Revista de Economía Aplicada E A *Número 60 (vol. XX), 2012, págs. 5 a 24*

EU INTEGRATION AND PRODUCTION NETWORKS*

LETICIA BLÁZQUEZ
CARMEN DÍAZ-MORA
ROSARIO GANDOY
Universidad de Castilla-La Mancha

The aim of this paper is to analyse the participation of Spain in International Production Networks using parts and components trade data from 1990 to 2009. We are particularly interested in understanding the potential contribution of factor endowment differences in networking and the impact of belonging to a common geographical and trading area such as the European Union on this participation strategy. Using an extended gravity panel data model, we find that Spain's integration into production networking results from its comparative advantage but also from other factors such as EU membership and good quality transport and communication infrastructures.

Key words: International Production Networks, trade in parts and components, Spanish economy, European Union, gravity model.

JEL classification: F10, F14, F15.

In recent decades, the increasing implementation of strategies in international production fragmentation has been a significant phenomenon. Advances in information and communication technology and the progressive liberalization of exchanges in goods and services have encouraged companies, particularly, but not exclusively, multinationals, to segment and relocate different phases of the production process in new locations beyond their borders. Moreover, the emergence of China and other emerging countries onto the economic panorama, as well as the accession of Central and Eastern European countries (CEEC's) to the European Union (EU), all with wage advantages, have boosted the processes of the geographical reorganisation of production. International Production Networks (IPNs) are thus created allowing firms to improve their production efficiency and competitive position in global markets.

(*) Financial support from the Consejería de Educación y Ciencia of the Junta de Comunidades de Castilla-La Mancha under the project PPII10-0154-9251 (co-financed by FEDER funds) is gratefully acknowledged. We wish thank the anonymous referees for their helpful suggestions.

Apart from case studies based on the performance of multinational companies, there has been little empirical analysis of the nature of these IPNs. Since the available statistics did not enable the distinction between components and assembled or final products, advances in this field have been severely limited. However, over the past decade, a new line of research using trade in parts and components (P&C) has been developed. This trade is particularly appropriate for the analysis of IPNs as, due to their intermediate nature, trading parts and components must necessarily be destined for further processing or assembly in another country (except spare parts).

The present work pertains to the aforementioned line of research. Our aim is to establish the determinants of the participation of Spanish manufacturing industries in IPNs.

Theoretical literature indicates the existence of comparative advantages between countries as a key determinant of IPNs. In capital and technology intensive industries, such as machinery and transport equipment, the production of P&C is relatively capital intensive while their assembly is relatively more labour intensive [Kim (2002) and Athukorala (2007)]. Therefore, capital and/or skill abundant economies would be expected to have an advantage in producing parts and components while labour abundant economies would have an advantage in assembly. This hypothesis is confirmed by several studies. The empirical evidence for higher income countries [the OECD in Yeats (2001), the EU in Barba Navaretti *et al.* (2002) and Zeddies(2010)] reveals their specialization in the export of high-quality and capital intensive P&C. The empirical evidence for lower income economies shows that, in general, the most labour intensive stages, among them assembly, are moved to countries with lower labour costs. Most of these studies focus on Asian countries [Ng and Yeats (1999), Athukorala (2005), Athukorala and Yamashita (2006) and Kimura *et al.* (2007)] and on countries from Central and Eastern Europe [Kaminski and Ng (2001 and 2005), De Simone (2008)] where cross-border production sharing has undergone a remarkable growth in recent years.

The experience of the Spanish economy constitutes an interesting case study because it is a middle income country that belongs to an enlarged regional integration agreement. Compared to the most advanced EU economies, Spain exhibits a poor technological capacity and a comparative advantage in lower labour costs. According to the classical trade theories, technological and factor endowment differences between countries are determinants of the European countries' specialization in different production process phases. If so, the accession of a country like Spain to the EU could have fuelled a relocation of the most labour intensive tasks towards its territory. Furthermore, it would have encouraged P&C imports for assembly and re-export as more complex components or as final products. Nevertheless, in the enlarged EU context, the gradual incorporation of lesser income countries increases the competition in labour intensive production tasks. Therefore, if comparative advantage prevails in the configuration of networks, Spain, and other middle income countries, would have difficulties maintaining themselves in these IPNs. This would only be possible if there are other factors apart from comparative advantages that explain its participation in a dispersed value chain.

Using P&C trade from COMTRADE[1], empirical analysis suggests that Spanish manufacturing firms have been actively participating in IPNs since 1990. P&C trade has been extraordinarily dynamic in Spain: exports increased at a cumulative annual rate of 8.1% (5.1% in the EU-14, that is, the Fifteen not including Spain), while imports increased at a rate of 7.2% (5% in the EU-14). This strong growth has facilitated a progressive increase in the P&C share in total trade, from 24% of exports in 1990 to 29% in 2009; and from 27% of imports to 39%. Moreover, when the geographical distribution of Spain's trade in P&C is analysed, we find that intra-EU flows are dominant (around 70% of P&C trade is between Member States), suggesting a regional dimension of the production networks. Here, we formulate our first hypothesis: the deepening of the EU integration process has reduced trade costs between Member States and promoted Spain's further involvement in European networks.

Beyond these figures, the most striking fact is Spain's ability to maintain its share in world P&C markets (Figure 1) despite the increasing competition from lower wage areas such as the Asian economies and the Central and Eastern European countries (CEEC-10), with both groups leading in the international production fragmentation processes. In contrast, the rest of the EU-15, along with Japan and the USA, have registered a sharp loss in their world trade shares which is mainly related to the growth of P&C trade in Asia and the CEEC-10 [Athukorala (2005), Athukorala and Yamashita (2006) and Kimura *et al*. (2007)][2].

Moreover, in the European area where P&C trade flows have been particularly dynamic, Spain increased its trade share between 1990 and 2009 (from 3.1% to 5% of EU-15 P&C exports and from 5.5% to 8% of EU-15 P&C imports). Therefore, both the enlargement of the EU towards the East and the CEECs' rising presence in European regional networks have been compatible with an increasing importance of Spain as a trading partner of the EU-15. In fact, Spain has been the only EU-15 country that has managed to improve its position as an export destination for EU P&C trade, moving up from eighth to sixth position in the ranking. Spain has also been able to rise in the ranking of P&C suppliers to the EU-15 (from eleventh position in 1990 to tenth in 2009) despite the inclusion of some emerging countries such as China and the Czech Republic in the top 10.

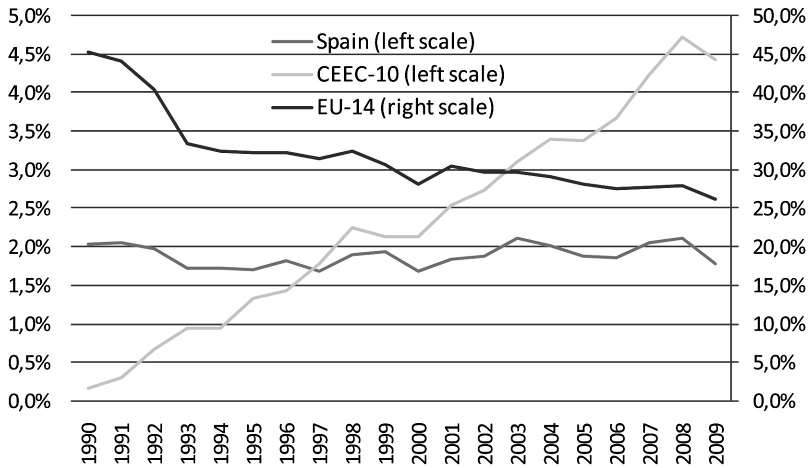
These facts reveal that Spanish firms involved in IPNs have managed to withstand the increasing low-cost competition from new EU members. At this point, we formulate our second hypothesis: Other factors besides comparative advantage determine Spanish engagement in production networks.

In order to test these hypotheses, we will estimate an extended gravity panel data model for the period 1990-2009. Our aim is to identify the factors influencing Spanish trade in parts and components. We are particularly interested in understanding the potential contribution of factor endowment differences in networking and the fact of belonging to a common geographical and trading area such as the EU.

(1) The selection of items of P&C follows Athukorala (2005) and 99 items of P&C (at the 4 or 5 digit level of SITC Rev. 3) are considered. See Table A.1. in the Statistical Appendix.

(2) The stability of Spanish shares is a common trend in export and import flows. A detailed description of both for the period 1990-2006 can be found in Blázquez *et al.* (2010).

Figure 1: World trade shares in P&C



Note: The trade shares are calculated as the country's exports plus imports divided by the sum of world exports and imports.

Source: Authors' calculation, based on UN COMTRADE.

The rest of the paper is structured as follows. The extended gravity model to be estimated is described in Section 1 and the econometric results are presented in Section 2. The paper concludes with some final considerations.

1. Estimating a gravity model for parts and components trade

In order to identify the impact of factors influencing Spanish trade linked to IPNs, we propose to estimate a gravity model. These models, initially developed by Tinbergen (1962) and Anderson (1979), are often applied in empirical literature on international trade. Gravity models explain the volume of bilateral trade flows according to the size of the trading economies (with a positive influence since it is associated with a wider available market) and the bilateral trade costs (which depend on variables such as the physical distance between trading partners, sharing a border or a language, and belonging to the same regional integration agreement). In the scarce empirical literature that examines the determining factors of P&C trade, gravity models are still widely used [Athukorala and Yamashita (2006) and Kimura *et al.* (2007), Frensch (2010), Baldwin and Taglioni (2011)].

Among the standard variables in gravity models of international trade, we are particularly interested in the membership of regional integration agreements, in our case, the European Union, since intra-EU flows are especially important for Spain. As the theoretical literature on the international fragmentation of production maintains, the specific characteristics of trade associated with the international fragmentation of production allow us to consider that trade costs might have a greater impact on trade in intermediate goods than in final goods. Since the product has to cross the border for production stages or tasks located in foreign countries, the amount of trade costs (duties, transport and insurance costs, time costs or communication costs) will have more impact on trade associated with the fragmentation of production than on trade in final goods [Yi (2003)]. In this context, it is expected that being a member of a common regional integration agreement will stimulate cross-border production sharing between the Member States, since trade barriers between them are much lower[3]. In addition, intra-EU trade is less subject to economic, legal and political uncertainties or exchange risks than trade with non-member states [Zeddies (2010)]. Thus, EU membership would favour the regional (and European) character of production networks. In fact, the proliferation of regional integration agreements seems to have driven the fragmentation of production processes and changed their geography in such a way that some authors insist that regional, rather than global networks have emerged[4]. Therefore, we expect that the country's EU membership will be a determining factor in explaining Spanish integration in cross-border production networks.

We augment the standard gravity model with additional explanatory variables proposed by the theoretical literature on international production fragmentation.

The first group of specific variables link trade associated with the international fragmentation of production to the exploitation of comparative advantages in every one of the phases or tasks of the production process[5] [Arndt (1997), Deardorff (2001), Jones and Kierzkowski (1990 and 2001)]. They are "kaleidoscopic comparative advantages" [Bhagwati and Dehejia (1994)]. These advantages may be based on relative factor endowment (according to Heckscher-Ohlin type models) and/or on relative productivity (in accordance with Ricardian type models). Per capita income differences are considered a good proxy for differences in comparative advantages between countries. These differences can be introduced into the models in relative terms or in absolute terms. The latter form is used in several previous papers on P&C trade. Kimura *et al.* (2007) find a positive coefficient for Asia and a negative one for Europe. They deduce that P&C trade in Asia is the result of the existence of cross-border production networks which exploit the comparative advantages of each location in this economic area. Meanwhile, in Europe, the trade of horizontally differentiated goods, which is not driven by per capita income differences between countries, dominates. Athukorala and Yamashita (2006) obtain a negative coefficient for a model with 50 world economies. They explain

(3) Particularly, Gil-Pareja *et al*. (2008) analyse the effect of monetary agreements on trade flows and show that this is of a similar order of magnitude to that of regional trade arrangements. They also show how these agreements have boosted trade with non-member countries. They find that the European Monetary Union has the greatest intra-bloc impact.

(4) [Rugman (2001) and Zysman *et al.* (1996)].

(5) As a product's comparative advantage depends on each of the competitive advantages which can be exploited at each stage or task of the production chain, Bhagwati and Dehejia (1994) use the term "kaleidoscopic comparative advantages".

this result through the dominance of advanced countries (therefore, with lower differences in comparative advantages) in world trade, both in terms of final goods and P&C. Lastly, Frensch (2010) finds a positive coefficient for trade among the EU-25, highlighting supply-side differences as driving the fragmentation process across Europe, specifically between the original EU-15 and new Member States.

In the model proposed in this paper, the interpretation of the absolute differences in per capita income is somewhat different. It is based on the idea that certain minimum conditions concerning technological or institutional capacity must be guaranteed in countries to participate in these networks [Yeats (2001)]. In this respect, the negative sign of absolute differences in per capita income would mean that an excessive gap in the economic development of trading countries could act as an obstacle to networking. This is in accordance with available empirical evidence showing that production sharing networks are integrated by countries with a medium level of development. In these countries, the minimum requirements that make the internationalization of the value chain feasible in terms of the highest efficiency are guaranteed.

In addition, we introduce the relative differences in income per capita in order to define the incidence of the comparative advantage on P&C trade. At this point, we adopt two assumptions: production of P&C is a less labour intensive activity than assembly and there is a positive correlation between the capital labour ratio and per capita income [Helpman (1987)]. With these assumptions, we expect that countries with higher per capita income enjoy a comparative advantage in the production and exportation of P&C, while countries with lower per capita income enjoy a comparative advantage in the importation of P&C and assembly stages. That is, the higher the per capita income in Spain compared to country *j*, the greater the P&C exports from Spain to country *j* because Spain will have a comparative advantage in production and exportation of P&C while country j will have a comparative advantage in assembly activities. For the same reasons, the higher the per capita income in country *i* compared to Spain (used as a proxy variable of *i's* greater relative abundance of capital), the greater the P&C exports from *i* to Spain, because country *i* benefits from a comparative advantage in production and exportation of P&C (which require more capital and technology) whereas Spain has a comparative advantage in assembly activities. As a result, we would expect the relative per capita income variable to be positive.

Additionally, the exploitation of the advantages of the international division of labour requires extensive markets. In the context of increasing returns to scale in the phases or tasks of the production cycle, market size determines the optimum degree of production fragmentation: the production scale establishes the extent to which the international division of labour can be exploited [Jones *et al.* (2005)]. In this regard, trade liberalisation policies and the decrease in transport and communication costs have increased the size of the markets. Moreover, the larger the market, the easier it is to find an adequate location and/or partner to establish production sharing networks [Grossman and Helpman (2005)]. In short, economy size is a principal factor in the international fragmentation of production. As a result, with sufficiently extensive markets and locations with different comparative advantages, certain areas or regions will specialise in providing specific phases or tasks.

Nevertheless, the efficiency gains derived from the exploitation of the comparative advantages at each stage of production may diminish or even disappear if the costs of coordination and supervision of the connection of geographically dispersed production blocks are excessively high. Jones and Kierzkowski (1990 and 2001) name these costs "service link costs". The more complex the production fragmentation procedure and the wider the IPNs, the greater the exploitation of comparative advantages, but the costs of these services will also be higher. The balance between service link costs and benefits derived from the maximum exploitation of the advantages of the international division of labour and from intra-product specialisation will determine the optimal degree of the international fragmentation of production.

Among the service link costs, the costs of communication between the companies that make up the international production network are particularly significant. Production networks require fluidity, low costs and security in the transmission of information. For this reason, a high quality telecommunications system is essential. In recent decades, developments in the information and communication technology field, as well as the deregulation and liberalisation of these services have resulted in quicker, cheaper and more reliable communication systems, which can practically be used worldwide. This has been of enormous benefit in terms of the connections between phases or tasks which are internationally dispersed, promoting the spatial disintegration of production in order to benefit from the comparative advantages of different locations.

However, these service link costs continue to differ greatly across countries. To a great extent, they can determine decisions for localising each stage of the production process and, therefore, the possibilities that a country has of taking part in production sharing networks[6].

To take into account the aforementioned theoretical considerations, the standard gravity model is extended to include a second group of variables which introduces service link costs such as the quality of transport and telecommunications infrastructure. A plus sign in their coefficients is expected: the greater the infrastructure quality, the lower the service link costs and the higher the trade linked to production sharing networks. This hypothesis is tested in Jones *et al.* (2005) and Egger and Egger (2005). The former find that, for the world and for the three main economic regions (EU-15, NAFTA and Eastern Asia), trade associated with the international fragmentation of production (estimated by P&C trade) depends negatively on the service link costs (estimated by the telephone rate for companies in each region), as predicted by the theoretical models. Egger and Egger (2005) consider that the impact of infrastructure (size of the road network, size of the telephone network and extent of electricity availability) is beneficial to EU-12 bilateral processing trade.

(6) Grossman and Helpman (2005) also indicate that the cost of searching for adequate partners decreases and, therefore, the possibility of reaching agreement with companies from other countries in order to localise parts of the production process increases when there are good transport and communications infrastructures in these countries. In this regard, a minimum quality of infrastructures is required for both the initial establishment and the proper functioning of an international production network.

Finally, time dummy variables (D_t) are included to control the impact of time varying factors that affect all countries, such as technological improvements or the multilateral reduction of trade barriers, which result in lower costs for connecting segmented stages of the production process.

Therefore, the gravity model specification that we propose is the following:

[Specification 1]

$$\ln X_{ijt} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 \ln \text{Bilateral distance}_{ij} + \beta_4 \text{Shared border}_{ij} + \beta_5 \text{Shared language}_{ij} + \beta_6 EU_{ijt} + \beta_7 \ln \text{PCI-abs-differences}_{ijt} + \beta_8 \ln \text{Relative-PCI}_{ijt} + \beta_9 \ln \text{Transport infrastructure}_{ijt} + \beta_{10} \ln \text{Telecommunications-infrastructure}_{ijt} + D_t + \varepsilon_{ijt}$$

where *i* and *j* respectively refer to the countries of origin and destination of the exports, and *t* to the year. The dependent variable X_{ijt} represents the exports in nominal terms[7]. The model is estimated for Spanish bilateral trade with its main trading partners in P&C for the period 1990-2009. More specifically, 28 countries are included[8], which account for approximately 95% of Spanish P&C trade. Since gravity models are designed to explain bilateral trade flows, 56 observations are introduced every year: 28 corresponding to Spain's exports to each selected country and another 28 corresponding to the exports from each of those countries to Spain[9].

Regarding the explanatory variables, the GDP_{it} and GDP_{jt} variables measure the size of the trading economies. Therefore, if imperfect competition and economies of scale are important in P&C trade, we would expect a positive value for both coefficients[10]. On the other hand, trade associated with the international fragmentation of production will increase as the distance between the trading countries decreases *(Bilateral distance$_{ij}$)*. It will also increase if the countries share a border *(Shared border$_{ij}$)*, share a language *(Shared language$_{ij}$)* or belong to the European Union *(EU$_{ijt}$)*. As regards the more specific hypotheses of international fragmentation models, we would expect a negative impact of the *PCI-abs-differences$_{ijt}$* variable and positive coefficients for the *Relative-PCI$_{ijt}$*, *Transport infrastructure$_{ijt}$* and *Telecommunications-infrastructure$_{ijt}$* variables[11].

(7) A common error in works that estimate gravity models is the deflation of exports. Baldwin *et al.* (2008: 15) qualify this as the "bronze medal" in the race of errors in gravity models in international trade. According to these authors, deflation in this case is an error because "all the prices in the gravity equation are measured in terms of a common numeraire, so there is no price illusion".

(8) See Table A.2. in the Statistical Appendix. Since only main trade partners in P&C are selected, there are no zeros in the trade data used. In the case of a predominance of zeros, the coefficients may be overestimated [Helpman *et al.* (2008)].

(9) Theoretically, the exports from i to *j* should be the same as the imports *j* obtains from *i*, but the different cif/fob valuation of the import/export flows means it is advisable to always use the same flow, specifically, that of exports.

(10) Baldwin and Taglioni (2011) raise doubts about the use of GDP as the mass variable in the gravity equation when P&C trade is important. They argue that, in a context of rapid internationalization of supply chains, gross trade flows are increasingly unrepresentative of the value-added flows. But, as they also point out, a new, more accurate proxy for economic mass has not yet been identified [Baldwin and Taglioni (2011)].

(11) See Table A.3. in the Statistical Appendix for an explanation of the measurement of the model's variables and the sources used.

2. Estimation results

2.1. Results for the extended gravity model

Table 1 presents the estimation results for our extended gravity model by the traditional OLS method. Since White's Test and the Breusch-Pagan/Cook-Weisberg Test indicate the presence of heteroskedasticity in the data, heteroskedastic-consistent standard errors using the HC3 procedure were computed in all the estimations[12].

In the first column, we observe that all the coefficients are significant and display the expected sign. Concerning the standard variables in the gravity models, the economic size of the trading countries has a positive impact on P&C trade with coefficients close to the unit as predicted by the theory, while the bilateral trade costs have a negative impact. In particular, the distance between countries discourages trade associated with production sharing networks (because it increases bilateral trade resistance), while sharing a border or a language increases the trade value (given that it reduces the bilateral resistance). As a result, P&C trade in Spain is greater with countries that are geographically closer and share a border or a language with it[13]. The sign for the EU membership variable is positive and significant, so that P&C trade is greater with other Member States.

With regards to the specific variables for models of the international fragmentation of production, the negative and significant coefficient of the absolute differences in per capita income allows us to defend our hypothesis that an excessive gap in relative terms in the economic development of countries implies a restriction for P&C trade as well as for networking. These results are in concordance with Athukorala (2005), who emphasizes that multinational companies have traditionally tended to extend their production networks towards industrialized countries, or at least towards countries with an intermediate level of development.

The proxy variable of comparative advantages or disadvantages (the relative per capita income) yields a positive and significant coefficient. The greater the Spanish per capita income compared to another trading partner (and the greater the Spanish relative capital labour ratio), the greater the Spanish P&C exports to this partner; while the greater the per capita income of a trading partner compared to Spain (and the greater its capital labour ratio in relation to Spain), the greater the P&C exports of that partner to Spain (or greater the Spanish P&C imports from that partner).

The positive sign obtained for variables that approximate the quality of transport and telecommunications infrastructure supports the hypothesis that participation in global production networks increases with the quality of these infrastructures in the countries involved[14]. This will guarantee that the service link costs

(12) [White (1980), MacKinnon and White (1985) and Long and Ervin (2000)].

(13) Taking into account that, in our sample, the number of countries sharing a common language or border with Spain is fairly small, the results for these variables should be interpreted with caution.

(14) Although the percentage of paved roads and internet users may be insufficient to measure the service link costs accurately, to our knowledge, there is no any other accessible set of proxies that are both rigorous enough to capture them and widely available for the period 1990-2009. The last point is particularly relevant since more sophisticated indicators are rarely obtainable for countries such as Turkey and Morocco or even Argentina, Brazil, Mexico, Singapore and Malaysia.

Table 1: EXTENDED GRAVITY MODEL ESTIMATES FOR P&C TRADE IN SPAIN

	Specification 1			Specification 2	Specification 3
Coefficients	Column (1)	Column (2)	Column (3)	Column (4)	Column (5)
GDPi	0.766*** (0.034)	0.758*** (0.035)	0.884*** (0.034)	1.073*** (0.122)	
GDPj	0.761*** (0.035)	0.754*** (0.035)	0.644*** (0.035)	1.068*** (0.122)	
Bilateral distance	-0.552*** (0.064)	-0.525*** (0.061)	-0.553*** (0.062)		
Common border	0.614*** (0.091)	0.640*** (0.089)	0.606*** (0.101)		
Common language	0.501*** (0.139)	0.485*** (0.137)	0.495*** (0.160)		
EU	0.671*** (0.081)	0.729*** (0.073)	0.675*** (0.090)	0.145* (0.087)	1.455** (0.731)
PCI-abs-differences	-0.090* (0.051)		-0.089* (0.051)	-0.031 (0.047)	0.129 (0.182)
Relative-PCI	0.365*** (0.033)	0.365*** (0.033)		0.365*** (0.025)	0.283*** (0.059)
Transport Infrastructure	0.192*** (0.067)	0.206*** (0.066)	0.199** (0.081)	0.145 (0.201)	0.535 (1.382)
Telecommunications Infrastructures	0.249*** (0.055)	0.256*** (0.055)	0.238*** (0.066)	0.223*** (0.064)	0.209*** (0.051)
Time dummies	Yes	Yes	Yes	Yes	No
Country-pair specific fixed effects (D_{ij})	No	No	No	Yes	Yes
Time varying exporter and importer fixed effects (D_{it}, D_{jt})	No	No	No	No	Yes
Number of observations	1088	1088	1088	1088	1088
Adjusted R^2	0.737	0.737	0.701	0.803	0.810
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (p-value)	0.000	0.000	0.000	0.000	0.001
Wald test (p-value)	0.000	0.000	0.000		

Notes: HC3 heteroskedastic-consistent standard errors are reported in parentheses. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively. The null hypothesis of the Wald test is that all coefficients are identical for both P&C and final goods trade equations.

Source: Own elaboration.

associated with the fragmentation and dispersion of the production will not be so high as to nullify the profits derived from exploiting the comparative advantages of different locations.

Although there are no problems of correlation between the absolute differences in the per capita income variable and the relative per capita income variable (the coefficient of correlation is -0.007), the second column of Table 1 shows the results excluding the absolute differences in per capita income variable. The results for the rest of variables are not significantly affected, nor does the omission of the relative per capita income variable noticeably change the results (third column of Table 1). The absolute difference in the per capita income variable remains negative and significant, coinciding with the results obtained for Europe in the study by Kimura *et al*. (2007) and for the 50 countries examined by Athukorala and Yamashita (2006).

Finally, in order to test whether both the P&C and final goods trades are similarly affected by the same factors, we conduct a Wald test with the null hypothesis that all coefficients are identical in both equations (last line of Table 1). The Wald test confirms that the differences are significant. The regression results from the gravity model for Spain's trade in final goods are reported in Table A.4 in the Statistical Appendix. Comparative advantages also play an active role in explaining trade in final goods, a result which is consistent with the predominance of vertical intra-industry trade in Spanish trade flows [Díaz-Mora (2002), Martín and Orts (2008)]. However, important determinants of participation in cross-border production networks such as differences in development and good telecommunications infrastructures are not relevant for trade in final goods.

2.2. *Robustness analysis*

In order to check the robustness of the results obtained, we have conducted some sensitivity analyses (two last columns of Table 1). Specifically, we estimate the model by incorporating different types of fixed effects. First of all, we estimate the model introducing country-pair-specific dummy variables (D_{ij}). Gravity models tend to include variables for establishing the impact of natural trade barriers (distance, shared border), cultural barriers (shared language) or barriers imposed by trade policy (member of the same regional integration agreement). However, these variables may not represent all the potential bilateral trade costs. It is very likely that other factors (specific to each country-pair) have an impact on bilateral trade; so that the estimation results will be biased when they are omitted from the model. To control for the impact of any time-invariant bilateral variables, the gravity equation is estimated by replacing time-invariant bilateral variables such as bilateral distance, common language or common borders with fixed country-pair effects[15]. Thus, the model specification to be estimated is as follows:

[Specification 2]

$$\begin{aligned}\ln X_{ijt} = {} & \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_3 EU_{ijt} + \beta_4 \ln \text{PCI-abs-differences}_{ijt} + \\ & \beta_5 \ln \text{Relative-PCI}_{ijt} + \beta_6 \ln \text{Transport infrastructure}_{ijt} + \\ & \beta_7 \ln \text{Telecommunications-infrastructure}_{ijt} + D_{ij} + D_t + \varepsilon_{ijt}\end{aligned}$$

Column (4) of Table 1 presents the results of introducing country-pair-specific fixed effects into the model (dummy coefficient estimates are omitted for the sake of brevity). The coefficient estimates are robust to using country-pair fixed effects. Only the transport infrastructure variable becomes statistically insignificant.

Secondly, we estimate the model including time-varying exporter and importer fixed effects (D_{it} and D_{jt}). As Anderson and van Wincoop (2003 and 2004) point out, the volume of trade between any two countries does not only depend on

(15) This would be the classic fixed effects estimator in panel data models.

the cost of bilateral trade (or bilateral trade resistance). It also depends on bilateral trade costs relative to the cost of trade with other economies (which is termed multilateral trade resistance). *Ceteris paribus*, the greater the multilateral trade resistance, the greater the bilateral trade. These multilateral trade costs can be captured by the exporter and importer price indexes, P_{it}^{1-s} y P_{jt}^{1-s}, where s is the elasticity of substitution between goods from different countries. Therefore, following Anderson and van Wincoop (2003), the model to be estimated would be[16]:

$$\ln [X_{ijt} / GDP_{it}\ GDP_{jt})] = \beta_0 + \beta_1 EU_{ijt} + \beta_2 \ln \text{PCI-abs-differences}_{ijt} + \\ \beta_3 \ln \text{Relative-PCI}_{ijt} + \beta_4 \ln \text{Transport infrastructure}_{ijt} + \\ \beta_5 \ln \text{Telecommunications-infrastructure}_{ijt} - \ln P_{it}^{1-\sigma} - \ln P_{jt}^{1-\sigma} + D_{ij} + D_t + \varepsilon_{ijt}$$

Although these multilateral trade costs (which are extracted from the exporter and importer price indexes) are unobserved, biased estimates will be obtained when they are omitted from the gravity equation[17]. A simple method to control for this effect of multilateral trade resistance is to use time-varying exporter and importer dummy variables (D_{it} y D_{jt})[18], thus eliminating exporter and importer GDPs from the model. Taking these considerations into account, the specification to be estimated is the following:

[Specification 2]

$$\ln [X_{ijt} / GDP_{it}\ GDP_{jt})] = \beta_0 + \beta_1 UE_{ijt} + \beta_2 \ln \text{PCI-abs-differences}_{ijt} + \\ \beta_3 \ln \text{Relative-PCI}_{ijt} + \beta_4 \ln \text{Transport infrastructure}_{ijt} + \\ \beta_5 \ln \text{Telecommunications-infrastructure}_{ijt} + D_{it} + D_{jt} + D_{ij} + + \varepsilon_{ijt}$$

The introduction of exporter-time and importer-time dummies as well as time-invariant country-pair fixed effects does not alter the sign and significance of the coefficients as is shown in the last column of Table 1 (again dummy coefficients are omitted for brevity). Consequently, our results are robust to the introduction of different fixed effects. The only notable change is the loss of significance of the transport infrastructure variable and the considerable increase in the value of the coefficient of the EU variable. When the multilateral resistance term

(16) To ensure the unitary elasticity for income restriction (coefficients close to unity for GDP_{it} and GDP_{jt} variables) derived from the theoretical foundations of the gravity equation, Anderson and van Wincoop (2003) divide the dependent variable by the product of exporter and importer GDP's. Although Anderson (1979) proposes a theoretical model with non unitary income elasticities once non tradable goods are taken into account, moving exporter and importer GDPs to the left-hand side allows us to control for potential endogeneity between GDP and bilateral trade flows, since exports and imports are part of GDP. This potential endogeneity is pointed out by Baier and Begstrand (2007) but they also defend that it could be ignored without affecting the results.

(17) "Gold medal" error of gravity models [Baldwin *et al*. (2008)].

(18) In a model with cross-sectional data, Feenstra (2008) proves that the use of country fixed effects to measure price indexes enables unbiased estimates to be obtained. As a result, considering its easy implementation, it has become the preferred empirical method to approximate multilateral trade resistance compared to more complex alternative solutions such as those proposed by Baier and Bergstrand (2001) and Anderson and van Wincoop (2003). Anderson and van Wincoop (2004) argue that, with panel data, time-varying country fixed effects must be included since multilateral trade resistance can change over time.

is taken into account, that is, when the costs of trading with other economies are considered, the condition of EU membership gains great relevance (because trade costs with other EU countries are much lower than those with non-EU Member States). Spanish trade in P&C is far greater with countries immersed in the European construction process as revealed in the Introduction.

3. Concluding remarks

Some stylized facts about the participation of Spain in International Production Networks have enabled us to formulate two main hypotheses. First, Spain's EU membership works as a determinant factor in explaining Spanish integration in IPNs. Second, comparative advantages are important in determining Spanish engagement in production sharing systems, but other additional factors seem to matter as well.

The results of our extended gravity model estimates support these hypotheses. Firstly, the estimates confirm that the European integration process has been a fundamental driving force behind P&C trade, fostering Spain's participation in international networks. As predicted by theories on the international fragmentation of production, a reduction in the cost of trade associated with regional integration processes (and the consequent growth in market size) has favoured the international segmentation of production processes.

Secondly, Spain's integration into cross-border production networks is related to comparative advantage, but other factors emerge as important in medium-high technology industries. Geographic proximity and the availability of good quality transport and telecommunications infrastructures have encouraged Spain's participation in cross-border networking. In addition, differences in per capita income between trading partners should not be very high in order to guarantee a legal and institutional framework and a technological capacity, in short, a level of economic development that allows participation in international production sharing. Some of these determining factors seem not to be relevant for trade in final goods.

Likely future EU enlargements towards lower costs countries could threaten Spain's position in networking. In order for Spain to protect itself against this competition, factors other than their comparative advantages must be taken into account. The reinforcement of these factors would act as a key element to strengthen Spain's participation in cross-border networks.

Statistical Appendix

Table A.1: List of parts and components according to the standard international classification (sitc) system (revision 3)

Divisions	Codes of subgroups and Codes of basic headings
Power-generating machinery and equipment	711.9, 712.8, 713.19, 713.31, 713.32, 713.9, 714.9, 716.9, 718.19, 718.78, 718.99
Machinery specialized for particular industries	721.29, 721.39, 721.98, 721.99, 723.9, 724.39, 724.49, 724.67, 724.68, 724.88, 724.9, 725.9, 726.89, 726.9, 727.19, 727.29, 728.19, 728.39, 728.5
Metalworking machinery	735.9, 737.19, 737.29, 737.39, 737.49
General industrial machinery and equipment, n.e.s., and machine parts, n.e.s.	741.28, 741.35, 741.39, 741.49, 741.59, 741.72, 741.9, 742.9, 743.8, 743.9, 744.19, 744.9, 745.19, 745.29, 745.39, 745.68, 745.9, 746.99, 747.9, 748.39, 748.9, 749.9
Office machines and automatic data-processing machines	759.1, 759.9
Telecommunications and sound-recording and reproducing apparatus and equipment	764.9
Electrical machinery, apparatus and appliances, n.e.s., and electrical parts thereof	771.29, 772.2, 772.3, 772.4, 772.5, 772.6, 772.8, 774.29, 775.49, 775.79, 775.89, 776.1, 776.2, 776.3, 776.41, 776.43, 776.45, 776.49, 776.8, 778.11, 778.12, 778.17, 778.19, 778.29, 778.33, 778.35, 778.48, 778.69, 778.83, 778.85
Road vehicles	784.2, 784.3, 785.35, 785.36, 785.37, 786.89
Other transport equipment	791.99, 792.9

Source: Own elaboration.

Table A.2: Countries included in the model (Spain's main partners in P&C trade)

Regions	Countries
EU-25	Austria, Belgium, Czech Rep., Denmark, France, Germany, Hungary, Italy, Ireland, Netherlands, Portugal, Slovak Rep., Sweden, UK, and Poland
Rest of Europe	Switzerland and Turkey
America	USA, Argentina, Brazil, Canada and Mexico
Northern Africa	Morocco
Asia	Singapore, China, Japan, Korea and Malaysia

Source: Own elaboration.

Table A.3: DEFINITION OF VARIABLES AND DATA SOURCE

Label	Definition	Source
X_{ij}	Value of the exports from country *i* to country *j* in nominal terms (US dollars)	COMTRADE (United Nations)
GDP_i	Gross Domestic Product of country *i* in nominal terms (US dollars)	World Development Indicators. The World Bank
GDP_j	Gross Domestic Product of country *j* in nominal terms (US dollars)	World Development Indicators. The World Bank
Bilateral distance$_{ij}$	The Great Circle distance between capital cities of the two countries (*i* and *j*)	CEPII <http://www.cepii.fr>
Shared border$_{ij}$	Dummy variable, which is unity if *i* and *j* share the same border and zero otherwise	
Shared language$_{ij}$	Dummy variable, which is unity if *i* and *j* have a common language and zero otherwise	CEPII <http://www.cepii.fr>
EU_{ij}	Dummy variable, which is unity if *i* and *j* belong to the EU and zero otherwise	
PCI-abs-differences$_{ij}$	Absolute differences in per capita incomes between *i* and *j* (in nominal US dollars). The conversion to dollars uses the Atlas method	World Development Indicators. The World Bank
Relative-PCI$_{ij}$	Ratio of per capita income of country *i* to per capita income of country *j*	World Development Indicators. The World Bank
Transport Infrastructure$_{ij}$	The minimum percentage of paved roads of trading partners *i* and *j*.	World Development Indicators. The World Bank
Telecommunications Infrastructures$_{ij}$	The minimum percentage of Internet users of trading partners *i* and *j*.	World Development Indicators. The World Bank

Source: Own elaboration.

Table A.4: Gravity model estimates for Spain's final goods trade

Coefficients	Column (1)	Column (2)	Column (3)
GDPi	0.715***	0.711***	0.771***
	(0.031)	(0.032)	(0.031)
GDPj	0.686***	0.683***	0.632***
	(0.029)	(0.029)	(0.029)
Bilateral distance	-0.700***	-0.687***	-0.698***
	(0.054)	(0.054)	(0.052)
Common border	0.147*	0.158*	0.147*
	(0.087)	(0.087)	(0.088)
Common language	-0.026	-0.033	-0.028
	(0.161)	(0.161)	(0.172)
EU	0.730***	0.755***	0.736***
	(0.075)	(0.064)	(0.077)
PCI-abs-differences	-0.039		-0.041
	(0.056)		(0.058)
Relative-PCI	0.176***	0.176***	
	(0.034)	(0.034)	
Transport Infrastructure	0.302***	0.308***	0.307***
	(0.066)	(0.065)	(0.069)
Telecommunications Infrastructures	0.116	0.119	0.110
	(0.087)	(0.086)	(0.088)
Time dummies	Yes	Yes	Yes
Country-pair specific fixed effects (D_{ij})	No	No	No
Time varying exporter and importer fixed effects (D_{it}, D_{jt})	No	No	No
Number of observations	1088	1088	1088
Adjusted R^2	0.721	0.721	0.712
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity (p-value)	0.000	0.000	0.000

Notes: HC3 heteroskedastic-consistent standard errors are reported in parentheses. ***, ** and * indicate significance levels of 1%, 5% and 10%, respectively.

Source: Own elaboration.

REFERENCES

Anderson, J.E. (1979): “A Theoretical Foundation for the Gravity Equation”, *American Economic Review,* vol. 69(1), pp. 106-116.

Anderson, J.E. and van Wincoop, E. (2003): “Gravity with Gravitas: A Solution to the Border Puzzle”, *American Economic Review*, vol. 93, pp. 170-192.

Anderson, J.E. and van Wincoop, E. (2004): “Trade Costs”, *Journal of Economic Literature*, vol. 45, pp. 691-741.

Athukorala, P. (2005): “Product Fragmentation and Trade Patterns in East Asia”, *Asian Economic Papers,* vol. 4(3), pp. 1-27.

Athukorala, P. and Yamashita, N. (2006): “Production Fragmentation and Trade Integration: East Asia in a Global Context”, *The North American Journal of Economics and Finance,* vol. 17(3), pp. 233-256.

Athukorala (2007): “Multinational production networks and the new geo-economic division of labour in Pacific Rim countries”, in Juan J. Palacios (ed.) *Multinational corporations and the Emerging Network Economy in Asia and the Pacific*, Routledge, London.

Arndt, S.W. (1997): “Globalization and the Open Economy”, *The North American Journal of Economics and Finance,* vol. 8(1), pp. 71-79.

Arndt, S.W. (2003): “Production Sharing and Singapore’s Global Competitiveness”, in Ramkishnen Rajan (ed.) *Sustaining Competitiveness in the New Global Economy: The Experience of Singapore*, Institute of Policy Studies, Singapore.

Baier, S.L. and Bergstrand, J.H. (2001): “The Growth of World Trade: Tariffs, Transport Costs and Income Similarity”, *Journal of International Economics,* vol. 53(1), pp. 1-27.

Baier, S.L. and Bergstrand, J.H. (2007): “Do Free Trade Agreements Actually Increase Members”, *Journal of International Economics,* vol. 71(1), pp. 72-95.

Barba Navaretti, Haaland, G. and Venables A. (2002): “Multinational Corporations and Global Production Networks: The Implications for Trade Policy”, Centre for Economic Policy Research, London.

Baldwin, R., Di Nino, V., Fontagné, L., De Santis, R.A. and Taglioni, D. (2008): “Study on the Impact of the Euro on Trade and Foreign Direct Investment”, European Economic and Monetary Union Working Paper 321.

Baldwin, R. and Taglioni, D. (2011): “Gravity Chains: Estimating Bilateral Trade Flows when Parts and Components Trade is Important”, NBER Working Paper 16672.

Bhagwati, J. and Dehejia, V. (1994): “Free Trade and Wages of the Unskilled: Is Marx striking again?”, in Bhagwati, J., Kosters, M., *Trade and Wages*, The American Enterprise Institute, Washington.

Blázquez, L., Díaz-Mora, C. and Gandoy, R. (2010): “El comercio de partes y componentes: una aproximación a la posición española en las redes de producción internacionales”, *Principios: Estudios de Economía Política, vol.* 18, pp. 5-29.

Deardorff, A.V. (2001): “Fragmentation in Simple Trade Models”, *North American Journal of Economics and Finance,* vol. 12(2), pp. 121-137.

De Simone, G. (2008): “Trade in Parts and Components and the Industrial Geography of Central Eastern European Countries”, *Review of World Economics,* vol. 144(3), pp. 428-457.

Díaz-Mora, C. (2002): “The Role of Comparative Advantage in Trade within Industries: A Panel Data Approach for the European Union”, *Weltwirtschaftliches Archiv-Review of World Economics,* vol. 138(2), pp. 291-316.

Díaz-Mora, C., Gandoy, R. and González, B. (2007): “Fragmentación internacional de la producción en las manufacturas españolas”, *Papeles de Economía Española*, vol. 112, pp. 74-88.

Egger, H. and Egger, P. (2005): "The Determinants of EU Processing Trade", *The World Economy,* vol. 28(2), pp. 147-168.

Feenstra, R. (2002): "Border Effects and the Gravity Equation: Consistent Methods for Estimation", *Scottish Journal of Political Economy*, vol. 45(5), pp. 491-506.

Frensch, R. (2010): "European Trade in Parts and Components: Searching (for a Trade Model for Searching) for Offshoring Evidence", Working Paper 280, Osteuropa-Institut Regensburg.

Gil-Pareja, S., Llorca-Vivero, R. and Martínez-Serrano, J.A. (2008): "Trade Effects of Monetary Agreements: Evidence for OECD Countries", *European Economic Review,* vol. 52, pp. 733-755.

Grossman, G.M. and Helpman, A. (2005): "Outsourcing in a Global Economy", *Review of Economic Studies,* vol. 72(1), pp. 135–159.

Helpman, E. (1987): "Imperfect competition and international trade: Evidence from fourteen industrial countries", *Journal of the Japanese and International Economics,* vol. 1(1), pp. 62-81.

Helpman, E., Melitz, M. and Rubinstein, Y. (2008): "Estimating Trade Flows: Trading Partners and Trading Volumes", *Quarterly Journal of Economics,* vol. 123, pp. 441-487.

Jones, R.W. and Kierzkowski. H. (1990): "The Role of Services in Production and Internacional Trade: A Theoretical Framework", in Jones, R., Krueger, A. (eds.) *The Political Economy of International Trade*, Basil Blackwell, Oxford.

Jones, R.W. and Kierzkowski, H. (2001): "A Framework for Fragmentation", in Arndt, S.W., Kierzkowski, H. (Eds.) *Fragmentation. New Production Patterns in the World Economy*, Oxford University Press, Oxford.

Jones, R.W., Kierzkowski, H. and Lurong, C. (2005): "What does the evidence tell us about fragmentation and outsourcing?", *International Review of Economics and Finance,* vol. 14(3), pp. 305-316.

Kaminski, B. and Ng, F. (2001): "Trade and Production Fragmentation: Central European Economies in EU Networks of Production and Marketing", Policy Research Working Paper 2611, The World Bank.

Kaminski, B. and Ng, F. (2005): "Production Disintegration and Integration of Central Europe into Global Markets", *International Review of Economics and Finance,* vol. 14(3), pp. 377-390.

Kim, Ch. (2002): "Production Sharing and Comparative Advantage: The Cases of East Asia and Mexico", *Economía Mexicana,* vol. XI(2), pp. 409-430.

Kimura, F., Takahashi, Y. and Hayakawa, K. (2007): "Fragmentation and Parts and Components Trade: Comparison between East Asia and Europe", *The North American Journal of Economics and Finance,* vol. 18(1), pp. 23-40.

Long, J.S. and Ervin, L.H. (2000): "Using Heteroscedasticity Consistent Standard Errors in the Linear Regression Model", *The American Statistician,* vol. 54, pp. 217-224.

MacKinnon, J.G. and White, H. (1985): "Some heteroskedasticity consistent covariance matrix estimators with improved finite sample properties", *Journal of Econometrics*, vol. 29, pp. 53-57.

Martín, J. and Orts, V. (2008): "Comercio y Especialización de la Economía Española: Flujos Interindustriales, Comercio de Variedades y Calidad de Productos", *Papeles de Economía Española*, vol. 116, pp. 46-64.

Ng, F. and Yeats, A. (1999): "Production Sharing in East Asia: Who Does What for Whom and Why?", Policy Research Working Paper 2197, The World Bank.

Rugman, A. (2001): *The End of Globalization*. London. Random House Business Books.

Tinbergen, J. (1962): *Shaping the World Economy: Suggestions for an International Economic Policy*, The Twentieth Century Fund, New York.

White, H. (1980): "A heteroskedastic-consistent covariance matrix estimator and a direct test of heteroskedasticity", *Econometrica,* vol. 48, pp. 817-838.

Yeats, A.J. (2001): "How Big is Global Production Sharing?" in Arndt, S.W., Kierzkowski, H. (Eds.) *Fragmentation. New Production Patterns in the World Economy*, Oxford University Press, Oxford.

Yi, K.-M. (2003). "Can vertical specialization explain the growth of World trade?", *Journal of Political Economy,* vol. 111, pp. 52-102.

Zeddies, G. (2011): "Determinants of International Fragmentation of Production in the European Union", *Empirica*, vol. 38 (4), pp. 511-537.

Zysman, J., Doherty, E. and Schwartz, A. (1996): "Tales from the 'Global' Economy: Cross National Production Networks and the Re-Organization of the European Economy", BRIE Working Paper 83.

Fecha de recepción del original: noviembre, 2010
Versión final: noviembre, 2011

RESUMEN

Este trabajo tiene por objeto analizar la participación española en redes internacionales de producción a partir del comercio de partes y componentes, para el periodo 1990-2009. En particular, nuestro interés se centra en conocer con mayor profundidad la contribución que en el desarrollo de esta estrategia tienen las diferencias de dotación factorial entre los países y la pertenecía de éstos a tratados regionales de integración comercial como la Unión Europea. La estimación de un modelo de gravedad ampliado con datos de panel ha puesto de manifiesto que la integración de España en las redes de producción transnacionales responde, efectivamente, a su ventaja comparativa, pero que también otros factores como su pertenencia a la Unión Europea y la disponibilidad de unas buenas infraestructuras de transportes y comunicaciones resultan ser determinantes.

Clasificación JEL: F10, F14, F15.

Palabras clave: Redes de producción internacional, comercio de partes y componentes, economía española, Unión Europea, modelo de gravedad.