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THE FACTOR CONTENT OF REGIONAL BILATERAL TRADE: THE ROLE OF TECHNOLOGY AND DEMAND[1]

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Abstract

The Heckscher-Ohlin-Vanek (HOV) model in its strict form has been strongly rejected by the data. Relaxing some assumptions of the standard HOV model is key to find improvements in its performance. We apply Davis and Weinstein (2001) methodology to analyse the validity of the HOV model using regions rather than countries. Surprisingly, our results using data for 17 Spanish regions are similar to theirs with international data for OECD countries. Accounting for technological differences improve the predictive capacity of the factor proportions model and including trade costs and geography reduce significantly the missing trade problem. However, relaxing the assumption of factor price equalisation does not improve the performance of the HOV model in a regional setting.

Key words: Heckscher-Ohlin-Vanek (HOV) model, technological differences, gravity equation, Spanish regions.

JEL classification: F11, F14, R12.

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1. Introduction

The Heckscher-Ohlin (HO) factor-proportion theory of comparative advantage has been used for almost a century by academics and policy makers to explain the determinants of trade flows, the impact of trade on factor remuneration within a country, and the consequences of factor mobility on regions´ welfare (Helpman, 1999). According to the HO model, commodity trade flows between regions compensate the uneven geographic distribution of productive resources. Indeed, the basic insight of the HO model is that traded commodities are really bundles of factor services (capital, labour and land). The Heckscher-Ohlin-Vanek (HOV) theorem says that, under the assumptions of identical technology and identical and homothetic preferences, the net export of factor services will be the difference between a region's endowment and the endowment typical in the world for a region of that size (Vanek, 1968).

The strict version of the HOV model has been strongly rejected by data. Leontief (1953) and Maskus (1985) reported the *Leontief paradox* - that the USA, the most capital abundant country in the world was a net importer of capital services. Using a large number of countries and factors, Bowen et al. (1987) found that the basic HOV model predicted the factor service trade as well as *flipping a coin*. Trefler (1995) documented the *mystery of missing trade* –that measured factor service trade is an order of magnitude smaller than that predicted based on national endowments– and the *endowment paradox* –that developing countries are revealed to be abundant in most production factors.

The lack of correspondence between the theory in its strict version of the HOV model and the data has stimulated considerable research activity. Recent studies provide positive results for variants of the HOV model after adjusting the assumptions of the theoretical model, improving the data sets and developing more powerful and robust empirical tests.

Bowen et al. (1987) showed that the predictive capacity of the HOV model improved slightly after relaxing *ad hoc* the assumptions of identical technology and identical and homothetic preferences. Trefler (1993, 1995) also reported a significant improvement after measuring country differences in factor endowments in efficiency units rather than in physical units. Maskus and Webster (1999), Hakura (2001) and

Trefler and Zhu (2010), with differing samples of countries, used country-specific input-output tables to calculate the factor content of net exports, reporting a good performance of the HOV model and confirming that the assumption of identical technology is not valid at international level. Davis and Weinstein (2001) [DW 2001 henceforth] made several contributions to the empirical HOV literature. First, they show how aggregation may systematically bias measured factor trade downward relative to the theoretically appropriate measure. Second, they recognize the crucial role played by the non-tradable sector in the HOV model. Finally, they incorporate trade frictions into the HOV model by using a gravity model. With all these departures from the simple HOV specifications, the "missing trade problem" almost disappears in a sample of 10 OECD countries.

A second line of research has employed the regions of a country as a more robust sample to test the HOV model in its original version. The use of regional data is preferable on three grounds. First, information at national level is more comparable than at international level. For example, regional-specific input-output tables employ a homogeneous methodology alleviating the serious problem of measurement error in technology that appears in international studies (Harrigan, 1997 and 1999; DW, 2001). Second, some of the assumptions behind the HOV theorem, such as identical technology and preferences, factor price equalisation, and lack of trade barriers, are more likely to hold within a country than between countries. Davis et al. (1997) and Requena et al (2008a) analysed the factor content of trade of the Japanese regions and Spanish regions, respectively and tested the importance of relaxing the assumptions of world factor price equalisation (FPE) and world identical and homothetic (IHP) preferences. For Japan, Davis et al. (1997) focused on the international trade of Japanese regions, and showed that by relaxing the world FPE assumption was enough to get an excellent performance of the HOV model. However, for our case, focusing on the interregional Spanish trade, a significant improvement emerged after relaxing both the world FPE and world IHP. Nevertheless, compared to DWBS (1997) for the case of the Japanese prefectures, we did not find an impressive improvement of the model´s performance as they found in their paper.

Our paper investigates again the performance of the HOV model using interregional data, making three novel contributions. First, we use the *Intertio database*, a unique dataset which contains comparable input-output tables for each of the 17 Spanish regions as well as sector specific interregional trade flows in the year 1995 (Llano et al., 2004). In our previous research we used information from 14 individual regional TIOs and we had only information on aggregated trade flows.

Second, we use the 17 technology matrices to test for technological differences between regions so we are able to incorporate Hicks neutral technological differences into the standard HOV model. Moreover, we accommodate the standard HOV to allow for the presence of non-tradable sectors.

Third, we show the importance of taking into account economic geography as a determinant of trade flows before assessing the validity of the HOV model in a regional setting. The access to *bilateral* trade flows between Spanish regions allows us to incorporate a gravity model into the regional HOV framework to account for the role of transport barriers and physical distance as determinants of trade flows.

As a starting point and in line with our previous findings, the HOV model is strongly rejected by data, even after relaxing the two key HOV assumptions (world factor price equalisation and world identical and homothetic preferences). Therefore, there is extra room to further investigate other explanations. In this paper we explore two of them: technological differences and the role of geography.

The results show that Hicks-neutral technological differences do not play a major role in improving the performance of the HOV model at a regional level. However, after taking into account the existence of non-tradable sectors, the relative factor intensity is more affected by relative factor abundance in tradable good sectors than non tradable sectors. We observe that regions that are abundant in high educated labour tend to use more intensively this factor and less intensively the low educated labour in the production of traded goods. Incorporating this new feature into the HOV model improves significantly its performance.

Another important finding related to technology is the lack of evidence on the violation of factor price equalisation among regions, so a model of multiple diversification cones is rejected at a regional level in contrast to recent studies using international data. The last finding is that the presence of costs of trade alters significantly the HOV predicted level of trade flows between Spanish regions. Once we account for the role of distance on trade, the modified HOV model improves its performance again, and the mystery of missing trade remains but becomes ‘a little bit less mysterious’.

So, in accordance to our findings, both technical differences and divergences in demand structure are necessary to successfully match the HOV theory with regional data. This result is quite striking and suggests that the modifications that DW (2001) implemented to improve the performance of the HOV model with data for 10 OECD countries are basically the same as those needed to improve the performance of the HOV model with data for the 17 Spanish regions. Additionally we show that technological differences among regions, though clearly exist, are of less extent than those among countries, as one will expect.

The rest of the paper is structured as follows. Section 2 describes the standard HOV equation and provides a parsimonious and plausible set of departures from the standard model. Section 3 presents the data and Section 4 the empirical results. Section 5 summarises the main findings of our investigation.

2. Theory and empirical specification

In this section we lay out the theoretical framework for our empirical investigation. We present the standard HOV model and the proposed hypotheses that may explain the divergence between theory and data, such as the existence of technical differences and divergences in demand structure in a regional space.

The empirical evidence at the country level of factor proportions literature shows that allowing for technological differences improves the performance of the HOV model. While Trefler (1993, 1995) allows for Hicks-neutral technological differences, other studies by Maskus and Webster (1999), DW (2001), Hakura (2001) and Trefler and Zhu (2010) introduce Ricardian technological differences. In order to evaluate the importance of Hicks-neutral technological differences and Ricardian technological differences in the observed performance of the HOV equation, we follow the step-by-step approach used by DW (2001). Their contribution is to systematically show the importance of each modelling assumption to "close the gap" between factor content measures and factor endowment predictions.

We first estimate the technology parameters using the 17 regional–specific technological matrices. In a second stage we incorporate these parameters into the HOV model to assess which specification better fits the data. We will use three primary factors in our study: capital (K), high-education labour (H), and low-education labour (L).[2]

Specification 1: Using a common technology (Spanish technological matrix)

Let *r*, *i*, and *f* index region, industry, and primary production factor, respectively. There are *R* regions in country *S*, *N* industries, and *M* primary factors. Regions trade between them (interregional trade) and with the rest of the world (international trade). Each industry uses primary factors and intermediate goods from other industries to produce a final good. In region *r*, the production of one unit of good *i* requires b_{if} units of factor *f* and a_{ij} units of intermediate good *j*. Denote the *M*x*N* matrix Z^r as the direct factor requirement matrix of region *r*, whose element is z_{if}^r. Denote the *N*x*N* matrix A^r as the input-output matrix of region *r*, whose element is a_{ij}^r. Adding the direct factor input and the indirect factor input in intermediate goods yields total factor input. The total factor requirement matrix is given by $B^r = Z^r (I - A^r)^{-1}$, where I is an identity matrix. In the literature B^r is usually called technology matrix, although a more precise name is technique matrix since its elements reflect the choice of production techniques that are based on both production technology and factor prices (Davis and Weinstein, 2003).

The standard HOV model assumes that all regions have identical, constant returns to scale production technology ($B^r = B^{r'} = B^S$), all goods are produced in every

[2] DW (2001) used only two factors, capital and labour. In our case total labour is split into high-educated workers (with completed secondary school or above) and low-educated workers (rest of employed labour force).

region, the number of tradable goods is no less than the number of primary factors and all markets are perfectly competitive. Under the full employment of primary factors,

$BY^r = V^r$ and $BY^S = V^S = \sum_r V^r$

where Y is the net output and V the vector of primary input. There are no barriers to trade and transport costs are zero, so traded goods prices equalize while factor price equalisation (FPE) equalise non-traded goods prices. Under the assumption of identical and homothetic preferences (IPH) across regions the demand in a region, D^r, is proportional ($s^r = GDP^r / GDP^S$) to the country net output (Y^S),

$BD^r = s^r BY^S = s^r V^S = s^r \sum_{r'} V^{r'}$.

If net exports, $X^r - M^r$, is the difference between production and demand, $Y^r - D^r$, the key test of the standard HOV model in a regional framework with all regions using the same technology matrix, B^{Spain}, and holding factor price equalisation (FPE) at the national level is:[3]

$$B^{Spain}(X^r - M^r) = V^r - s^r \sum_{r'} V^{r'} \qquad (1)$$

A complete test of the HOV equation requires information on net export flows ($X^r - M^r$), the state of technology (B^{Spain}), factor endowments at a regional level (V^r) and relative size of each region (s^r). In the next sections we propose alternative specifications of the standard HOV model, altering either the measurement of the factor content of trade (left hand side) or the excess of endowment supplies (right hand side). We first examine the existence of regional technical differences and secondly the role of economic geography in regional trade.

Specification 2: Estimated technology (Common technology with measurement error)

In the standard HOV model we assume that both the true and measured technology matrices are identical across regions. In our first departure from the standard equation [1], and before we pursue more elaborated hypothesis on the nature of existing

[3] Davis et al (1997) show that assuming FPE at national level rather than at international level simply implies to use $(GDP^r / GDP^{Spain})BY^{Spain}$ instead of $(GDP^r / GDP^{World})BY^{World}$.

technological differences among Spanish regions, we investigate the case in which the observed technology matrices could have been measured with error. Assume that for region *r* and factor *f* the measured element of the technology matrix is given as:

$$\ln b_{fi}^{r} = \beta_{fi} + \varepsilon_{fi}^{r} \qquad (2)$$

where b_{fi}^{r} is the observed element of the regional technology matrix, the estimated parameters β_{fi} provide an average estimate of the true (common technology) total factor requirement and ε_{fi}^{r} is a normal error term that reflect errors in measurement for the observed element of the regional technology matrix.

Specification 2 allow us to estimate a total input requirement parameter and therefore constructing a new common technology matrix without measurement errors ($\overline{B}$), providing a new test of the HOV model as follows :

$$\overline{B}(X^{r} - M^{r}) = \mathrm{V}^{\mathrm{r}} - \mathrm{s}^{\mathrm{r}} \sum_{\mathrm{r}'} \mathrm{V}^{\mathrm{r}'} \qquad (3)$$

Specification 3: Hicks-neutral technical differences

We can econometrically identify Hicks-neutral factor-augmenting technical differences by estimating:

$$\ln b_{fi}^{r} = \theta^{r} + \beta_{fi} + \varepsilon_{fi}^{r} \qquad (4)$$

where the estimated parameters β_{fi} provide average estimates of the factor-requirements across regions and the predicted factor-requirements in each region differ from this average depending on the parameters θ^{r} , which measure technology differences across regions that are uniform across industries (Hicks-neutral).[4]

Specification 3 allows for Hicks-neutral technological differences. A primary convenient way of thinking about technical (productivity) differences in the HOV framework is as reflecting efficiency differences of the factors themselves. Therefore, we can express a region´s endowment in efficiency terms employing the right hand side of the next HOV specification:

[4] In this paper we replicate the methodological approach of DW (2001) and therefore we allowed only for Hicks neutral (HN) technical differences. An interesting extension is to allow for factor augmenting industry neutral technology differences (FAIN), as proposed recently by Maskus and Nishioka (2009).

$$\overline{B}_{HN}(X^r - M^r) = \theta^r_{\mathrm{HN}}\mathrm{V}^{\mathrm{r}} - \mathrm{s}^{\mathrm{r}}\sum_{r'}\theta^{r'}_{\mathrm{HN}}\mathrm{V}^{\mathrm{r}'} \qquad (5)$$

Specification 4: Goods continuum model (DFS model with factor price equalisation)

So far we have assumed that differences in input usage across regions arise only by existing differences in factor efficiency in a Hicks-neutral fashion. So the assumption of "adjusted FPE" still holds for the model and we are then assuming that capital to labour (educated or not) ratios are fixed by industry across regions. However, empirical evidence shows that cross-country differences in input usage are correlated with their relative factor endowment differences (Dollar et al., 1988; Wood, 1994). We investigate this issue in a regional space, first considering that "approximate FPE" still holds and observed differences are due to aggregation problems on data (aggregating goods of heterogeneous factor content within the same industry category) as Dornbusch, Fischer and Samuelson (1980) [DFS henceforth] proposed, and second, assuming that input usage differences arise due to the failure of FPE assumption (Dollar et al., 1988; Helpman, 1999).

DFS (1980) introduced a continuum of products into the Heckscher-Ohlin model to show that if factor prices are not equal, but approximate, then the capital to labour ratios of traded goods must be systematically related to each region's relative endowments. Therefore, a region with a high capital to labour endowment will tend to have higher capital to labour intensities in the production of *all of its* tradable goods. This relationship can be modelled as:

$$\ln b^r_{fi} = \theta^r + \beta_{fi} + \gamma^T_f \ln(K^r / H^r)TRADE_i + \upsilon^T_f \ln(H^r / L^r)TRADE_i + \varepsilon^r_{fi} \qquad (6)$$

where $\sum_f \left(\gamma^T_f + \upsilon^T_f\right) = 0$

The estimated parameters β_{fi} provide average estimates of the factor-requirements across regions and the predicted factor-requirements in each region differ from this average depending on the parameters θ^r , which measure uniform technology differences across regions, and on $\gamma_f \ln\left(K^r / H^r\right)$ and $\upsilon_f \ln\left(H^r / L^r\right)$, which measures the impact of relative factor endowments on input usage. To ensure a parsimonious description of technology differences across regions, we impose that the impact of relative factor abundance on input usage is the same for all tradable industries.

In Specification 4 exports and imports do not use the same technology, so the factor content of exports is calculated using the technology matrix of the exporting region and the factor content of bilateral imports are calculated using the technology matrix of each source region.

$$\bar{B}^{r}_{DFS} X^{r} - \sum_{r'} \bar{B}^{r'}_{DFS} M^{rr'} = \theta^{r}_{DFS} V^{r} - s^{r} \sum_{r'} \theta^{r'}_{DFS} V^{r'} \qquad (7)$$

Specification 5: Helpman model without factor price equalisation

For the case that FPE does not hold, we should follow the next specification of the HOV equation in order to capture differences in input usage through industries and regions in our data set (Helpman, 1999):

$$\ln b^{r}_{fi} = \theta^{r} + \beta_{fi} + \gamma^{T}_{f} \ln(K^{r}/H^{r}) TRADE_{i} + \gamma^{NT}_{f} \ln(K^{r}/H^{r}) NOTRADE_{i}$$
$$\upsilon^{T}_{f} \ln(H^{r}/L^{r}) TRADE_{i} + \upsilon^{NT}_{f} \ln(H^{r}/L^{r}) NOTRADE_{i} + \varepsilon^{r}_{fi}$$

where $\sum_{f} \left(\gamma^{T}_{f} + \upsilon^{T}_{f} + \gamma^{NT}_{f} + \upsilon^{NT}_{f} \right) = 0$ (8)

Unfortunately we were not able to estimate all the parameters of interest due to over-parametrisation of the system (12 extra technological parameters). As a solution we used two primary inputs only (capital, K and aggregated labour, H+L) in line with DW (2001):

$$\ln b^{r}_{fi} = \theta^{r} + \beta_{fi} + \gamma^{T}_{f} \ln(K^{r}/(H+L)^{r}) TRADE_{i} + \gamma^{NT}_{f} \ln(K^{r}/(H+L)^{r}) NOTRADE_{i} + \varepsilon^{r}_{fi}$$

where $\sum_{f} \left(\gamma^{T}_{f} + \gamma^{NT}_{f} \right) = 0$ (9])

In Specification 5 exports and imports do not use the same technology, so the factor content of exports is calculated using the technology matrix of the exporting region and the factor content of bilateral imports are calculated using the technology matrix of each source region.

$$\bar{B}^{r}_{H} X^{r} - \sum_{r'} \bar{B}^{r'}_{H} M^{rr'} = \theta^{r}_{H} V^{r} - s^{r} \sum_{r'} \theta^{r'}_{H} V^{r'} \qquad (10)$$

Before we conclude this section on technology differences, we explain how we estimate the technology parameters in the different specifications. In each specification we have 60 equations (3 factors times 20 sectors), one for each factor-industry pair. In specifications 3 and 4 we have cross-equation restrictions that require us to estimate the equations jointly. Ideally, we would use a seemingly unrelated regression (SURE) procedure and exploit the cross-equation correlations in the error terms, but we lack of the necessary degrees of freedom. Therefore we decide to stack the data by factor. Finally, we need to control for potential heteroskedasticity originated by the difference economic size of the regions and by the fact that factor endowments are measured on different units. For that reason, in all regressions we weighted all observations by $\overline{B}_{fi}\sqrt{\ln Y_{ir}}\big/\overline{B}_{f}$, where $\overline{B}_{fi}$ corresponds to the average across all regions of the unit factor requirement in sector *i*, $\overline{B}_{f}$ is the average of $\overline{B}_{fi}$ factor intensities across all sectors and Y_{ir} refers to net output in sector *i* for region *r*.

2.2. Allowing for differences in absorption structures

After relaxing the technology assumption, we are now interested in introducing in the regional space the existence of transport costs and observing its effects on the HOV model performance. Departing from a frictionless, wholly costless trade, world is not a great theoretical effort since this assumption of the HOV has been widely criticised by the country studies (Mc Callum, 1995~~ Engel and Rogers, 1996~~) and even there exists evidence of the importance of geography in explaining the Spanish regions trade flows (Minondo, 2003; Requena and Llano, 2010).

The relevance of introducing trade costs in the HOV framework is that it can affect the predicted factor content of trade for the Spanish regions and help to reduce the missing trade problem in our research, because a frictionless specification of the model wildly overstates the expected domestic demand of imported products. Moreover, this is the first paper as far as we know that introduces costs of trade in a regional HOV setting.

We follow DW (2001) by introducing costs of trade in the model through a two-steps approach. The first step consists of estimating demand for imports bilaterally amending this demand to account for bilateral trade costs. The procedure we follow is to use a gravity equation that proxy costs of trade through geographical distance, estimating predicted bilateral imports as follows:

$$\ln M_i^{rr'} = \alpha_i + \beta_i \ln(s_i^r Y_i^{r'}) + \delta_i \ln(dist^{rr'}) + \psi_i adjacent^{rr'} + \zeta_i^{rr'} \quad (11)$$

where s_i^r is total domestic absorption (of final and intermediate goods) as a share of Spanish gross output, $Y_i^{r'}$ is gross output in sector *i* in region (or country) *r´*, $dist^{rr'}$ is the distance between regions *r* and *r´*, $adjacent^{rr'}$ is a dummy variable that takes value of 1 when the regions share a common border, 0 otherwise; α , β , δ and ψ are sector-specific parameters to be estimated and ζ is a normal error term. The parameter estimates are used to generate predicted bilateral interregional imports ($\hat{M}^{rr'}$) and total (interregional and international) imports as $\hat{M}^r = \sum_{r'} \hat{M}^{rr'} + M^{rROW}$. We then set demand for domestically produced goods equal to the difference between total regional demand and total imports ($\hat{D}^r = D^r - \hat{M}^r$). This procedure ensures that the predicted domestic demand equals the actual domestic demand. [5]

In Specification 6 the predicted factor content of exports and imports is calculated using the "preferred" technology of the regions. As we will see in the results, our "preferred" technology is the DFS model with factor price equalisation. The difference with respect to previous specifications is that predictions for bilateral absorption are generated by a gravity equation, weighted by the factor usage matrices appropriate for each partner.

$$\overline{B}_{DFS}^r X^r - \sum_{r'} \overline{B}_{DFS}^{r'} M^{rr'} = V^r - \left[\overline{B}_{DFS}^r \hat{D}^r + \sum_{r',ROW'} \overline{B}_{DFS}^{r'} \hat{M}^{rr'} \right] \quad (12)$$

3. Data and tests

3.1. Data

[5]. Since interregional imports represent 80% of total trade of a region we expect that the measurement error provoke for the omission of international imports in the gravity equation is small enough to make valid our exercise. Notice that in equation (12) the factor content of international imports is calculated using the technology matrix of ROW, which is proxied by the technology matrix of Spain. See DW (2001) for a discussion on the treatment of "rest of the world"·in the gravity equation.

The multi-regional multi-factor tests on the HOV equations are performed using data in the year 1995. The data set contains information for 17 Spanish regions, 20 sectors and 3 factors: capital, high-educated labour and low-educated labour. Our research was possible due to the existence of a unique data set, *the Spanish Intertio database (Llano, 2004)*, which corresponds to the first interregional input-output table estimated for Spain. This database contains comparable input-output tables for each one of the 17 Spanish regions (containing homogeneous data on gross output, domestic demand, exports and imports, and technical Leontief coefficients). In addition, it provides a breakdown of sectoral trade vectors of every Spanish region with the other Spanish regions and with the rest of the world. For a typical Spanish region, international trade flows account for less than 20% of total trade, while the rest corresponds to intra-regional and inter-regional trade (see the Appendix for a descriptive analysis of the dataset). It is also worth mentioning that, due to the process of estimation of the 17 homogenous Spanish input-output tables and the interregional one, some of the sectors that are normally considered as pure non-tradable (construction and service), may have some (but limited) amount of interregional and international trade. This fact should also have to be considered as a more realistic feature of our database, compared to the ones used in previous papers (DW, 2001), where national input-output tables barely register international trade flows for these sectors.

There are three empirical issues that must be addressed before we present our results: the calculation of the technology matrices, the use of interregional trade flows only and the definition of tradable and non-tradable sectors.

The technology matrices (total input requirements matrices) imply multiplying direct requirement vectors by corresponding Leontief inverse tables. Direct input requirements are constructed as physical factor endowments divided by gross output. Data on physical labour is taken from Encuesta de Población Activa (EPA), which breakdowns labour force by region, industry and education levels, with high educated individuals defined as those with secondary and above levels of enrolment and low educated ones as those that have not finished the secondary studies or have a lower level of education. The total number of workers from National Accounts (INE-National

Statistics Institute; www.ine.es) is split into high educated or low educated according to the shares obtained from EPA. Data on physical capital stock comes directly from the publication *El Stock de Capital en España* (Fundación BBVA, www.fbbva.es). [6]

Unlike DW (2001) we do not include "rest of the world" as a trading partner when we compute the factor content of regional net exports. Thus we calculate the factor content of interregional trade of a Spanish region *r*, which represents 80% of total trade of a typical Spanish region. Three reasons for excluding the “rest of the world” in work are: (1) we did not find a convincing way to calculate the technology matrix of "rest of the world". If we would followed DW (2001) we would have had to use the Spanish total technological matrix to calculate the factor content of international imports to a particular region. (2) DW (2001) made some heroic assumption in order to include "rest of the world", something that we try to avoid in this paper. Moreover·they showed that the evaluation of the performance of the HOV under different specifications did not change when they excluded the partner "rest of the world". (3) Requena et al. (2008b) show that the uneven distribution of production factors that induces intra-national specialization and different regional factor prices is not an issue in Spain. Since factor endowments differences are not too large across Spanish regions (i.e. national FPE holds), intra-national space becomes a viable setting to investigate the impact of technology differences on the factor trade model.

In specifications 4 and 5 we split our 20 sectors into tradable and non-tradable sectors. The criterion is based in the importance of interregional exports and international exports on total domestic production. As Table A.1. in the Appendix shows, there are 6 sectors whose volume of inter-regional and inter-national exports represent less than 25 percent of total domestic production: construction (8%); hotels and restaurants (10%); public services (12%); financial sector (15%); repair, retail and

[6] Recent research by Fisher and Marshall (2010) shows that technology matrices could still be measured with error because the direct technological matrix is calculated using physical inputs obtained from sources outside the input-output (which explicitly omits the influence of regional factor prices) while the indirect technological matrices are obtained directly from the regional input-output tables. We hope that this source of measurement error is small in our regional framework because, under the assumption of factor price equalization, endowments can be measured in physical units (i.e. number of employees) rather than in currency (i.e. labour compensation) as factor prices are the same across regions.

wholesale (17%); and, Real estate and other market services (21%). These 6 sectors are classified in our study as non-tradable sectors, so there are 14 tradable sectors.

3.2. Tests

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, the measured factor content of trade (MFCT) and the predicted factor content of trade (PFCT), and checks if they are the same. For a typical element,

$$sign(MFCT_j^r) = sign(PFCT_j^r) \quad r = 1,...R;\ j = 1,...,M$$

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 in its predictions.

The rank test compares the ranking, by factor (across regions) or by region (across factors), of the *measured* and *predicted* factor content of trade matrices (MFCT vs PFCT). If the corresponding cells of the matrices are supposed to be identical, as the standard model states, 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 for this measures. An alternative way is to perform this test for each pair of elements:

$$MFCT_k^r > MFCT_l^r \Leftrightarrow PFCT_k^r > PFCT_l^r \quad r = 1,...R;k,l = 1,...,M$$

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, $\sigma^2(MFCT)/\sigma^2(PFCT)$. If the theory fits the data perfectly, 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 the overall theory performance and can control for the variation in individual factors and regions, thus regression analysis complements 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 predictions are showed again perfect, 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 may be substantial gains from considering alternative specifications of the HOV equation relaxing some critical assumptions.

4. Empirical results

We start in subsection 4.1 presenting the findings that support the existence of both technological differences and trade costs across Spanish regions. Next we incorporate these features into the HOV model in order to assess the predictive capacity of the basic and extended versions of the HOV model.

4.1. Technology differences

In this paper we study the capacity that the factor proportions model has to explain the direction and volume of net trade flows in a regional framework and to which extent it depends on identical technology assumption. With this objective in mind, we start developing technological variations of the HOV equation and investigate its role in the model performance (Table 1). The parsimonious approach employed in the paper contemplates different technological specifications of the model: identical technology among regions, measurement errors in regional technology, the existence of Hicks-neutral technological differences in the regional space and the existence of aggregation problems affecting technology measures, both in a FPE and no FPE framework.

Table 1 presents the results of estimating technology equations [2, 4, 6, 8, 9] in the previous section, each one following every theoretical defined assumption. The first specification of the model [T2, equation 2] assumes that all Spanish regions share the same technology matrix, that is, the Spanish technology matrix. The next specification introduces Hicks-neutral technological differences across regions [T3, equation 4]. The expanded model performs better according to the Schwarz model selection criterion. The estimated parameters θ indicate how much more inefficient is a region compared to another. Our measure of technological differences among Spanish regions in efficiency terms is obtained from the transformation of the estimated coefficient θ, and is equal to $\exp(\theta)$. The estimates are reported in the last column of Table 1. Basque Country is the most productive region in the national space, very close to the performance of Madrid (1.01), Catalonia (1.03) and the Valencian region (1.06). Less productive regions in Spain are Extremadura (1.93), the Canary Islands (1.79) and Balearic Islands (1.83). Compared to the estimates of DW 2001 for 10 OECD countries, inter-regional technological differences are of less extent that international ones.

The best estimate of the technology matrix for Spanish regions is the one that includes the existence of Hicks-neutral technological differences and differences in input usage across regions due to aggregation problems in an approximate Factor Price Equalisation (FPE) framework *à la Dornbusch-Fischer-Samuelson* (DFS) [T4, equation 6]. The Schwarz criterion favours clearly the superiority of this technological specification, indicating that the violation of the FPE assumption not seems to be a feature of the HOV model in a regional setting. [7] This is an striking result because it reports evidence contrary to the results of the international literature, where no-FPE technological equation *à la Helpman* (T5 column, equation 8) best captured differences in technology among OECD countries, or provided? the best explanation for observed international differences in input usage by industries (DW, 2001). So, it could be said that, for the Spanish regional space, we can reject the hypothesis that input coefficients are independent of every region's endowments, and in an approximate FPE framework, observed technical differences seem to be best explained by aggregation problems.

A novelty of the paper is the breakdown of the labour vector into high and low educated labour force. This allows us to investigate in more detail, through the use of T4 specification, how factor endowments affect input usage across the regional industries of Spain. At this respect, we can observe that for a typical abundant region in high educated labour compared to low educated labour (H/L), input usage for tradables is upwards biased towards a more intense use of this abundant factor (high educated labour) in its production function and downwards biased to the use of the scarce factor (low educated labour). In addition, when a region is observed to be relatively scarce in high educated labour compared to capital (ratio K/H), low educated labour also tend to be used intensively in the production of tradables. In this case we found a good match of theory and data for the Spanish regional case and aggregation problems seem to be a good theoretical argument accounting for the observed technical differences among the regions of Spain.

To check out the robustness of this result we apply the same test for an aggregate of the labour force (high educated labour and low educated labour), thus obtaining

[7] Requena et al. (2008b) cannot reject FPE for the Spanish regions using a different theoretical approach.

comparable results with those of DW (2001).[8] Column T4´ reports the estimation results. We obtain that an increase in a region's capital to labour ratio typically raises each tradable industry capital to labour usage, increasing the relative usage of high educated labour and decreasing the one of low educated labour, a similar result as the one we found in the T4 specification, and consistent with the results obtained by DW (2001).

The last specification in our analysis examines the Helpman approach based on the relaxation of factor price equalisation. Results for this equation are reported as T5 specification and show a bias towards high educated labour for tradables, in line with specification T4 and T4', although the coefficients are not statistically significant for the non-tradable sectors. Nevertheless the Schwarz criterion reports a lower value than the previous specification, suggesting that we cannot reject the assumption of FPE for the regions of Spain.

4.2. Gravity-driven demand

Our dataset provide us with data on bilateral trade for interregional flows, so we have the opportunity to direct estimate the role of trade costs in bilateral trade flows in a gravity equation setting. Table 2 presents the results of estimating equation (11). As expected the hypothesis of no trade costs is rejected in all but one sector (the coefficients of the variables distance and border are statistically different from zero). Moreover, as expected the coefficient on distance is negative in all but four (non-tradable) sectors, while the coefficient on common border is positive in all but one (non-tradable) sector. The results suggest that the assumption of perfect specialization and zero trade costs tends to overestimate the actual level of import flows across regions. Together with technological differences we will incorporate the gravity-type absorption model into the trade specification in the next section.

4.3. Testing HOV

Once we have discussed the results of the technology variations, we present in Table 3 the main results of the proposed tests in order to check the performance of the

[8] See, page 1439, Table 1, column 4 in Davis and Weintein (2001).

HOV model in a regional setting. We run the battery of proposed tests for every above defined technological specification of the model. As in previous studies the standard version of the model is rejected by data, showing that its ability to predict a successful match between *observed* and *predicted* factor content of trade is less convincing than a pure random match pattern (*flipping a coin*) (Table 3: column T1-common technology). The sign (weighted or not) and the rank (by region or factor) tests present values below the 50 per cent of correct matches for the standard version of the model (basically when assumptions of World-Factor Price Equalisation and World Identical and Homothetical Preferences hold). The variance ratio presents a value of 3 per cent, far below the expected 100 per cent value corresponding to a perfect match, and the slope test shows a negative trend value contrary to the economic intuition.

Our first departure from the standard technological assumption of the model considers that all Spanish regions share the same technology, but observed technology matrix is measured with error. Estimating true technology matrix and observing the performance of the model provide no significant improvement of its ability to predict trade factor flows for the Spanish regions (Table 3: column T2-estimated technology with measurement errors). We must note that numerical tests do not show an improvement of the model performance, with a small increase of the variance ratio to a value of 5 per cent, which still reflects the enormous importance of the missing trade problem for the Spanish regions.

In our next technological specification of the model (Table 3: T3-Hicks-neutral technological differences, HNTD), we study the possibility that Spanish regions combine factors of production in the same proportions but technical dissimilarities array from differences in factor productivity, due to differences of efficiency. This approach is known as Hicks-neutral technological differences and remains a key point of the HOV literature since Bowen *et al*. (1987) and Trefler (1993, 1995) contributions.

Our results for T3-HNTD specification show that some differences exist in factor efficiency across Spanish regions. Compared to the sample of OECD countries used by DW (2001), efficiency disparities in the use of production factors are smaller across Spanish regions than across OECD countries, as one will expect. Probably that is why introducing technical differences *à la Trefler* in our regional setting do not report the significant improvement in the model performance that we see in the international literature (Trefler, 1993, 1995; Hakura, 2001). We must note that the model present a slightly improvement in the sign and rank tests values, that is, in its ability for capturing the direction of factor trade flows, being the value of the sign test above 50 per cent and of the rank test by factor and region of 25 and 52 per cent, respectively, although we still cannot observe the important improvement that characterised Davis et al. (1997) results for the regions of Japan with values around 99 per cent. Additionally, the missing trade problem remains as an important feature of this HNTD-T3 specification, with values of 4 per cent for the variance ratio and 0.065 for the slope test.

The following technical-side amendment we introduce in the model is related to the existence of differences in input coefficients for the Spanish regions, but now this differences are not yet neutral to all the industries of every region as in the above HNTD-T3 case, now we assume that observed differences in input usage arise from aggregation or composition problems (DFS 1980).

The idea is that in a two-regions DFS-type model with approximate FPE and this type of aggregation problem, we would expect to find that industry input usage is correlated with every region´s factor abundance for the tradable sectors but not for nontradables. The reason is that the necessity for each region to produce its own non tradables, in combination with the standard assumptions on preferences of the model, implies that input ratios will differ at most trivially for the non-traded sectors[9].

As it can be seen in Table 3, column 4 (T4 specification), the variance ratio and slope tests indicate that the DFS specification permits a reduction of the missing trade problem for the regional framework. This finding reveals again that the downward bias in measured factor content of trade found by DW (2001) is not a specific feature of the country analysis and it is shared by the regional one as well.

Sign and rank tests show an important improvement, with a value of 83 per cent for the weighted sign test, however the missing trade problem is still very important in this technology specification of the model with a variance ratio value of 9 per cent and a

[9] See Xu, 1993 and Davis and Weinstein, 1998, for a further discussion.

slope test of 0.17. It is worth noting that we provide new evidence, but now from a regional perspective, of the relevance that aggregation problems introduce in the performance of empirical tests for the HOV model.

Moreover, the previous exercise we made in this paper includes accounting for the existence of trade costs seriously affecting net trade flows levels, that is, introducing the assumption that the existence of geography, measured by distance between the location where goods are produced and afterward consumed, would imply that the model predictions are significantly overstating the expected volume of bilateral trade flows as well as the opportunities for trade arbitrage between regions (or nations) as a result of existing factor endowment differences. In other terms, this insight is very closely related to the missing trade mystery and the proposed test very well suited for its accounting, so we proceed in order to see if it can solve part of our large missing trade problem.

Finally we examine the importance of taking into account geographic distance as determinant of interregional trade flows. In the gravity model specification (Table 3-T6: HNTD, DFS and Gravity), we integrate the existence of costs of trade or frictions in the equation and we find that it accounts for a part of the story about the lack of fit between theory and data. Now the weighted sign test shows an 89 per cent of correct matches and the rank test for factors shows a 71 per cent value. In general terms, all of the tests reflect an increase in their successful matches and the variance ratio (slope test) performs a 32 per cent (0.373) value in contrast to the 3 per cent (-0.101) of the standard model and the 9 per cent (0.178) of the T4 DFS-HNTD specification.

These results suppose that barriers to trade are playing an evident role in the missing trade story in a regional framework, as it was expected, because predicted factor trade flows are of less extent now than in the frictionless standard framework (McCallum, 1995). This result shows also that relaxing some assumptions related to the absorption (demand) side of the Vanek equation is necessary to obtain some improvements in the empirical tests of the model, that is, a better fit of the data by the model, and it is specially well-suited for solving an important part of the missing trade mystery.

Table 4 and Table 5 present the results of the sign and rank tests by region or by factor, respectively. As in country studies (Bowen et al., 1987; Trefler, 1995), the model presents their best performance for high educated labour (sign and rank tests); additionally the rank test by regions shows that the model doesn't work satisfactory in order to capture the volume of factor trade flows in a regional space.

Finally, graphical analysis allows us to identify the influence of relaxing the technological assumption in the model´s performance. At this respect the Figure 1-T1, that is, the standard version of the model, shows the same poor result already observed in the slope test for the model performance[10]. Measurement errors (Figure 2-T2) and Hicks-neutral Technological Differences (Figure 3-T3) versions of the model not introduce any remarkable change in the models ability to capture trade flows in a regional space. Only when we allow for differences in input usage between Spanish regions *à la Dornbusch-Fischer-Samuelson* (Figure 4-T4) and the existence of trade costs (Figure 5-T6) in the model, we obtain a significant, though not definitive, reduction of the missing trade problem.

Conclusions

Davis and Weinstein (2001) showed that technological differences and trade frictions are reasons explaining why the HOV model performs so badly at international level. We follow their methodology and examine the role of measurement errors, Hicks-neutral technological differences, differences in input intensity usage to be related to relative factor abundance, the role of non-tradable goods and the presence of trade frictions using regional data rather than international data. Our findings provide new evidence that corroborates the need to account for regional technological differences and trade impediments to improve the performance of the HOV model across regions within the same country and providing new as well about the existence of not perfect and quick technological diffusion in a regional space.

[10] One can think of graphical analysis as a graphical representation of the slope test. A perfect matching of the model, where measured and predicted factor trade flows measures match perfectly, will lead to observe a slope of the draw relationship with a value of one.

Technological differences among the geographical units in a regional space are found to be of less extent than for an international arena, as one will expect. In this respect, Hicks-neutral technical differences are playing a minor role in improving the performance of the factor proportions model for the regions of a country, in contrast with the important role that they are playing in explaining international factor trade flows. Another important finding is that we cannot reject the Factor Price Equalisation assumption for the regions of Spain. This is an interesting result in the HOV literature since recent studies show that both how we test the HOV model and the performance of the HOV itself are affected by this assumption in studies using international data (Choi and Krishna, 2004).

Breaking down the labour force matrix by education level has allowed us to identify more accurately the correlation between factor abundance and factor usage, as the theoretical literature have been pointing out. Introducing this assumption in our model specification has allowed us to improve its performance in a regional space and we have been able to identify an upward bias for high educated labour in production and trade (and a complement relationship with capital services), and a downward bias for low educated labour in the case of regions abundant in high versus low educated labour.

In summary, we have provided new evidence of the performance of the factor proportions theory for a regional space, given that there only is one (pioneering) contribution at this respect in the literature, namely DWBS (1997). Our results do not give such an importance to the technology assumption as DWBS for the regions of Japan, but reintroduces the importance of geography in the regional setting of the model as a novelty. At this respect, the model captures the direction of factor trade flows well once we account for HNTD-DFS technological differences and costs of trade in a regional space: 89 per cent of correct matches!

Appendix

Table A.1 shows the spatial distribution of regional production by sectors, according to the *intertio* database . Non-tradable sectors in the paper are those with a smallest share of interregional and international trade (in shadow) .

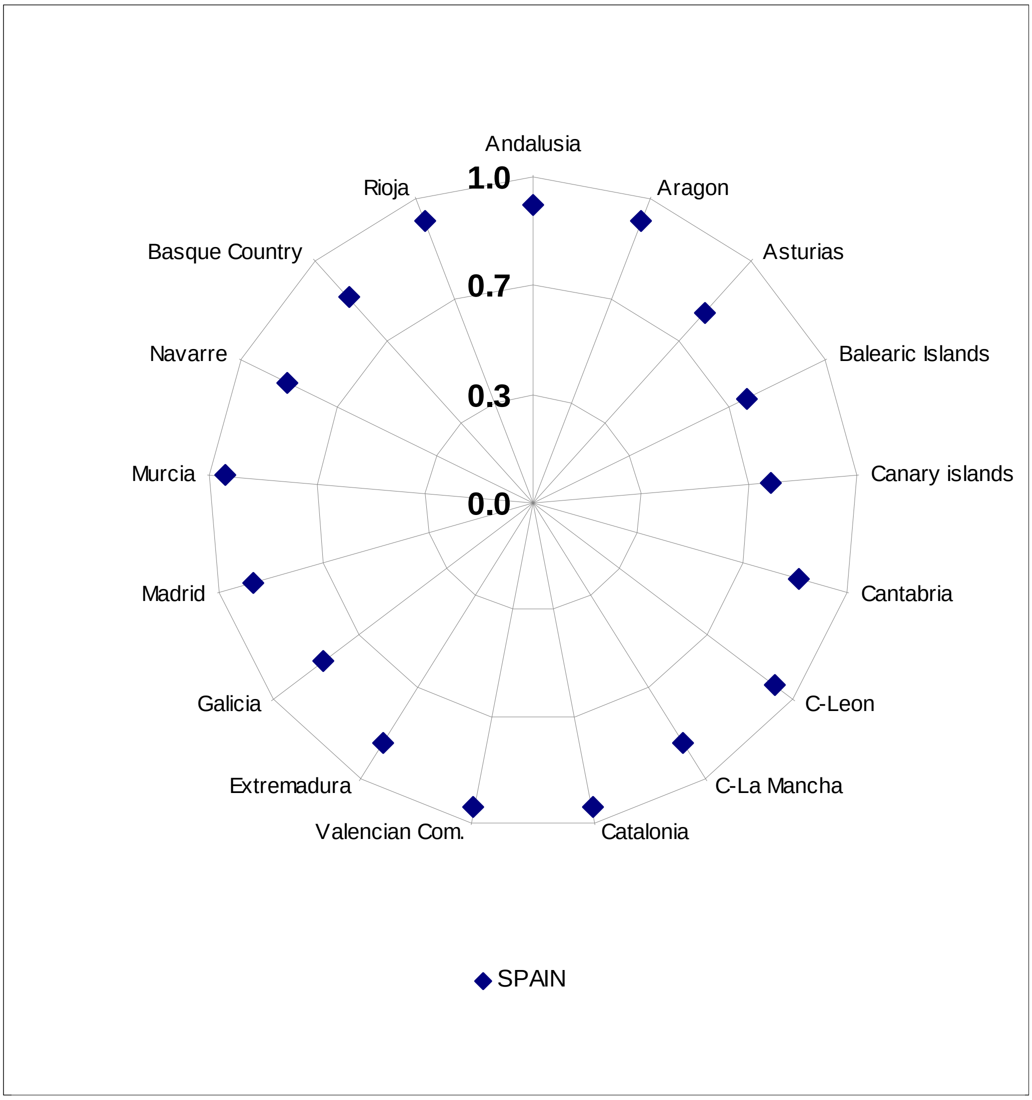
Table A.1. Distribution of domestic production in 1995 by industry and destination (local/intra-regional, rest of Spain/interregional, rest of the world/international)

Sectors	% Intra/Intra+Inter+Intern	% Inter/Intra+Inter+Intern	% Intern/Intra+Inter+Intern
Agriculture	48%	36%	16%
Mining, quarrying, electricity, water, gas	64%	30%	6%
Food, beberages and tobacco	43%	48%	9%
Textiles, apparel, leather	20%	60%	20%
Wood, cork and other manufacturing	43%	44%	13%
Paper and printing	41%	47%	12%
Chemical products	21%	51%	28%
Rubber and plastic	23%	54%	24%
Non metallic mineral products	52%	31%	16%
Basic and fabricated metal products	33%	48%	19%
Mechanical engineering	25%	41%	33%
Electric, electronic and optic products	18%	46%	36%
Transport equipment	15%	31%	54%
Construction	92%	8%	0%
Repair, retail and wholesale	82%	11%	6%
Hotels and restaurants	90%	10%	0%
Transport and communication	67%	21%	12%
Financial sector	85%	13%	2%
Real estate and other market services	78%	17%	4%
Public services	88%	12%	0%

Note: Own elaboration using *intertio* database 1995. Non-tradable sectors are marked in grey. "Intra" stands for domestic production for local consumption, "inter" is domestic production whose destination is other Spanish regions, "intern" is whose destination is outside Spain.

As an additional piece of information we have measured how similar/dissimilar the regional technological matrices are from the Spanish one. In Figure A.1. we have calculated the correlation coefficient obtained when comparing the A^r matrices and the A^N matrices (vectorialized). Note that the largest dissimilarities when comparing each pair of matrices (A^r, A^{SPAIN}) comes from the insular regions (Canary Islands, Balearic Islands) and two small-sized regions (Asturias and Cantabria). The first two are mainly specialised in the tourism sector (non-tradable). The other two exhibit a strong specialisation in heavy industries and equipment.

Figure A.1. Correlation coefficient computed over the A^r matrices (vectorialized) of the 17 Spanish regions and the Spanish one A^N. Intertio database, 1995



Source: Own calculation based on the Intertio database, 1995.

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Table 1. Technology variations.

	Measurement error T2	Hicks-neutral tecnical differences HNTD T3		DFS model with HNTD and FPE T4		DFS model with HNTD and FPE T4´		Helpman no-FPE model with HNTD T5		Implied lambda T3
θ										
Andalucia	--	0,189	(1,17)	0,169	(0,96)	0,166	(1,11)	0,130	(0,92)	1,21
Aragon	--	0,243	(1,81)	0,265	(1,41)	0,312	(1,77)	0,222	(1,26)	1,28
Asturias	--	0,314	(2,24)	0,205	(1,86)	0,246	(2,21)	0,287	(1,41)	1,37
Balearic Islands	--	0,580	(3,27)	0,595	(3,19)	0,563	(3,10)	0,533	(2,70)	1,79
Canary Islands	--	0,606	(4,69)	0,573	(4,12)	0,600	(4,73)	0,596	(3,73)	1,83
Cantabria	--	0,210	(0,86)	0,304	(0,74)	0,205	(0,81)	0,285	(0,68)	1,23
Castilla-Leon	--	0,349	(3,21)	0,314	(2,85)	0,350	(3,23)	0,322	(2,77)	1,42
Castilla-La Mancha	--	0,476	(2,39)	0,453	(1,90)	0,472	(2,36)	0,427	(2,00)	1,61
Catalonia	--	0,030	(0,26)	0,010	(0,08)	0,030	(0,26)	0,021	(0,02)	1,03
Valencian region	--	0,055	(0,59)	0,032	(0,28)	0,054	(0,58)	0,038	(0,17)	1,06
Extremadura	--	0,659	(4,64)	0,597	(4,06)	0,637	(4,69)	0,589	(3,71)	1,93
Galicia	--	0,348	(1,73)	0,207	(1,80)	0,323	(1,87)	0,265	(1,48)	1,42
Madrid	--	0,005	(0,01)	-0,018	(0,25)	0,004	(0,02)	-0,013	(0,12)	1,01
Murcia	--	0,226	(1,98)	0,173	(1,75)	0,230	(2,02)	0,185	(1,57)	1,25
Navarra	--	0,165	(1,52)	0,147	(1,33)	0,165	(1,52)	0,154	(1,20)	1,18
Basque Country	--	0,000		0,000		0,000		0,000		1,00
Rioja	--	0,127	(1,27)	0,129	(0,78)	0,127	(1,33)	0,123	(0,66)	1,13
γ Tradables - ratio capital/high edu labour										
Capital		--		-0,030	(0,18)					
High edu labour		--		-0,161	(1,34)					
Low edu labour		--		0,126	(2,15)					
υ Tradables - ratio high edu/low edu labour										
Capital		--		0,121	(1,01)					
High edu labour		--		0,211	(1,18)					
Low edu labour		--		-0,267	(3,87)					
γ Tradables - ratio capital/labour										
Capital		--				0,244	(1,50)	-0,037	(0,80)	
High edu labour		--				0,188	(1,03)	0,345	(1,07)	
Low edu labour		--				-0,432	(2,27)	-0,224	(9,49)	
γ Non Tradables - ratio capital/labour										
Capital		--						0,051	(0,62)	
High edu labour		--						-0,141	(0,14)	
Low edu labour		--						0,006	(0,73)	
N of parameters	60	77		83		79		81		
Log L	-600,0	-536,3		-507,4		-534,2		-547,1		
Schwartz criterion	-1549,7	-1521,4		-1498,6		-1528,9		-1566,3		

Table 2. Trade costs in bilateral trade flows. Dependent variable: Bilateral imports.

	ln(s*Y)	t-stat	ln(dist)	t-stat	adjacent	t-stat	constant	t-stat	R2
Agriculture	1,09	(7,32)	-0,94	(2,92)	2,73	(5,05)	5,696	(2,55)	0,352
Mining, quarrying, electricity, water, gas	1,05	(7,80)	-0,74	(2,20)	2,74	(4,77)	-3,88	(1,51)	0,441
Food, beberages and tobacco	1,01	(11,16)	-2,15	(7,83)	0,65	(1,41)	5,26	(2,48)	0,489
Textiles, apparel, leather	1,43	(11,99)	-1,26	(3,77)	0,56	(0,99)	-9,43	(3,57)	0,490
Wood, cork and other manufacturing	0,94	(12,02)	-1,12	(4,23)	0,82	(1,94)	-4,88	(2,34)	0,532
Paper and printing	1,03	(11,98)	-1,70	(5,02)	0,58	(1,48)	-7,30	(2,73)	0,513
Chemical products	1,14	(12,95)	-1,49	(4,99)	1,52	(3,02)	-7,35	(3,13)	0,587
Rubber and plastic	0,82	(6,23)	-0,95	(2,56)	1,29	(2,06)	-4,10	(1,40)	0,314
Non metallic mineral products	1,15	(11,96)	-1,96	(7,12)	1,51	(3,25)	-1,17	(0,57)	0,619
Basic and fabricated metal products	1,07	(11,85)	-2,53	(8,25)	0,45	(0,86)	2,04	(0,84)	0,594
Mechanical engineering	0,96	(6,35)	-1,06	(3,12)	0,74	(1,29)	-3,07	(1,41)	0,277
Electric, electronic and optic products	1,13	(11,40)	-1,70	(5,08)	0,65	(1,18)	-6,28	(2,37)	0,495
Transport equipment	1,09	(12,60)	-1,16	(3,40)	1,20	(2,09)	-12,16	(4,51)	0,517
Construction	0,90	(11,52)	-1,18	(3,98)	0,69	(1,26)	-2,68	(1,12)	0,444
Repair, retail and wholesale	1,15	(6,85)	-0,42	(1,89)	2,07	(4,00)	-8,56	(3,06)	0,486
Hotels and restaurants	0,95	(12,54)	0,83	(0,91)	0,90	(3,14)	-10,10	(7,50)	0,412
Transport and communication	1,15	(13,59)	-0,76	(4,00)	-0,36	(1,14)	-2,37	(1,58)	0,426
Financial sector	1,26	(16,95)	0,10	(0,63)	0,78	(2,75)	-10,50	(7,93)	0,526
Real state and other market services	1,28	(14,66)	0,13	(0,69)	0,28	(0,85)	-9,86	(6,35)	0,438
Public services	1,17	(18,80)	0,12	(0,89)	0,43	(1,84)	-7,71	(7,01)	0,579

Note: See equation 11 for a description of the explanatory variables. SUR estimation (272 observations *20 sectors)

Table 3. Main results

	Common technology (Spain) T1	Estimated technology T2	Estimated technology HNTD T3	Estimated technology DFS HNTD T4	Estimated technology DFS HNTD Gravity T6
Sign test	0.41	0.41	0.57	0.72	0.66
Weighted sign test	0.23	0.23	0.72	0.83	0.89
Rank test regions	0.25	0.25	0.25	0.21	0.55
Rank test factors	0.34	0.33	0.52	0.70	0.71
Variance ratio	0.03	0.05	0.04	0.09	0.32
Slope test	-0.101	-0.133	0.065	0.178	0.373
t-stat	1.98	2.07	1.92	3.37	3.98
R2	0.07	0.08	0.06	0.19	0.24

Table 4. Sign and rank test region by region

	T1	T2	T3	T4	T6
Sign test					
Andalusia	0.75	0.75	0.75	0.75	0.75
Aragon	1.00	0.75	1.00	1.00	0.75
Asturias	0.50	0.75	0.50	1.00	1.00
Balearic Islands	0.50	0.25	0.50	1.00	1.00
Canary Islands	0.25	0.25	0.25	1.00	1.00
Cantabria	0.00	0.50	0.50	0.50	0.50
C-Leon	0.75	0.50	0.50	0.75	0.75
C-La Mancha	0.50	0.50	0.75	0.50	0.50
Catalonia	0.00	0.00	0.75	0.75	0.75
Valencian Com.	0.50	0.50	0.50	0.75	0.75
Extremadura	0.25	0.50	0.50	0.75	0.75
Galicia	0.00	0.00	0.50	0.75	0.75
Madrid	0.50	0.50	0.50	0.50	0.75
Murcia	0.50	0.25	1.00	0.75	0.25
Navarra	0.25	0.25	0.50	0.75	0.50
Basque Country	0.75	0.75	0.75	0.75	0.50
Rioja (La)	0.00	0.00	0.00	0.00	0.00
Average	0.41	0.41	0.57	0.72	0.66
Rank test					
Andalusia	0.38	0.25	0.25	0.25	0.50
Aragon	0.13	0.25	0.13	0.00	0.38
Asturias	0.25	0.25	0.25	0.25	0.63
Balearic Islands	0.25	0.25	0.38	0.13	0.63
Canary Islands	0.13	0.25	0.13	0.13	0.63
Cantabria	0.13	0.25	0.25	0.38	0.38
C-Leon	0.38	0.38	0.25	0.25	0.63
C-La Mancha	0.38	0.25	0.25	0.25	0.63
Catalonia	0.25	0.25	0.25	0.13	0.63
Valencian Com.	0.13	0.13	0.38	0.13	0.50
Extremadura	0.38	0.25	0.13	0.13	0.38
Galicia	0.38	0.25	0.38	0.25	0.75
Madrid	0.38	0.38	0.25	0.25	0.75
Murcia	0.13	0.25	0.25	0.25	0.50
Navarra	0.25	0.38	0.13	0.25	0.63
Basque Country	0.13	0.00	0.38	0.38	0.75
Rioja (La)	0.38	0.25	0.25	0.13	0.13
Average	0.25	0.25	0.25	0.21	0.55

Table 5. Sign and rank test factor by factor

	T1	T2	T3	T4	T6
Sign test					
Capital	0.47	0.47	0.65	0.65	0.59
High edu labour	0.47	0.47	0.65	0.88	0.82
Low edu labour	0.29	0.29	0.41	0.65	0.59
Average	0.41	0.41	0.57	0.72	0.66
Rank test					
Capital	0.28	0.32	0.55	0.66	0.77
High edu labour	0.44	0.37	0.60	0.80	0.79
Low edu labour	0.31	0.30	0.40	0.64	0.58
Average	0.34	0.33	0.52	0.70	0.71

Figures

Figure 1- T1. Common technology - Spain

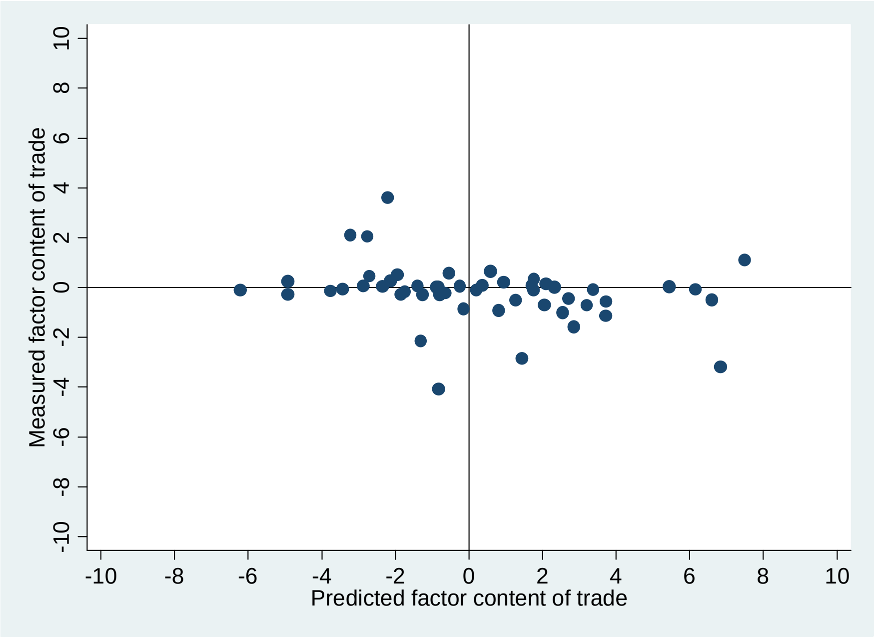

Figure 2 - T2. Average technology

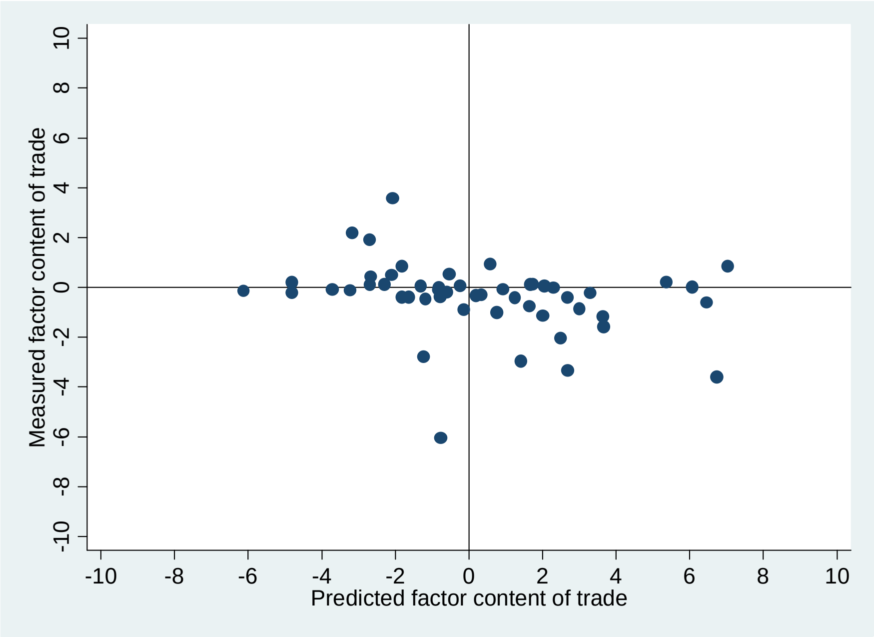

Figure 3 - T3. Factor augmenting Hicks-neutral technology (HN)

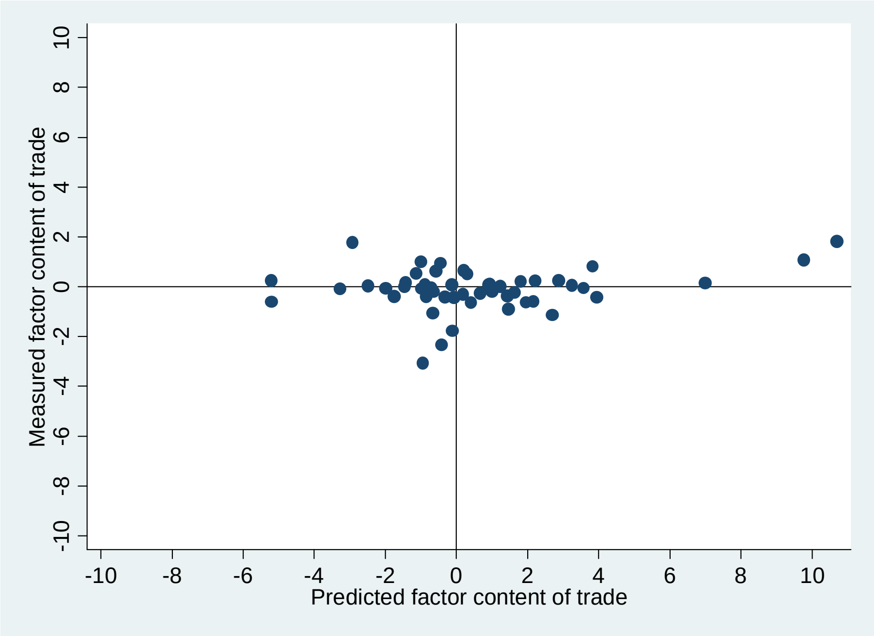

Figure 4 - T4: DFS model with Hicks-neutral technology

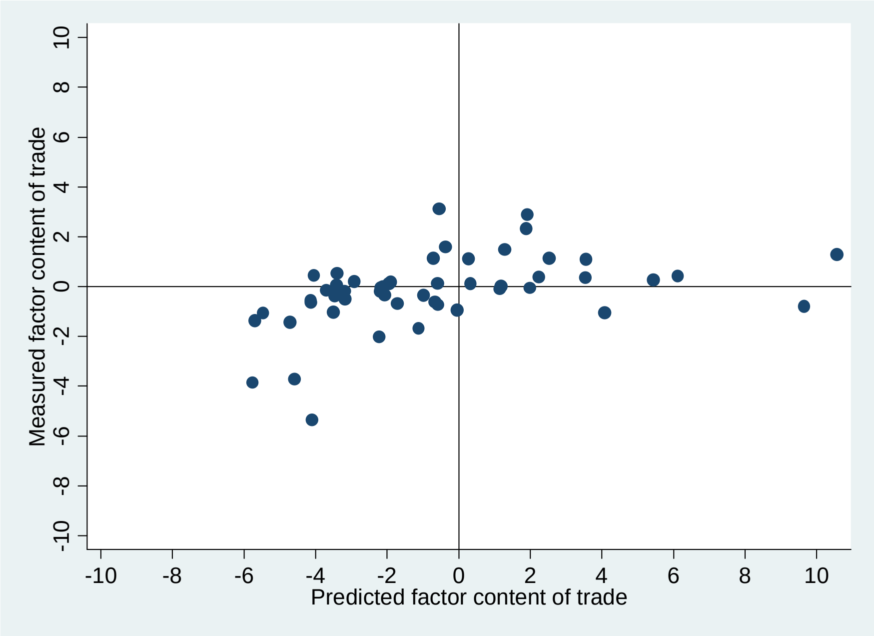

Figure 5 - T6: DFS model, HN technology with gravity demand specification