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EU Integration and Production Networks: Evidence from Spain♣

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Abstract:

The aim of this paper is to advance knowledge of Spain's participation in international production networks using data on trade in parts and components from 1990 to 2006. Using an extended gravity panel data model, we find that Spain's integration in production networking responds to comparative advantage but also to other factors such as EU membership and a good quality transport and communication infrastructures. Some lessons from the experience of a middle-income country like Spain may be useful for the CEECs, which have increased their presence in European production sharing in the last decade. Future EU enlargement towards lower costs countries could threaten their position in networking. The reinforcement of these other factors, besides comparative advantage, would act as key element to strengthen their participation in cross-border networks.

JEL Classification: F10, F14, F15

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

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1. INTRODUCTION.

A significant phenomenon in recent decades has been the increasing use of strategies of international production fragmentation. Advances in information and communication technology and the progressive liberalisation of exchanges in goods and services have encouraged companies, especially but not exclusively multinationals, to segment and relocate different phases of the production process to new locations beyond their borders. Moreover, the emergence of China and other emerging countries in the economic panorama, and the accession of Central and Eastern European countries to the European Union (EU), all with wage advantages, have boosted the processes of geographical reorganisation of production. Companies from different countries carry out independent tasks of the value chain, exploiting the comparative advantages in each of its phases to the maximum. International production networks are thus created. These production sharing networks allow firms to improve their production efficiency and, therefore, recover their competitive position.

Apart from case studies based on the performance of multinational companies, there has been little empirical analysis of the nature of these international production networks. Since the available statistics have not enabled 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 has been developed. This trade is particularly appropriate for the analysis of international production networks because, due to their intermediate nature, trading parts and components must necessarily be destined for further processing or assembly in another country.

This work belongs in the aforementioned line of research. Our aim is to analyze the participation of the Spanish manufacturing industries in international production networks and to establish its explanatory factors.

The available empirical evidence for higher income countries (the OECD in Yeats, 2001; the European Union in Barba Navaretti, Haaland and Venables, 2002 and Zeddies, 2007) reveals their specialization in the export of high-quality and capital-intensive parts and components. In general, the most labour-intensive stages, among them assembly, are moved to countries with lower labour costs. These results are confirmed by most studies that focus on lower income economies, mainly on Asian countries (Ng and Yeats, 1999; Kim, 2002; 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) where cross-border production sharing has experienced remarkable growth in recent years. Thus, the

existence of comparative advantages between countries would explain, as theoretical literature indicates, the creation of international production networks.

The experience of the Spanish economy constitutes an interesting case of study as the country holds an intermediate position between the most technologically-advanced countries with the highest production costs and the less advanced countries where labour cost are relatively low. Compared to advanced economies, Spain's poor technological capacity[1] determines a specialization in industries of medium-low technological content. Moreover, its comparative advantages have come resting on relative lower labour costs, especially in the context of the EU where, according to Eurostat statistics, the labour cost per hour worked was at 61% of the UE-15 average for 2006; only superior to those of Portugal and Greece. If, as noted above, technological and factor endowment differences between countries are determinants of the European countries' specialization in different production process phases, the accession to the EU of a country like Spain, with labour costs advantages, could have boosted a relocation of the most labour-intensive tasks towards this country, encouraging production sharing strategies. Since the deepening of the EU integration process has reduced the trade costs, our hypothesis is that this process would have increased even more the Spanish involvement in European networks.

Nevertheless, these labour cost comparative advantages are not guaranteed. In the context of an increasing globalized world economy, the cost advantages of middle income countries like Spain disappear. In the enlarged EU context, the gradual accession of less income countries increases the competition in labour intensive production tasks. So, if comparative advantage prevails in the networks configuration, middle-income countries will have difficulties in involving and maintaining in them. This only will be possible if, apart from comparative advantages, there are other factors to face low cost competition.

For these reasons, we estimate the factors influencing trade in parts and components using an extended gravity panel data model for the time period 1990-2006. The object is to help us to define the influence of factor endowment differences in networking and the influence of belonging to a common geographical and trading area such as the EU. Spain would constitute an important precedent for Central and Eastern European Countries in

[1] All the indicators show Spanish technological weakness compared to the most developed countries. In spite of the considerable increase since the mid-eighties, the expenses in research and development over the GDP were 1.2 percent in 2006, scarcely reaching 2/3 of the EU-15 average (1.9 percent). The European Innovation Scoreboard places the Spanish economy in the group of "moderately innovators" countries, which also includes the Czech Republic, Greece, Hungary, Italy, Lithuania, Malta, Poland, Portugal and Slovakia.

relation to their participation in production sharing systems and their stay in them in case of future EU enlargements.

The rest of the paper is structured as follows. In Section 2 we present the data and the descriptive analysis of Spanish trade flows in parts and components that will reveal the dynamism of this type of trade between 1990 and 2006, mainly in the European area. The extended gravity model to be estimated is described in Section 3. The econometric results are shown in Section 4. These outcomes of the estimation support that technological and factor endowment differences between Spain and its trading partners and the belonging to the EU have explanatory power in understanding the Spain's integration in production networking. The work is closed with some final considerations.

2. DATA AND DESCRIPTIVE ANALYSIS.

Our main data source is the United Nations Commodity Trade Statistics Database (UN COMTRADE), which offers detailed information on international trade flows for practically every country in the world. More specifically, we use the information classified and recorded using the Standard International Trade Classification Revision 3 (SITC Rev.3), which makes a distinction between trade in parts and components (P&C) and final goods within the "Machinery and transport equipment" group (SITC 7). The selection of items of P&C follows Athukorala (2005) and 99 items of P&C (at 4 or 5 digit level of SITC Rev. 3) are considered[2].

The main restriction is that the analysis does not provide information for the entire range of activities involving product fragmentation[3]. As a result, some industries such as textiles and clothing where cross-border production sharing seems to have a significant presence in Spanish economy are excluded (Díaz-Mora *et al.*, 2007). Nevertheless, the incidence of this limitation is reduced when two facts are taken into consideration. Firstly, the "Machinery and transport equipment" sector has a high relevance in total manufacturing trade (more than half). Secondly, according to empirical studies, this sector includes the industries where the strategy of international production fragmentation is prevalent.

The Spanish P&C trade has been extraordinarily dynamic since 1990, both from an export and an import perspective (Figure 1). Exports rose from 5.166 million dollars in 1990

[2] See Table A.1. in the Statistical Appendix.

[3] In fact, the SITC Rev. 3 also provides P&C trade data within "Miscellaneous manufactured articles" (SITC 8) but only for a few of the industries included in this section. Since only 5% of Spanish P&C trade comes from these industries, it has been eliminated from the analysis.

to 23.206 million in 2006; and imports from 8.906 million to 37.592 million. That is, both flows increased at an accumulative annual rate of more than 9%. This growth has facilitated a progressive increase in the share of P&C in Machinery and transport equipment trade, from 24% of exports in 1990 to 28% in 2006; and from 27% of imports to 32%. The observed dynamism of P&C trade seems to confirm that Spanish manufacturing firms are increasingly participating in international production networks. The significance of P&C is greater in the import side; in fact, a pronounced trade deficit, which is around 25% of the sector's trade in P&C, is observed.

Figure 1. Spanish Trade in P&C, 1990-2006

(in million of US$ and as a percentage of Machinery and transport equipment trade)

Source: authors' calculation, based on UN COMTRADE.

The dynamism of P&C trade flows in Spain becomes even clearer when we analyse export and import shares in world trade. Export shares are usually used as an indicator of competitiveness in the production of goods, in this case P&C. In P&C trade analysis, import shares can be interpreted as an indicator of the attractiveness of an economy for further processing and assembly operations. In this regard, two aspects should be noted (Table 1).

The first is the stability of Spanish shares in world P&C trade, despite the increasing competition from lower wage areas such as the Asian economies and the Central and Eastern European countries (CEEC-10). The latter even tripled their shares in world P&C trade between 1995 and 2006. Although these countries are leaders in the processes of international

production fragmentation (Athukorala, 2005; Athukorala and Yamashita, 2006; Kimura *et al*. 2007), Spain has been able to maintain its presence in such dynamic markets. In contrast, the EU-15, as well as Japan and the USA, has registered a sharp loss in their world shares which is mainly related to the growth of P&C trade in Asia and CEEC-10.

The second point to be considered is that, from 1990 to 2006, Spain's share both in EU-25 and EU-15 trade in P&C has significantly increased; even in a context of intense expansion in EU trade flows. In this context, the increasing import and import shares of Spain in the European market are still more striking. This trend reveals a progressive and solid engagement of Spanish industry in European production sharing networks. It must be noted that the EU enlargement to the East and the CEECs' increasing presence in P&C trade have been accompanied by the growth of the Spanish trade share in P&C, at least until 2003. Since then, the Spain's share has been slightly reduced, pointing out the effects of increasing competition from new EU members.

Table 1. Shares in World and EU trade in P&C, 1990-2006 (in percent)

	WORLD SHARES							
	EXPORTS				IMPORTS			
	1990	2000	2003	2006	1990	2000	2003	2006
Spain	1,4	1,3	1,7	1,4	2,6	2,1	2,5	2,3
EU-15	46,5	30,0	32,6	31,0	48,2	30,2	31,0	28,2
CEEC-10	1,5*	1,8	2,8	3,3	0,2*	2,5	3,4	4,1
	SHARES IN EU-25							
Spain	3,3*	4,0	4,8	4,2	6,0*	6,3	7,3	7,0
CEEC-10	3,2*	5,5	8,0	9,6	4,2*	7,8	9,9	12,8
	SHARES IN EU-15							
Spain	3,0	4,2	5,2	4,7	5,5	6,8	8,1	8,1
Intra	2,3	2,9	3,7	3,3	4,2	5,5	6,7	6,2
Extra	0,7	1,3	1,5	1,4	1,3	1,3	1,4	1,8

* These data correspond to 1995. CEEC-10: The ten countries are Czech Republic, Estonia, Hungary, Poland, Slovenia, Bulgaria, Romania, Slovakia, Latvia and Lithuania
Source: authors' calculation, based on UN COMTRADE.

Moreover, in the EU context, there are not important differences in the performance of P&C trade between a country like Spain —a long-standing EU Member and a middle income economy— and the new EU accession countries. In the left side of Figure 2 we observe the magnitude and evolution of the ratios of Spanish and CEECs intra-EU imports to EU-15 exports in the market of P&C. Spanish share has been quite dynamic, playing an increasing role as destination of EU P&C exports; as CEECs has done afterwards. The EU enlargement in 2004 has hardly decreased the Spain's attractiveness for assembling and further processing of European P&C. Furthermore, Spain has moved up from eighth to fifth position in the

ranking of destinations of EU P&C exports. It has been the only EU-15 country that has managed to increase its share in EU P&C exports (from 4,5% to 5,1%). Therefore, the redirection of European production networks to China and new EU accession countries, especially Poland, the Czech Republic and Hungary, which in the last years appear among the main destinations for European P&C, does not seem to significantly reduce the attractiveness of the Spanish economy for further processing and assembly of P&C.

The right side of Figure 2 provides insight into the Spain's role as a supplier of P&C to the EU-15. The evolution of the ratio of Spanish intra-regional P&C exports to the EU-15 P&C imports shows the increasing contribution of Spain to the European firms' demand of foreign P&C. Obviously, CEECs' behaviour is more dynamic, but it must be emphasized the relevance of maintaining the Spanish shares in this context. Also, the ranking of P&C supplier countries to EU-15 illustrates the Spanish involvement in European networks. In contrast with the rest of EU-15 Members States, Spain has been able to move up in that ranking (from eleventh position in 1990 to ninth in 2006) despite the inclusion of some emerging countries such as China or Czech Republic in the top 10.

Figure 2. SPAIN AND CEECs AS ORIGIN AND DESTINATION OF EU-15 P&C TRADE

(In percentage)

Source: authors' calculation, based on UN COMTRADE.

Finally, the geographical distribution of the Spanish trade in P&C (Table 2) clearly shows two features. Firstly, the predominance of the EU-15, suggesting a regional dimension of the production networks. This intra-regional trade is far more intense than in the EU-15 (about 20 percent points above in 2006) and it has not decreased as it has done in European

advanced countries and the whole EU-15. In words, Spain seems to be deeply involved in European networks.

Secondly, the growing presence of the CEEC-10 (particularly as a destination for Spanish P&C exports) and Asian countries, especially China (as a P&C supplier), takes place at the expense of the participation of more developed areas such as the EU-15 and, especially, the USA. Therefore, Spain is taking part in the geographical reorganisation processes of European production in two ways. On the one hand, by reorienting its P&C exports towards new markets in order to exploit their comparative advantages in assembly activities based on lower labour costs. On the other hand, by obtaining a larger amount of P&C from countries with lower levels of income and salaries.

Table 2. Direction of trade in P&C, 1990 and 2006 (in percent)

	Exports (% total P&C)		Imports (% total P&C)	
	1990	2006	1990	2006
	Intra-EU15 trade			
Germany*	56,0	46,0	45,0	41,7
France	63,6	52,1	60,9	59,5
Italy	61,3	50,7	75,3	65,7
United Kingdom	57,4	46,4	62,4	54,2
EU-15	63,6	51,1	67,2	55,1
	Spain's trade by regions			
EU-15	75,5	70,1	77,1	77,1
CEEC-10	0,2	4,9	0,0	3,1
USA	8,1	4,8	11,1	3,9
North Africa	3,2	2,1	0,0	0,2
Asia (excluded China)	4,0	6,9	9,6	13,3
China	1,0	1,9	0,1	3,0

* Data for 1990 correspond to 1995.

Source: authors' calculation, based on UN COMTRADE.

3. ESTIMATING A GRAVITY MODEL FOR PARTS AND COMPONENTS TRADE

In order to identify the impact of factors influencing Spanish trade linked to international production networks, 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, or 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).

Among the standard variables in gravity models of international trade, we are particularly interested in the membership of regional integration agreements, in our case of the European Union, since, as outlined in section 2, intra-EU flows are especially important for Spain. The specific characteristics of trade associated with international fragmentation of production allow us to consider that trade costs might be different for final and intermediate goods. In fact, the theoretical literature on international fragmentation of production maintains that trade costs may represent, a priori, a very relevant factor in P&C trade. 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. In this context, it will be expected that the membership of a common regional integration agreement will stimulate cross-border production sharing between the Member States, since trade barriers between them are much lower. Moreover, as Zeddies (2007) points out, we could expect trade with other Member States to be more secured and less subject to economic, legal and political uncertainties or exchange risks. In this sense, 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 more than global networks, regional networks have emerged[4]. So, 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 pointed out by the theoretical literature on international production fragmentation.

The first group of specific variables link trade associated with international fragmentation of production to the exploitation of comparative advantages in every one of the phases or tasks of the production process (Arndt, 1997; Deardorff, 2001; Jones and Kierzkowski, 1990 and 2001); either based on relative factor endowment (according to

[4] Rugman (2001) and Zysman, Doherty and Schwartz (1996).

Heckscher-Ohlin type models) and/or on relative productivity (in accordance with Ricardian type models). They are "kaleidoscopic comparative advantages" (Bhagwati and Dehejia, 1994). 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 to find an adequate location and/or partner to establish production sharing networks (Grossman and Helpman, 2005). In short, the size of economies is a principal factor in 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.

In this sense, 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 previous literature on P&C trade: Kimura *et al.* (2007) and Athukorala and Yamashita (2006). The first paper finds a positive coefficient for Asia and a negative one for Europe. The authors 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 justify this result by the dominance of advanced countries (therefore, with lower differences in comparative advantages) in world trade, both in terms of final goods and P&C.

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 a certain minimum conditions concerning technological or institutional capacity must be guaranteed in countries to participate in these networks. The quality of country's legal system will be essential, for example, to guarantee the compliance of contracts, reduce obstacles and deadlines when starting business activities or to carry out international trade exchanges (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[5]. 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 internationalisation of the value chain feasible in the best conditions of efficiency are guaranteed.

Additionally, we introduce the relative differences in income per capita in order to define the incidence of the comparative advantage on P&C trade. The positive correlation between the capital-labour ratio and per capita income (Helpman, 1987) allows us to expect that the higher the per capita income in country *i* compared to country *j* (used as a proxy variable of its greater relative abundance of capital), the greater the P&C exports from *i* to *j*, since country *i* will benefit from a comparative advantage in production and exportation of P&C (which require more capital and technology). Or, similarly, the higher the per capita income in country *i* compared to country *j*, the greater the P&C imports to *j* from *i,* since its lower per capita income compared to *i* (result of its lower relative abundance of capital) implies a comparative advantage in assembly activities. As a result, we would expect the relative per capita income variable to have a positive impact on P&C exports.

Nevertheless, efficiency gains derived from the exploitation of the comparative advantages at each stage of production can be reduced and 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 international production networks, the greater the exploitation of comparative advantages, but the costs of these services will also be larger. The balance between service link costs and benefits derived from maximum exploitation of the advantages of the international division of labour and from intra-product specialisation will determine the optimal degree of 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

[5] The World Trade Organization states that, in general terms, a positive correlation can be observed between the per capita income level of countries and the quality of their institutional frameworks (WTO, 2008).

deregulation and liberalisation of these services, have resulted in quicker, cheaper and more reliable communication systems, which can be used practically worldwide. This has been of enormous benefit to connections between phases or tasks which are internationally dispersed, promoting the spatial disintegration of production in order to capture the comparative advantages of different locations.

Although trade liberalisation policies and technological advances have brought about a general decrease in the cost of the transport and communication of goods and services and in the cost of management, supervision and coordination of the phases or tasks located abroad; these service link costs continue to differ greatly between countries. To a great extent, it determines decisions for localising every 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 above theoretical considerations, the standard gravity model is extended to include a second group of variables which introduces the service link costs, such as the quality of transport and telecommunications infrastructure. A positive 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 contrasted 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 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) on EU-12 bilateral processing trade is positive.

Finally, time dummy variables (D_t) are included to control for 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 production process.

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

[6] Grossman and Helpman (2005) also indicate that the cost of the search for adequate partners 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 proper functioning of an international production network.

[Specification 1]

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

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 1990-2006. More specifically, 28 countries, that amount to approximately 95% of Spanish P&C trade, are included[8]. While the 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 one 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. On the other hand, trade associated with 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 the 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[10].

4. ESTIMATION RESULTS.

Table 2 presents the estimation results for our extended gravity model. 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

[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 not zeros in the trade data used. In the case of predominance of zeros, the coefficients could 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, in particular that of exports.

[10] See Table A.3. in the Statistical Appendix for an explanation of the measurement of the model's variables and the statistics used.

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 sharing a border or a language. The sign for the EU membership variable is positive and significant, so that P&C trade is greater with other Member States.

Table 2. Extended gravity model estimates for P&C trade in Spain

	Specification 1		
Coefficients	Column (1)	Column (2)	Column (3)
GDPi	0.773*** (0.034)	0.753*** (0.033)	0.901*** (0.034)
GDPj	0.768*** (0.033)	0.746*** (0.033)	0.633*** (0.034)
Bilateral distance	-0.530*** (0.054)	-0.484*** (0.052)	-0.526*** (0.058)
Common border	0.606*** (0.121)	0.651*** (0.121)	0.685*** (0.130)
Common language	0.573*** (0.134)	0.553*** (0.134)	0.570*** (0.144)
EU	0.702*** (0.096)	0.797*** (0.091)	0.697*** (0.103)
PCI-abs-differences	-0.142*** (0.047)		-0.136*** (0.051)
Relative-PCI	0.385*** (0.031)	0.384*** (0.031)	
Transport Infrastructure	0.288*** (0.063)	0.289*** (0.063)	0.283*** (0.068)
Telecommunications Infraestructures	0.234*** (0.047)	0.253*** (0.047)	0.235*** (0.051)
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	980	980	980
Adjusted R^2	0.734	0.731	0.691
Wald test (p-value)	0.000	0.000	0.000

Notes: Standard error in brackets. ***, ** 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.

As regards the specific variables for models of 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 and for networking.

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 greater Spanish relative capital-labour ratio), the greater Spanish P&C exports to this partner; while the greater the per capita income of a trading partner compared to Spain (and 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. This will guarantee that the service link costs associated with the fragmentation and dispersion of the production will not be as high as they cancel the profits derived from exploiting the comparative advantages of different locations.

Although there are no problems of correlation between the absolute differences in per capita income variable and the relative per capita income variable (the coefficient of correlation is -0.007), the second column of Table 2 shows the results excluding the absolute differences in per capita income variable. The results for the rest of variables are not significantly affected. Omission of the relative per capita income variable does not change the results noticeably either (third column of Table 2). The absolute difference in 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 P&C and final goods trade are affected by the same factors similarly, we conduct a Wald test with the null hypothesis that all coefficients are identical in both equations (last line of Table 2). The results of the Wald test confirm that such differences are significant[11].

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[11] The regression results from the gravity model for Spain's trade in final goods are reported in Table A.4. Comparative advantages also play an active role in explaining trade in final goods, a result which is consistent

Robustness analysis.

In order to check the robustness of the obtained results, we have conducted some sensitivity analyses (Table 3). Specifically, we estimate the model 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). But, these variables may not represent all such potential trade bilateral 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, gravity equation is estimated replacing time-invariant bilateral variables such as bilateral distance, common language or common borders with fixed country-pair effects[12]. That is, the model specification to be estimated is as follows:

[Specification 2]

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

The fourth column of Table 2 presents the results of introducing country-pair-specific fixed effects into the model (dummy coefficient estimates are omitted for 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} y 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 the cost of bilateral trade (or bilateral trade resistance). It depends, rather, on bilateral trade costs relative to the cost of trade with other economies (what they term 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, $P_{it}^{1-\sigma}$ y $P_{jt}^{1-\sigma}$, where σ is the

with the predominance of vertical intra-industry trade in Spanish trade flows (Díaz-Mora, 2002; Martín and Orts, 2008). However, factors such as basic requirements and common language are important for integration into production sharing networks but they are not for final goods trade.

[12] This would be the classic fixed effects estimator in panel data models.

elasticity of substitution between goods from different countries. Therefore, following Anderson and van Wincoop (2003), the model to be estimated would be[13]:

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

Nevertheless, these multilateral trade costs (which are captured by the exporter and importer price indexes) are unobserved, but biased estimates will be obtained when they are omitted from the gravity equation[14]. 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})[15], then eliminating exporter and importer GDPs from the model. Taking into account these considerations, the specification to be estimated is the following:

[Specification 3]

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

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 it is showed in the last column of Table 2 (again dummy coefficient are omitted for brevity). So 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 is taken into account, that is, when the costs in trading with other economies are considered, the condition of EU membership gains a great relevance (because trade costs

[13] 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 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 taking 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.

[14] "Bronze medal" error of gravity models (Baldwin et al., 2008).

[15] 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). In a previous paper, Anderson and van Wincoop (2004) argue that, with panel data, time-varing country fixed effects must be included since multilateral trade resistance can change over time.

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 section 2.

Table 3. Extended gravity model estimates for P&C trade in Spain (with fixed effects included)

Coefficients	Specification 2	Specification 3
GDPi	1.310*** (0.152)	
GDPj	1.302*** (0.153)	
Bilateral distance		
Common border		
Common language		
EU	0.241* (0.132)	1.449* (0.804)
PCI-abs-differences	-0.100* (0.053)	-0.676*** (0.206)
Relative-PCI	0.388*** (0.026)	0.699*** (0.120)
Transport Infrastructure	-0.075 (0.199)	0.704 (0.641)
Telecommunications Infraestructures	0.141** (0.067)	0.211*** (0.074)
Time dummies Country-pair specific fixed effects (Γ_{ij}) Time varying exporter and importer fixed effects (Γ_{it}, D_{jt})	Yes Yes No	No Yes Yes
Number of observations Adjusted R^2	980 0.806	980 0.771

Notes: Standard error in brackets. ***, ** and * indicate significance levels of 1%, 5% and 10% respectively.

5. CONCLUDING REMARKS.

This paper reveals the significant dynamism of the Spanish P&C trade since 1990, suggesting an active role in production sharing networks, especially in the European area. The country has managed to maintain its share in world P&C trade, and even to increase the share in EU trade, despite the intense competition from Asian and new EU accession countries in this type of trade. This is not the case for any other Member State of EU-15.

With regard to the explanatory factors influencing P&C trade, two main conclusions can be drawn from the results of our extended gravity model estimates. Firstly, Spain's integration in cross-border production networks responds to variables related to the comparative advantage that the country has in comparison with her trading countries; but other factors emerge as important in medium-high technology industries. Differences in per capita income must be not so great as to guarantee a legal and institutional framework, a technological capacity, in short, a level of economic development that allows participation in international production sharing. Moreover, factors such as geographic proximity and the availability of a good quality transport and telecommunications infrastructure have encouraged Spain's participation in cross-border 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.

Secondly, the estimates also 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 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.

The Spain's experience can be useful for the CEECs, which have increased their presence in European production sharing in the last decade. Likely future EU enlargements towards lower costs countries could threaten their position in networking. To protect themselves against this competition, other factors than their comparative advantages must be taken into account. The reinforcement of these factors would act as a key element to strengthen their participation in cross-border networks.

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Statistical Appendix.

Table A.1.: List of Parts and Components according to the Standard International Classification (SITC) System (Revision 3).

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

Table A.3.: Definition of variables and data source.

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

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

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.
North of Africa	Morocco.
Asia	Singapore, China, Japan, Korea y Malaysia.

Table A.3.: Definition of variables and data source.

Label	Definition	Source
$\mathbf{X_{ij}}$	Value of the exports from country *i* to country *j* in nominal terms (US dollars).	COMTRADE (United Nations)
$\mathbf{GDP_i}$	Gross Domestic Product of country *i* in nominal terms (US dollars).	World Development Indicators. The World Bank.
$\mathbf{GDP_j}$	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>
$\mathbf{EU_{ij}}$	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 is done using 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 Infraestructure$_{ij}$	The minimum percentage of paved roads of trading partners *i* and *j*.	World Development Indicators. The World Bank.
Telecommunications Infraestructures$_{ij}$	The minimum percentage of Internet users of trading partners *i* and *j*.	World Development Indicators. The World Bank.

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

Coefficients	Column (1)	Column (2)	Column (3)
GDPi	0,716*** (0,038)	0,706*** (0,037)	0,773*** (0,037)
GDPj	0,683*** (0,037)	0,672*** (0,037)	0,622*** (0,036)
Bilateral distance	-0,640*** (0,060)	-0,618*** (0,058)	-0,638*** (0,061)
Common border	0,205 (0,136)	0,226* (0,135)	0,213 (0,138)
Common language	-0,064 (0,151)	-0,073 (0,151)	-0,065 (0,153)
EU	0,663*** (0,108)	0,708*** (0,102)	0,661*** (0,109)
PCI-abs-differences	-0,067 (0,053)		-0,064 (0,054)
Relative-PCI	0,172*** (0,035)	0,172*** (0,035)	
Transport Infrastructure	0,652*** (0,071)	0,653*** (0,071)	0,650*** (0,072)
Telecommunications Infraestructures	0,152*** (0,053)	0,161*** (0,052)	0,153*** (0,054)
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	980	980	980
Adjusted R^2	0.669	0.669	0.661

Notes: Standard error in brackets. ***, ** and * indicate significance levels of 1%, 5% and 10% respectively.