE and W-IHP

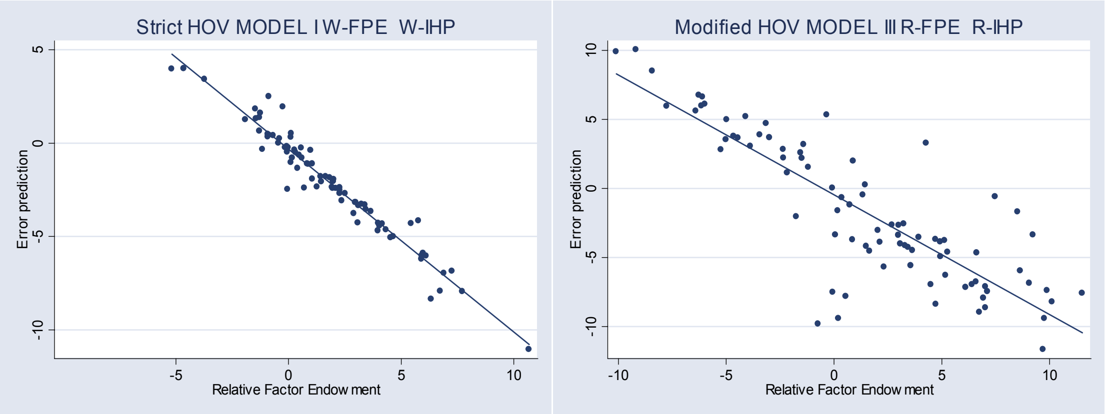
		K	LS	LU	RD	TA	TF	Sign	Rank
AND	F.C.	5	3	4	6	1	2		
	F.E.	4	3	1	6	2	5	**0.50**	**0.06**
ARA	F.C.	6	5	4	2	1	3		
	F.E.	3	5	1	6	2	4	**0.50**	**0.06**
AST	F.C.	1	2	3	5	6	4		
	F.E.	1	4	5	6	3	2	**0.67**	**0.06**
BAL	F.C.	5	3	4	2	6	1		
	F.E.	5	3	1	6	4	2	**0.50**	**0.06**
CAN	F.C.	3	1	6	4	5	2		
	F.E.	4	2	1	5	6	3	**0.67**	**0.33**
CLE	F.C.	3	2	4	6	1	5		
	F.E.	4	6	1	5	3	2	**0.33**	**0.06**
CMA	F.C.	5	4	2	6	1	3		
	F.E.	3	5	1	6	2	4	**0.50**	**0.33**
CAT	F.C.	5	4	2	3	6	1		
	F.E.	3	4	1	6	2	5	**0.50**	**0.20**
CV	F.C.	4	3	2	5	6	1		
	F.E.	3	4	1	6	2	5	**0.67**	**0.33**
EXT	F.C.	4	3	5	6	1	2		
	F.E.	4	5	1	6	2	3	**0.67**	**0.20**
GAL	F.C.	6	3	5	4	2	1		
	F.E.	5	4	2	6	3	1	**0.50**	**0.06**
MAD	F.C.	2	1	3	4	6	5		
	F.E.	4	5	1	6	2	3	**0.33**	**0.06**
NAV	F.C.	6	5	4	3	1	2		
	F.E.	4	6	1	5	2	3	**0.50**	**0.20**
PVS	F.C.	4	5	3	2	6	1		
	F.E.	5	4	1	6	2	3	**0.33**	**0.06**

Model III: R-FPE and R-IHP

		K	SK	UN	RD	TA	TF	Sign	Rank
AND	F.C.	5	3	4	6	1	2		
	F.E.	6	3	6	4	2	1	**0.83**	**0.60**
ARA	F.C.	6	5	4	2	1	3		
	F.E.	6	5	4	1	3	2	**0.83**	**0.60**
AST	F.C.	1	2	3	5	6	4		
	F.E.	1	5	3	4	6	2	**0.83**	**0.46**
BAL	F.C.	5	3	4	2	6	1		
	F.E.	5	3	2	6	1	4	**0.67**	**0.46**
CAN	F.C.	3	2	5	4	6	1		
	F.E.	4	3	1	6	2	5	**0.83**	**0.60**
CLE	F.C.	3	2	4	6	1	5		
	F.E.	4	5	1	6	2	3	**0.33**	**0.46**
CMA	F.C.	5	4	2	6	1	3		
	F.E.	4	5	1	6	3	2	**0.83**	**0.60**
CAT	F.C.	6	4	2	3	5	1		
	F.E.	4	5	1	2	6	3	**0.67**	**0.46**
CV	F.C.	4	3	2	5	6	1		
	F.E.	4	3	1	5	6	2	**0.67**	**0.86**
EXT	F.C.	3	4	5	6	1	2		
	F.E.	5	4	1	6	3	2	**0.50**	**0.20**
GAL	F.C.	6	3	5	4	1	2		
	F.E.	5	3	4	2	6	1	**0.67**	**0.20**
MAD	F.C.	2	1	3	4	6	5		
	F.E.	3	4	2	1	6	5	**0.67**	**0.46**
NAV	F.C.	6	5	4	3	1	2		
	F.E.	5	6	1	3	4	2	**0.67**	**0.46**
PVS	F.C.	4	5	3	2	6	1		
	F.E.	5	5	2	1	6	3	**0.50**	**0.46**

Notes: F.C. factor content measure ranking; F.E. factor endowment measure ranking. There are six factors, physical capital (K), R&D (RD), skilled labour (LS), unskilled labour (LU), land for arable and pasture (TA) and forest land (TF). Rank is the value of the Kendall´s coefficient of concordance [0, 1]. Sign is the proportion of sign matches based on one-by-one comparisons.

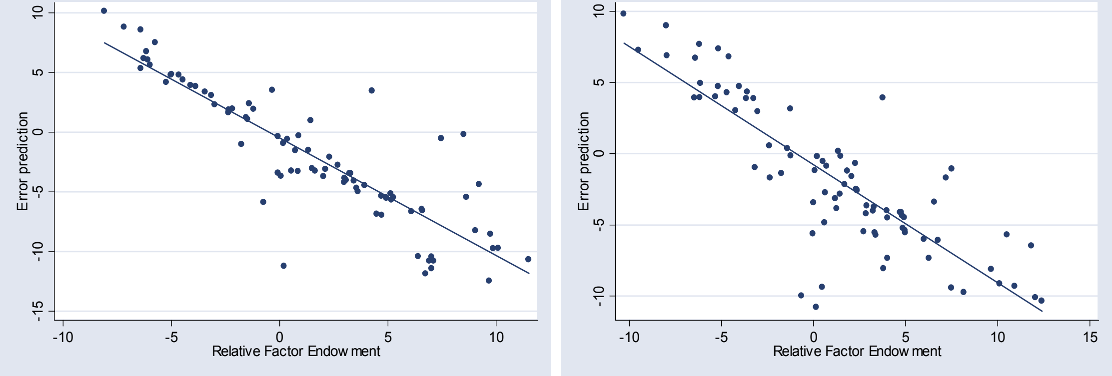
Figure 1.”Missing trade”. All regions share the same technology.



Model I

Model III

Figure 2. ”Missing trade”. Model III allowing for technology differences across regions



Hicks neutral technology differences.

Region-specific input-output matrices

[APPENDIX TABLE]
Table A.1. Regional input-output tables

Name of region		Available year	Number sectors
SPAIN	SPAIN	1995	R71
ANDALUSIA	AND	1995	R89
ARAGON	ARA	1992	R69
ASTURIAS	AST	1995	R59
BALEARIC ISLANDS	BAL	1995	R51
CANARY ISLANDS	CAN	1992	R59
CASTILLA-LEON	CLE	1995	R56
CASTILLA-MANCHA	CMA	1995	R39
CATALONIA	CAT	1989	R73
VALENCIA REGION	CV	1995	R69
EXTREMADURA	EXT	1995	R54
GALICIA	GAL	1994	R63
MADRID	MAD	1996	R56
NAVARRA	NAV	1995	R51
VASC COUNTRY	PV	1995	R84

[APPENDIX TABLE]
Table A2. Sector categories

Sector name	Sector	Spain IO Table (1995) R71 classification
Agriculture products	1	1 - 3
Energy and water	2	4, 5 , 8 - 11, 39
Metal minerals and primary iron & steel Mfg.	3	6, 29
Non metallic minerals and related manufactures	4	7, 25 - 28
Food, drinks and tobacco	5	12 - 16
Textiles, apparel, footwear, leather	6	17 - 19
Wood & cork products; Miscellaneous Mfg.	7	20, 38
Paper, printing & publishing	8	21, 22
Chemical	9	23
Rubber & Plastic	10	24
Metallic products	11	30
Agricultural and industrial machinery	12	31, 33
Office machines and professional goods	13	32
Electric and electronic products	14	34, 35
Transport equipment	15	36, 37
Construction	16	40
Retail services; reparation; other market services n.e.c.	17	41 - 43, 55 - 58 , 59 - 63 , 71
Hotels and restaurants	18	44
Transport services	19	45 - 49
Post and telecomunications services	20	50
Banking and insurance services	21	51 - 53
State services	22	54
Non-market orientated services	23	64 - 70

Note: We report only the sector conversion table for the Spain IO table. We omit the correspondence tables for the regional IO table (available on request).