Drivers of technological export performance in Spain: A regional approach, 2000–2016

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Having a high export capacity is a core element of achieving sustained long-term economic growth. To attain this goal, the technological sophistication of exports plays a key role (Hausmann et al. 2007, Rodrik 2006, Minondo 2010). In the context of stimulating exports with a high level of sophistication, it is crucial to identify the main drivers of exports in general and of high-tech exports. Specifically, the aim of this article is to study the determinants of the international trade flows of manufacturers according to their technological content in the case of Spanish regions.
The results obtained show strong evidence of the relevance of considering the technological content of manufacturers when studying the drivers of trade flows at the regional level. Moreover, the findings have significant implications for trade and industrial policies in Spain, a country that traditionally exhibits large trade imbalances, since these outcomes could enhance the effectiveness of policies targeting the technological upgrading of Spanish exports.

Introduction

The growing interdependence and increased globalization of the world economy since the 1980s have led to a rapid growth of international trade over the last decades. According to World Bank data [9], in 1980, world exports of goods and services reached 2,303 trillion USD compared to 25,137 trillion USD in 2018. Merchandize exports increased almost tenfold during those years, from 1.976 trillion USD to 19.6 trillion USD. Moreover, exports of manufactured goods increased more than twelve-fold, from 1.184 trillion USD to 14.501 trillion USD. This growth in international trade has increased the productivity of many economies and has boosted economic growth (Singh 2010).

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However, the positive impact of exports on long-term economic growth is due not only to the volume of such exports but also to their quality. Paradigmatic analysis carried out by some authors, such as Hausmann et al. (2007), Rodrik (2006) and Minondo (2010), pointed out that long-term economic growth depends to a large extent on the technological intensity of exports. Therefore, the more technologically sophisticated the exports are, the higher the long-term economic growth. Amiti–Freund (2010) and Hummels–Klenow (2005) showed clear signs that greater export diversification into new higher-productivity products also encourages long-term economic growth. Greater technological intensity in manufacturing leads to positive impacts on productivity growth, generates larger productivity spillovers and linkage effects, fosters the build-up of knowledge, and positively affects the country brand (Granstrand 1998, Ortin–Vendrell-Herrero 2014, Lee et al. 2012, Coeurderoy–Murray 2008, Colombo–Grilli 2005). In this context, the determinants of highly sophisticated exports have been studied empirically, concluding that factors such as human capital endowment, investment in research and development (R&D), foreign investment, the external openness of the economy, the level of human development and institutional quality determine such sophistication (Seyoum 2004, Braunerhjelm–Thulin 2008, Tebaldi 2011, Gökmen–Turen 2013, Basarac et al. 2013).

In line with the abovementioned results, international economic institutions such as the United Nations Conference on Trade and Development (UNCTAD), United Nations Industrial Development Organization (UNIDO), World Trade Organization (WTO), or the International Trade Centre have placed great emphasis on building the capability of countries to upgrade the technological sophistication of manufactured exports. Within the European Union (EU) context, countries such as France[2], Spain[3] and the United Kingdom[4] or institutions such as the European Commission[5] have launched industrial strategies that, among other objectives, seek to boost the technological intensity of their manufacturing industries, with the aim of promoting long-term growth and stimulating exports. Likewise, following the outbreak of the pandemic caused by the Covid-19 virus, many countries have highlighted the need to implement economic measures and policies to strengthen the industrial sector and, as much as possible, decrease foreign overdependence on certain essential products. The EU has stated that the consequences of the pandemic have consolidated the need for a new European industry strategy. In this regard, the EU has launched various

[2] In 2013, the French Government launched the initiative: „Nouvelle France Industrielle", which among other goals aims to accompany companies in the process of improving their market position and achieve an improvement in the technological composition of French manufacturing industry [1].

[3] In 2017, the Spanish Government implemented the „Strategy for the internationalization of the Spanish economy 2017–2027", in which the industries with a high technological content play a fundamental role [2].

[4] The British Government has published a green paper entitled: „Building our industrial strategy", in which the guidelines of the new British industrial strategy are defined. In this ambitious scheme, manufacturing production with a greater technological component has an important role [3].

[5] The European Commission has launched the strategy: „An integrated industrial policy for the globalization era", in which technology-intensive industry plays a key role [4].

initiatives, such as the „Covid-19 industrial clusters response portal," to address the challenges imposed by the pandemic, minimize its adverse effects, revitalize the industrial sector and value chains strongly hit during the health crisis [10]. Furthermore, to mitigate the economic and social damage caused by the pandemic, EU institutions have agreed on a 1.8 trillion EUR recovery plan that will lead the way out of the crisis and lay the foundations for a modern and more sustainable Europe. Among these funds, those earmarked for innovation and research, which will account for a significant part of the overall amount, offer a great opportunity for Spain and the Spanish regions to ensure a technological upgrading of exports.

The study of significant differences in trade flows according to the degree of sophistication, alongside academic interest, is particularly relevant from the point of view of economic policy. In recent years, some analyses have delved into the possible factors that led to an improvement in the sophistication of exports. Conversely, the role of economic policy in improving the sophistication of country exports is a relatively underdeveloped topic in the economic literature. Technology-intensive manufactured exports are in themselves an indicator of a country's external competitiveness, and as mentioned above, some studies have focused on the factors that determine the technological sophistication of exports. However, it has been a challenge for policy-makers to identify economic policy tools conducive to successful performance in technology-intensive manufactured exports. There is a certain degree of consensus regarding the role of policies that provide incentives for innovators in improving export technology sophistication in manufacturing industries (Hirsch–Bijaoui 1985, Sterlacchini 1999, Bernard–Jensen 2004). Thus, it is crucial for governments to attract foreign direct investment (FDI) from companies that manufacture high technology-intensive goods by providing a suitable investment climate that furnishes business with a predictable framework [5], promoting the availability of a relevant research infrastructure and skilled labor force (Cantwell–Iammarino 2001, Ramdhan 2021), fostering knowledge networking and sharing among organizations such as universities, private corporations, research institutes, etc., and building global R&D centers (Klerkx–Guimon 2017), among others.

However, with specific regard to Spain, research focused on differences in trade flows according to the sophistication of goods is limited. Against this background, using data from the Spanish regions, this article argues whether there are differences in the determinants of exported manufacturers according to their technology content. The analysis of the case of Spain is particularly relevant because this country exhibits a lifelong trade balance deficit, reaching 9 percent of gross domestic product (GDP) in 2007, with an inadequate technology content of the manufactured exports. Although the Spanish economy has undergone crucial reforms in recent decades, the need to improve the technological intensity of manufactured exports is a pending challenge to compete efficiently in international markets. Spanish authorities have set that improvement as a crucial goal to be achieved, and it has been included in the internationalization strategies for the Spanish economy outlined in recent years.

However, its scope has been narrowed to the country level, without devoting any attention to the regional approach, even though Spain´s current industrial policy is highly decentralized.

Regarding the modeling strategy, we apply an extended gravity model using data from Spain and its largest exporting regions to study whether there are differences between the determinants of export flows according to the degree of export sophistication. There are two relevant contributions arising from this study. The first is that the analysis is carried out using Spanish regional data. The most common approach in the literature is to analyze the determinants of exports using aggregate data at the national level, not with regionally disaggregated data. The analysis with regional data allows us to draw conclusions with implications for formulating policies at the regional level. The second contribution is to simultaneously analyze exports with high and medium-low technological content. This allows us to empirically analyze to what extent the determinants of exports at the regional level affect exports differently depending on their technology content. However, it has been common in the empirical literature to analyze the potential drivers of exports with high technology content but without testing whether these determinants are different from those with medium-low technology content.

Literature review

Seyoum (2004) carried out one of the pioneering studies in the analysis of the drivers of technology-intensive exports, supporting the fact that the level of factor conditions, such as human resources and technology, is a strong predictor of high-tech export performance and that other variables, such as domestic investment, domestic rivalry, and domestic demand, also influence high-tech exports. Srholec (2007) showed that in developing countries, the largest share of high-tech exports can be attributed to the propensity to import electronic components, which explains the largest part of the cross-country differences in the specialization of electronics exports.

Braunerhjelm–Thulin (2008) further explored the determinants of export flows, identifying evidence of the positive role of R&D expenditure in higher technology content manufacturing exports and in shaping comparative advantage between countries. Tebaldi (2011) examined the driving forces behind high-tech exports between 1980 and 2008 and found evidence that the quality of human capital, foreign direct investment, and the openness of countries to international trade are major factors in the export performance of high-tech exporting countries. Gökmen–Turen (2013) studied the determinants of high-tech exports in fifteen EU countries and found that foreign direct investment, the level of human development and the level of economic freedom have a significant role as drivers of high-tech exports. Abedini (2013), based on the gravity approach, aimed to identify key factors underlying the high-tech of established and emerging countries separately. Abedini (2013) concluded that high-tech exports from emerging countries are mainly based on FDI inflows and participation in the international production chain, as well as a high degree of export concentration, while high-tech exports from established exporters are mainly linked to industrial infrastructure, research and development, and export diversification.

Recently, Sepehrdoust–Mohsen (2021) explored the impact of scientific productivity on high-tech exports in targeted developing countries during 1996–2017, concluding that among other factors, economic risk, scientific productivity, financial risk, and political risk have significant effects on high-tech exports. Drapkin et al. (2021) studied the determinants of high-tech exports of major economies in Central and Eastern Europe, concluding that among others, the level of wages and resource prices, the degree of openness of the economy to foreign trade, the tax rate, the unemployment rate, and the quality of human capital may be factors that stimulate export growth in high-tech industries in the countries studied. Malik et al. (2021), based on a panel of 101 countries over 21 years, analyzed whether national culture moderates the link between national absorptive capacity and high-technology exports. On the role that global value chains play in export upgrading, Ndubuisi–Owusu (2021) showed that GVC participation matters to export upgrading but points to a potential heterogeneity in the channel of impact across countries at different levels of development. At the firm level, Perez Garrido et al. (2023) explore the innovation profiles of Spanish enterprises operating in high-tech manufacturing sectors using enriched alternative computational approaches.

Data and methodology

Data

Empirical research is carried out with data for the seventeen Spanish regions.[6] Data are available for each region regarding their manufactured exports over the period 2000–2016, differentiated by degree of sophistication (technological intensity of manufacturing). The classification of manufacturing industries according to their technological intensity used in this paper has been set by the Organisation for Economic Co-operation and Development (OECD) and is broken down into low-technology industries, medium-low-technology industries, medium-high-technology industries, and high-technology industries [6]. In our analysis, manufactured goods are grouped into high-technology industries and the remaining industries. Likewise, the Standard International Trade Classification (SITC) is the classification used for coding goods, with a high level of disaggregation up to five digits. The data on exports come from the Spanish DataComex [11] database and are denominated in thousands of EUR. Spanish exports to 70 countries are considered in our study (see Table A1

[6] Andalucía, Aragón, Asturias, Islas Baleares, País Vasco, Islas Canarias, Cantabria, Castilla-La Mancha, Castilla-León, Cataluña, Extremadura, Galicia, Madrid, Murcia, Navarra, La Rioja, and Valencia.

in the Appendix). Thus, panel data are available for 17 Spanish exporting regions, with 70 importing countries and two groups of manufactured goods according to their technological intensity, covering a period of 17 years and accounting for a total of 40,460 observations.

Table 1 shows the development of the technological disaggregation of manufactured goods exported by the Spanish regions during the period under review. For the sake of simplicity, the data have been grouped into three periods: 2000–2006, 2007–2011 and 2012–2016. Table 1 shows the variation in this disaggregation over the period from 2016 to 2000. We observe that Spain exhibits an inadequate breakdown profile according to the technological level of manufacturing exports (Minondo 2007, Gordo et al. 2003) since just 10 percent are high-technology exports. There are no significant time variations in the technological upgrading of Spain as a whole. Figure 1 shows the average percentage share of high-tech exports in terms of the total regional manufacturing trade for the years 2012–2016.

Table 1

Evolution of the technological disaggregation of regional manufactured exports in Spain

(%)

Region	HIGH	Medium-High	Medium-low	LOW	HIGH	Medium-High	Medium-low	LOW
	Average 2000–2006				Average 2007–2011			
Andalucia	**10**	25	31	34	**11**	25	32	32
Aragón	**3**	76	7	14	**3**	71	7	19
Asturias	**6**	20	59	15	**3**	22	62	12
Islas Baleares	**45**	25	3	27	**50**	19	4	27
Islas Canarias	**5**	14	31	50	**17**	38	15	30
Cantabria	**1**	49	33	17	**1**	47	36	16
Castilla-León	**5**	68	17	10	**9**	59	18	14
Castilla-la Mancha	**12**	36	12	40	**6**	41	14	39
Cataluña	**14**	51	11	24	**11**	51	13	25
C. Valenciana	**4**	41	25	30	**4**	48	26	22
Extremadura	**3**	22	22	53	**3**	23	30	44
Galicia	**1**	52	16	31	**1**	48	14	37
Madrid	**31**	40	13	16	**38**	35	13	14
Murcia	**11**	41	18	30	**4**	48	17	31
Navarra	**1**	75	13	11	**2**	75	13	10
País Vasco	**3**	49	39	9	**3**	47	42	8
Rioja	**1**	11	29	59	**1**	10	29	60
Spain	**11**	48	19	22	**10**	48	20	22

(Table continues on the next page.)

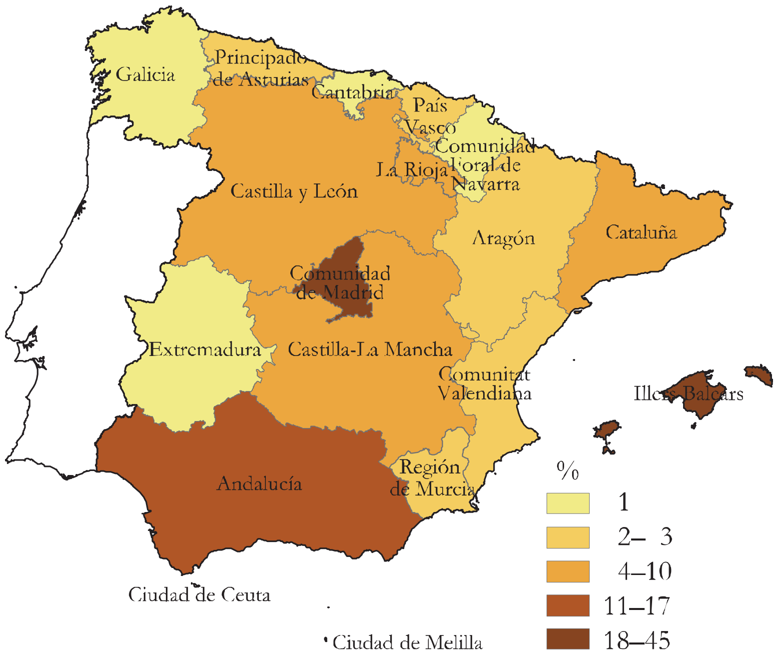
(Continued.)

Region	HIGH	Medium-High	Medium-low	LOW	HIGH	Medium-High	Medium-low	LOW
	Average 2012–2016				Diferences 2016–2000			
Andalucia	**16**	23	30	31	**13**	–7	–6	–1
Aragón	**3**	62	8	27	**0**	–16	1	16
Asturias	**3**	23	61	13	**–3**	5	1	–2
Islas Baleares	**45**	27	4	24	**–19**	27	2	–9
Islas Canarias	**17**	37	13	33	**10**	29	–18	–21
Cantabria	**1**	47	34	18	**0**	–1	–3	5
Castilla-León	**10**	62	15	13	**4**	–4	–3	3
Castilla-la Mancha	**6**	36	13	45	**–2**	–4	3	4
Cataluña	**10**	51	12	27	**–3**	1	1	2
C. Valenciana	**3**	53	24	20	**–1**	19	–3	–15
Extremadura	**1**	20	30	49	**–4**	–2	8	–2
Galicia	**1**	40	14	45	**0**	–17	–3	20
Madrid	**39**	34	14	13	**7**	–9	2	–2
Murcia	**3**	43	18	36	**–12**	2	2	9
Navarra	**1**	75	13	11	**0**	–1	2	–1
País Vasco	**3**	51	37	9	**0**	7	–6	–1
Rioja	**4**	10	26	60	**6**	1	–4	–3
Spain	**10**	47	19	24	**0**	–1	–1	2

Source: The authors based on data from DataComex [11].

Figure 1

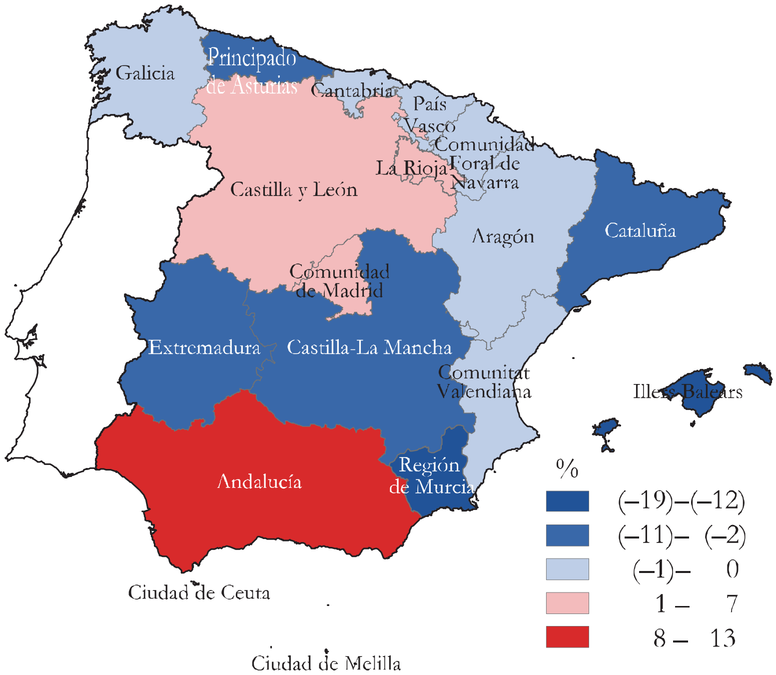
High technological part of regional manufactured exports in Spain, average 2012–2016



However, there is a great disparity in the technological pattern of regional manufactured exports. For illustration, 39 percent of the manufactured goods exported by Madrid between 2012–2016 are of high technological intensity, while Galicia exports barely 1 percent of this grade of manufacturers. Likewise, as Figure 2 shows, significant regional disparities can be observed in the trend over time in the technology content of exported manufacturers. Whereas in some regions, such as Andalucía, Islas Canarias, Castilla-León, Madrid and La Rioja, the technology content of exported manufacturers has improved over time, in others, such as Castilla-La Mancha, Cataluña and Murcia, the opposite is true. In other regions such as Cantabria, Navarra and País Vasco, there is a remarkable stability over time in the type of manufacturers exported in terms of technological content.

Figure 2

Differences in the high technological intensity part of regional manufactured exports in Spain, 2016–2000



Empirical model and hypotheses to be tested

To illustrate this wide divergence, it is useful to consider the drivers of manufacturing exports from the different Spanish regions according to their degree of technological sophistication. To do so, and in line with the previous literature on the analysis of trade flows, we use an extended gravity model (McCallum 1995, Helliwell 1996, Wall 2000, Baier–Bergstrand 2007, Head–Mayer 2014, De Benedictis–Taglioni 2011, Sangeeta–Martínez-Zarzoso 2020, [7]). The basic gravity model (Tinbergen 1962, Pöyhönen 1963) states that trade flows between two economies are largely explained by the size of the economies and the physical distance between them. It is worth noting that other factors having an impact on trade flows may be included, such as cultural affinities between economies, trade openness, or relevant variables from the economic policy perspective. The high explanatory ability of this model from an applied point of view is what makes it a fundamental tool for the empirical analysis of international trade (Head–Mayer 2014, [7]).[7] Thus, the model we will consider can be expressed as follows:

$$X_{ijt} = \gamma_0 GDP_{it}^{\varphi_1} GDP_{jt}^{\varphi_2} DIST_{ij}^{\varphi_3} A_{ijt}^{\varphi} e^{u_{ijt}} \quad (1)$$

The model states that manufactured exports X from region i to country j at time t depend directly on the size of the economy of region i and country j in terms of GDP and inversely on the geographical distance (DIST) between region i and country j. A_{ijt}represents other observable factors that may affect international trade in manufacturers between region i and country j, and u_{ijt} is a random disturbance that captures the unobservable factors affecting international trade in manufacturers. If the technology content of manufacturers (k=high or medium-low) can affect the value of the model parameters in Model (1), the model can be expressed as follows:

$$X_{ijt,k} = e^{\varphi_0+\theta_0 High_k} GDP_{it}^{\varphi_1+\theta_1 High_k} GDP_{jt}^{\varphi_2+\theta_2 High_k} DIST_{ij}^{\varphi_3+\theta_3 High_k} A_{ijt}^{\varphi+\theta High_k} e^{u_{ijt,k}} \quad (2)$$

$High_K$ is a dummy variable that takes a value of 1 when exports have high technological content and 0 otherwise.

In addition to GDP and DIST and in line with the literature, we consider a broad set of factors that may affect manufacturing exports based on their technology content in different ways and represented in (2) by A_{ijt}. Consistent with the empirical literature, these factors are grouped into three categories:

– Specific regional geographic characteristics. Several Spanish regions have external borders, and others do not. In addition, two regions (Islas Canarias and Islas Baleares) are archipelagos. To assess the likely impact of these factors on manufacturing exports, the dummy variables BORDER and ISLAND have been incorporated into the model to capture these features (Ghemawat et al. 2010).
– Importing countries' socioeconomic characteristics. Spain trades freely within the EU and the European Free Trade Association (EFTA). Likewise, Spain has many cultural ties with countries sharing a common language. To assess the likely impact of these phenomena, the dummy variables EUEFTA and SPANISH have been added to the model, indicating, respectively, whether the importing country belongs to the EU or EFTA or not or if it is a Spanish-speaking country (Ghemawat et al. 2010).

[7] McCallum (1995) was one of the first authors to use the gravity equation to analyze the determinants of regional trade flows Subsequently, many other researchers have applied the gravity model using regional data (Anderson–Van Wincoop 2003, Okubo 2004, Gallego–Llano 2014 Hayakawa–Yamashita 2011).

– Drivers of export sophistication. As discussed above, empirical literature has suggested that highly sophisticated exports are determined by factors such as human capital endowment, physical capital endowment, investment in R&D, FDI, or trade openness (Seyoum 2004, Braunerhjelm–Thulin 2008, Tebaldi 2011, Gökmen–Turen 2013, Basarac et al. 2013, Zhu–Fu 2013). Thus, the following variables have been included in the model:
  - OPENNESS measures the degree of trade openness of the host country, measured as net export flows over GDP.
  - Domestic knowledge endowment is proxied by R&D/GDP, which measures the percentage of R&D over GDP in the Spanish regions.
  - Physical capital endowment is proxied by GFCF/POP, which is the ratio of gross fixed capital formation over population in the Spanish regions.
  - Human capital endowment is proxied by UNIVERSITY_i, which is the percentage of the regional population with higher education.
  - Foreign knowledge endowment is proxied by FDI/GDP, which is the ratio of gross FDI flows over regional GDP.

The exact definition of the variables used in the analysis, as well as the source from which they are extracted, can be found in Table A2 of the Appendix.

Considering the whole set of variables mentioned, and if $u_{itj,k}$ has two components, $\xi_{t,k}$ are temporary or trend factors that may affect export flows and $\varepsilon_{it,k}$ are random disturbances with the usual properties, a log transformation is applied to Model (2), yielding:

$$\begin{aligned}\log(X_{ijt,k}) = {} & \varphi_0 + \theta_0 High_k + \varphi_1 \log(GDP_{it}) + \theta_1 High_k \times \log(GDP_{it}) \\ & + \varphi_2 \log(GDP_{jt}) + \theta_2 High_k \times \log(GDP_{jt}) + \varphi_3 \log(DIST_{ij}) \\ & + \theta_3 High_k \times \log(DIST_{ij}) \\ & + \varphi_4 \log(OPENNESS_{jt}) + \theta_4 High_k \times \log(OPENNESS_{jt}) \\ & + \varphi_5 \,(R\&D/GDP)_{it} + \theta_5 High_k \times (R\&D/GDP)_{it} \\ & + \varphi_6 (GFCF/POP)_{it} + \theta_6 High_k \times (GFCF/POP)_{it} \\ & + \varphi_7 \text{UNIVERSITY}_{it} + \theta_7 High_k \times UNIVERSITY_{it} \\ & + \varphi_8 (FDI/GDP)_{it} + \theta_8 High_k \times (FDI/GDP)_{it} + \varphi_9 \text{EUEFTA}_J \\ & + \theta_9 High_K \times \text{EUEFTA}_J + \varphi_{10} \text{SPANISH}_j \\ & + \theta_{10} High_k \times \text{SPANISH}_j \\ & + \varphi_{11} \text{BORDER}_i + \theta_{11} High_k \times \text{BORDER}_i + \varphi_{12} \text{ISLAND}_i \\ & + \theta_{12} High_K \times \text{ISLAND}_i + \xi_{t,k} + \varepsilon_{it,k}\end{aligned} \quad (3)$$

Note that in Model (3), whether there are differences in export flows according to their sophistication depends on the values of the parameter „θ”. If „θ” takes value 0, the model for high-tech manufacturing exports and the model for medium- and low-tech manufacturing exports necessarily coincide. In this regard, our main hypothesis is that the parameters „θ” are nonzero, and therefore, depending on the technology content of exports, the effect of the relevant determinants is different.

The method of estimation

A recurrent challenge when estimating models with trade flow is the presence of zero-value observations. For these observations, the logarithmic formulated gravity model could not be applied. It is possible to skip these observations from the analysis, but this omission introduces biases into the analysis because behind these zero values are the same economic factors that determine all other nonzero values, and information could be lost with low trade presence. Therefore, it is common to replace these zero-values with a numeric 1, so that in logarithms they are transformed back into zero values. However, this transformation does not prevent the least squares (LS) estimator from being an inconsistent estimator (Santos-Silva–Tenreyro 2006). To avoid these biases, different alternative estimators to LS have been suggested in the literature, and among those is the Poisson Pseudo Maximum Likelihood (PPML) estimator, proposed by Santos-Silva–Tenreyro (2011). Given that in our sample there is a total of 3409 zero-value observations, which represent 8.4% of the sample, in addition to estimating Model (3) by LS, we have also estimated the model using PPML.

Empirical results

Table 2 shows the results obtained from the estimated Model (3). Columns I to IV show the results obtained by LS, and Columns V to VIII show the results obtained by PPML. All observations, including zeros (Columns I, II, V, and VI) and positive observations (columns III, IV, VII, and VIII), have been considered. The model is also presented without considering the technology content of exports (Columns I, III, V and VII) and differentiating by technology content (columns II, IV, VI and VIII).

The results in Table 2 show that the suggested model explains to a large extent the export flow performance of manufactured goods exported by the Spanish regions, regardless of technological content or whether exports are disaggregated by technological content. Likewise, the results show the extent to which some factors, such as the membership of the importing country in the EU or EFTA, having a special relationship and deep cultural ties with Spain, or the insularity of the exporting region, play a significant role in determining the export flows of Spanish regions.

In general, and regardless of the method of estimation considered, statistically significant differences can be seen between the model for those manufacturers exported by the Spanish regions with medium-low technological content and those with high technological content. In fact, for all the estimation methods used in this paper, the joint hypothesis of equal parameters for the models is rejected (see Test for equal coefficients in Table 2 columns II, IV, VI and VIII).[8] In other words, there are statistically significant differences for manufactured exports with high technological content versus those with medium-low technological content.[9]

Note that the results are quite sensitive to the estimation methodology, showing that the presence of zero values leads to bias of the LS estimator. Therefore, it is important to estimate Equation (3) via PPML to avoid bias.[10] We focus on studying the results obtained by PPML (Table 2 Columns V to VIII), for which no great differences are seen when considering the entire sample (Table 2 Columns V and VI), or only when considering those observations that take positive values (Table 2 columns VII and VIII). In this regard, the overall result considering differences between the models according to the degree of sophistication of manufactured exports holds at the individual level for all the parameters of the model except for the GDP elasticity of the importing country (Table 2 columns VI and VIII)[11]. The nonrelationship between the GDP elasticity of the importing economy and the technology-content type of exports could indicate that international economic growth has favored Spanish manufactured exports with greater technological sophistication as much as those with lower technological sophistication. Furthermore, it is estimated that the GDP of the exporting region is more elastic for manufactured exports with high technological content when compared to those with lower technological content. Higher elasticity of regional GDP for manufactured exports with high technology content indicates that regional growth in Spain, at least over the study period, had a more positive impact on sophisticated manufacturing exports than on those of medium-low technology content.

[8] As a result, when comparing, method by method, the estimated values for the parameters of the model not considering the type of exported manufacture versus considering the type of manufacture (Table 2 Columns I vs. II, III vs. IV, V vs. VI and VII vs. VIII), it is noted that the estimated parameters take intermediate values when a distinction is not made by type of manufacture against to those estimated when a distinction is made by type of manufacture.

[9] Several robustness checks of the estimates were carried out. First, using the whole sample, a collinearity analysis was performed among the regressors used, concluding that there was no such problem. Specifically, the Variance Inflation Factors did not exceed the value of 5 in any case and the correlations between regressors did not exceed the value of 0.75. An analysis of the possible endogeneity of the variables OPENNESS, log (GDPi), FDI/GDP and R&D/GDP was also carried out. For this purpose, the Durbin-Wu-Hausman endogeneity test was carried out, considering lags of these variables as valid instruments. The test takes a value of 6.558 with a p value of 0.162 when the whole sample is considered. Thus, at the 5% level of significance, the null hypothesis of exogeneity of these variables cannot be rejected.

[10] For instance, as shown in Table 2, when estimating by PPML, the estimated distance elasticity regarding manufactured exports with a high technological content, regardless of whether it is estimated with full or part of the sample, differs from when it is estimated by LS. These findings are since most of the zero values are found among the manufactured exports with a high technological content (96.6%), which causes the LS estimator to tend to overestimate the impact of the distance for this group of manufactured exports. In addition, it can also be observed that LS tends to overestimate the elasticities linked to the size of the economies.

[11] For this elasticity, the hypothesis of equal elasticities for manufactured good exports with high and medium-low technological content cannot be rejected at the 5% significance level.

Table 2

Estimations of Model (3)

Denomination	LS				PPML			
	(whole sample)		(just positive sign)		(whole sample)		(just positive sign)	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
Intercept	–28.886* (0.440)	–13.557* (0.296)	–19.648* (0.416)	–12.947* (0.285)	–7.167* (0.493)	–4.989* (0.397)	–6.818* (0.497)	–4.983* (0.397)
High		–30.656* (0.489)		–24.957* (0.523)		–24.037* (0.933)		–23.777* (0.942)
log (GDP_i)	1.837* (0.020)	1.177* (0.013)	1.383* (0.019)	1.153* (0.013)	0.852* (0.021)	0.786* (0.017)	0.837* (0.021)	0.786* (0.017)
High x log ($GDP_{i,}$)		1.320* (0.022)		1.034* (0.024)		0.971* (0.041)		0.958* (0.042)
log (GDP_j)	0.999* (0.010)	0.967* (0.007)	0.875* (0.001)	0.943* (0.006)	0.843* (0.012)	0.843* (0.010)	0.837* (0.012)	0.843* (0.010)
High x log (GDP_j)		0.064* (0.012)		0.049* (0.013)		0.015 (0.017)		0.011 (0.017)
log ($DIST_{i,j}$)	–1.184* (0.025)	–1.295* (0.016)	–1.046* (0.024)	–1.270* (0.016)	–1.133* (0.034)	–1.173* (0.025)	–1.127* (0.034)	–1.173* (0.025)
High x log ($DIST_{i,j}$)		0.223* (0.030)		0.232* (0.031)		0.429* (0.052)		0.432* (0.052)
OPENNESS	0.008* (0.0003)	0.005* (0.0002)	0.006* (0.0002)	0.005* (0.0002)	0.0006 (0.0004)	0.0003 (0.0004)	0.0006 (0.0005)	0.0003 (0.0004)
High x OPENNESS		0.005* (0.0004)		0.005* (0.0004)		0.003* (0.001)		0.003* (0.001)
R&D/GDP	–0.387* (0.079)	–0.432* (0.048)	–0.073 (0.076)	–0.334* (0.047)	0.094 (0.092)	0.072* (0.069)	0.112 (0.091)	0.072* (0.069)
High x R&D/GDP		0.091 (0.078)		0.222* (0.078)		0.241* (0.123)		0.241* (0.123)
GFCF/POP	–0.017 (0.015)	–0.050* (0.010)	0.034** (0.015)	–0.031* (0.010)	0.039** (0.021)	0.024** (0.014)	0.041* (0.020)	0.024** (0.015)
High x GFCF/POP		0.066* (0.012)		0.081* (0.014)		0.058* (0.021)		0.059* (0.021)
% UNIVERSITY	0.093* (0.005)	0.096* (0.003)	0.060* (0.005)	0.086* (0.003)	0.016* (0.006)	0.016* (0.004)	0.014* (0.006)	0.016* (0.004)
High x % UNIVERSITY		–0.007 (0.004)		–0.023* (0.004)		–0.008 (0.006)		–0.008 (0.006)
FDI/GDP	0.100* (0.049)	–0.133* (0.050)	0.176* (0.050)	–0.109* (0.047)	0.010 (0.022)	–0.043 (0.029)	0.012* (0.022)	–0.043 (0.029)
High x FDI/GDP		0.467* (0.092)		0.456* (0.090)		0.136* (0.035)		0.136* (0.035)
EUEFTA	0.270* (0.044)	0.107* (0.028)	0.228* (0.042)	0.090* (0.027)	0.609* (0.049)	0.583* (0.041)	0.605* (0.049)	0.583* (0.041)
High x EUEFTA		0.326* (0.052)		0.303* (0.053)		0.354* (0.082)		0.349* (0.082)

(Table continues on the next page.)

(Continued.)

Denomination	LS				PPML			
	(whole sample)		(just positive sign)		(whole sample)		(just positive sign)	
	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)	(VIII)
SPANISH	1.512* (0.040)	1.256* (0.027)	1.133* (0.039)	1.187* (0.026)	0.925* (0.046)	0.931* (0.039)	0.910* (0.046)	0.930* (0.039)
High x SPANISH		0.511* (0.051)		0.396* (0.053)		–0.078 (0.081)		–0.087 (0.080)
BORDER	0.168* (0.030)	0.188* (0.020)	0.059* (0.029)	0.189* (0.020)	0.587* (0.038)	0.674* (0.030)	0.580* (0.038)	0.674* (0.030)
High x BORDER		–0.040 (0.037)		–0.065** (0.039)		–0.731* (0.056)		–0.731* (0.056)
Island	–2.216* (0.068)	–2.643* (0.050)	–2.195* (0.068)	–2.560* (0.048)	–2.011* (0.083)	–2.299* (0.069)	–1.999* (0.083)	–2.297* (0.069)
High x Island		0.852* (0.087)		0.912* (0.101)		2.272* (0.160)		2.320* (0.161)
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Test for equality of coefficients-Wald test (p value)		65,986.84 (0.000)		49,206.97 (0.000)		$9{,}31 \times 10^8$ (0.000)		12,227.16 (0.000)
Joint significance test "new variables"	1,461.35 (0.000)	3,857.80 (0.000)	1,118.61 (0.000)	3,362.40 (0.000)	121.80 (0.000)	331.46 (0.000)	119.87 (0.000)	332.30 (0.000)
R^2	0.448	0.786	0.385	0.738	0.415	0.705	0.413	0.704
Observations	40,460	40,460	37,050	37,050	40,460	40,460	37,050	37,050

Note: Values shown in parentheses are standard errors. (*) Significant at 5%. (**) Significant at 10%.

One of the best-established empirical findings in international economics is the fact that bilateral trade decreases with distance (Disdier–Head 2008, Wang et al. 2010). The estimation results achieved from Model (3) using PPML (Table 2 columns VI and VIII) are fully in line with the previously mentioned findings. Furthermore, the results provide evidence in favor of lower distance elasticity (in absolute terms) for exports of sophisticated manufacturers. Possibly, this result illustrates the existence of lower relative costs associated with manufactured exports of greater technological sophistication for the Spanish regions, compared with manufactured exports of lower technological sophistication. Among the possible causes of these lower costs, we can mention greater market power due to greater vertical specialization and quality of manufactured goods, structural competitiveness as a source of competitive and comparative advantages, participation in global value chains, etc. This result is also consistent with what is suggested by the economic complexity literature (Balland–Rigby 2017). According to this literature, goods with high technological content, due to their features, are complicated to produce and complicated to substitute. As such, their production tends to be concentrated in certain geographical areas. This geographic concentration of highly sophisticated activities could also mean that these industries (and their exporting activities) are less sensitive to geographical distance since there are no close substitutes in neighboring regions/countries.

It is observed that the openness to foreign trade of the importing country is a positive determinant of the Spanish regional manufactured exports with a high degree of technological sophistication. Likewise, the R&D/GDP ratio is a positive determinant of regional manufactured exports and is even more relevant for manufactured exports with a high degree of technological sophistication (Table 2 columns VI and VIII).

We note that the GFCF/Population ratio of the Spanish regions is a positive determinant of regional manufactured exports, and as in the case of exports of manufacturers with high technological content, that ratio takes on even greater relevance. The endowment of human capital is also relevant in explaining the manufacturing exports of the different Spanish regions, although there seem to be no differences by degree of technological sophistication. Additionally, relevant is the FDI/GDP ratio of the Spanish regions as a positive and statistically significant factor of manufactured exports with high technology levels, although this is not the case for the rest of manufacturers.

One of the main characteristics of the export pattern of Spain is its high geographical concentration, with EU-EFTA countries and countries with close cultural ties (Spanish-speaking)[12] being the largest trading partners of Spain. The results of the estimations using PPML (see Table 2 columns VI and VIII) confirm those results. However, in that pattern, there are nuanced differences according to the technological content of manufactured exports. For exports of high-tech manufacturers, the fact that the recipient is an EU-EFTA country is more relevant than for other exports. In contrast to the previous EU-EFTA remark, there is no evidence to assume that cultural affinity is a factor to consider in the determination of Spanish manufactured exports with high technological content.

In connection with the estimates using PPML obtained from the variables that capture the geographical characteristics of the Spanish regions (Table 2 Columns V to VIII), it should be highlighted that two region challenges, being an island and not having an external border (see Table 2 Columns V and VII), are not an obstacle when exporting manufacturers with high technological content (see Table 2 columns VI and VII). Therefore, this result may be interpreted as meaning that the production and export of high-technology manufacturers can be a driving force for regions with geographical characteristics that, beforehand, could make export processes harder.

[12] According to DataComex [11], during the period considered, and as an annual average during the study period, the weight of Spanish exports to EU-EFTA countries was 70% of the total and to countries with cultural affinity 7%.

In short, the empirical results presented in this section constitute clear evidence of the relevance of considering the technological content of Spanish manufacturing when explaining the behavior of international manufacturing trade flows.[13]

Concluding remarks and policy recommendations

Based on the outcomes obtained, it can be concluded that there are statistically significant differences regarding the drivers of manufacturing exports from Spanish regions in terms of technological content. Factors such as the EU or EFTA membership of the importing countries, the regional insularity, or the existence of close cultural ties with Spain are key determining factors in the export flows of technology-intensive manufacturers of the Spanish regions. Likewise, statistically significant differences are found regarding the main elasticities studied, that is, those referring to the economy size of both the exporting region and the recipient country for technology-intensive manufacturers. Furthermore, lower distance elasticity is observed for those manufacturers with high technological content compared to those with lower technological content. Similarly, it is found that the transfer of external knowledge plays a crucial role alongside the development of domestic knowledge in determining the regional exports of Spanish manufacturers with higher technological content. Another relevant determinant of regional exports with high technological content is physical capital, which in our research is proxied by the GFCF in terms of the regional population, and once again, relevance is greater in the case of regional manufactured exports with higher technological content.

The results reported in this research are clear evidence of the importance of considering the technological content in the study of the determinants of manufacturing exports at the regional level. Likewise, these results have important implications for Spain from the perspective of trade policy since it is a country traditionally in trade deficit. Therefore, trade policy should be geared toward favoring exports with high technological content. When stimulating exports of technology-intensive manufacturers, there are three key factors that policy-makers can control: fostering investment in R&D, encouraging investment in physical capital, and

[13] To re-enforce these empirical results, four alternative models were estimated. First, a basic gravity model was estimated, in which the variables concerning the specific factors of export differentiation by level of sophistication were eliminated from Model (2). Subsequently, a model analogous to the previous one was estimated, although the size of the economy is approximated by GDP per capita, population and land area. Likewise, a further model was estimated, like (2) but approximating the size of economies by GDP per capita, population and land area. Finally, to assess to what extent, the accumulation of physical capital, R&D and FDI might be relevant in determining exports and given that these variables were not available in its stock dimension, the cumulative data for these three variables were calculated for five years (the four years prior to the corresponding year plus the corresponding year) and the Model (2) was re-estimated. The results confirm and make valid claims about the existence of statistically significant differences between the parameters of the models of exports of manufactures with high and low-medium technological content (see Tables A3 and A4 in the Appendix).

promoting FDI. Spanish regions and Spain have R&D/GDP ratios far below the EU and OECD average [8]. Therefore, this evidence shows the need to envisage an ambitious national innovation system in which regions play a greater role. While regulatory mechanisms, such as property rights, are well strengthened in Spain, other economic and financial tools, such as tax incentives and other research incentives, need to be redesigned, combining efficiency in the allocation of scarce resources with less bureaucracy to avoid discouraging risk-taking.

Among the possible economic policy responses, we demonstrate that those measures aimed at attracting and consolidating FDI flows focused on the production of manufacturers with high technological content are the most promising. In the case of the Spanish economy, FDI has played a very significant role as a source of knowledge and dissemination of innovation and technology (Buesa–Molero 2001). To that end, it is necessary to eliminate regulatory barriers that may incorporate uncertainty that could discourage FDI. Given that these types of companies develop their activities in business environments characterized by high dynamism, flexibility, innovation, and fragmentation in the global chains of production, it would be desirable to design an efficient, predictable, and transparent regulatory framework more conducive to investment. It would also be appropriate to foster an international business environment to achieve joint investment projects between local and multinational companies to develop new technologies. Moreover, the results of this research show that it is likely that Spanish investment in R&D is not sufficiently focused on the generation of value added in the industrial and manufacturing sectors with high technological content. Therefore, it would be convenient to design more ambitious industrial policies that increase the levels of R&D focused on the mentioned industrial sectors. To achieve this objective, measures are needed to identify future needs in those changing markets, effective public–private collaboration in the field of innovation, continuous monitoring and evaluation of innovation processes, early detection of possible market failures and other limitations that prevent a wide dissemination of knowledge, among others.

Traditionally, factors such as labor costs and access to natural resources played an important role in firms' location decisions. However, companies with more sophisticated technological production also consider other factors in their decisions to move part of their production abroad, such as human capital formation and the availability of efficient innovation systems. Therefore, in the case of the Spanish regions, there is a need to strengthen the system of incentives for attracting FDI with a high technological component, improving R&D tax deductions, technology insurance schemes, R&D grants for business, and R&D partnerships between government, universities, and industry. Moreover, it is also essential to create, reform and enhance instruments and platforms to trigger, facilitate and disseminate innovation at the regional level, such as science and technology parks and partnerships with foreign companies to establish innovation or training centers. In the case of quite a few Spanish regions, there is a clear need to tie and attract high-skill human capital. Therefore, to achieve this aim, it is necessary to envisage cross-cutting policies such as housing, telecommunications, and health. From the point of view of achieving objectives, these issues need to be considered when designing projects.

Strategic collaboration and policy coordination between regional governments, the central government and the private sector is a key element for policy success. Following the Covid-19 pandemic, the Spanish government launched the Strategic Projects for Economic Recovery and Transformation (PERTE). These projects have a clear cross-cutting vocation, with the participation of the central government, regional administrations, and private companies. The aim of these mechanisms is to foster and coordinate priority projects that contribute to economic transformation, particularly when there is a clear market failure, important externalities or insufficient initiative or investment capacity on the private sector side. Some of these projects are focused on strategic technology sectors included in our study, such as the electric automotive sector, aerospace, naval sector, microelectronics, and semiconductors. In addition to the important bureaucratic framework that the Spanish law on subsidies entails, from the awarding to the justification of the project, regional authorities will manage only half of the budget. Simplifying the bureaucratic processes and entry barriers to the maximum extent would facilitate access to funding for small and medium-sized Spanish companies, which make up a large part of the Spanish business landscape.

At the micro level, emphasis should be placed on facilitating companies to improve their technological base by implementing measures to enhance the skills of the workforce, as this is a disadvantage faced by many companies that are in Spanish regions with a lower propensity to innovate. One potential mechanism to achieve this goal is funding from the European Social Fund, which should be focused on training to improve the technological skills of the workforce. Improving the management of innovation should be another crucial issue on the agenda, particularly those elements related to technology commercialization. In this respect, attention should be given to the multiple and interconnected elements that play an important role in the effectiveness of technology commercialization, such as technological infrastructures or the regional institutional context.

It is likely that the results obtained are relevant to other countries in the Spanish economic sphere. However, to determine to what extent this is the case, it is necessary to extend the study in the future by adding information at the regional level for other countries.

Appendix

Table A1

List of countries

Country			
France	Turkey	Canada	United Arab Emirates
The Netherlands	Poland	Mexico	Oman
Germany	Czech Republic	Guatemala	India
Italy	Hungary	Panama	Thailand
United Kingdom	Romania	Dominican Republic	Vietnam
Ireland	Bulgaria	Colombia	Indonesia
Denmark	Russia	Venezuela	Malaysia
Greece	Kazakhstan	Ecuador	Singapore
Portugal	Slovenia	Peru	Philippines
Belgium	Croatia	Brazil	China
Luxembourg	Morocco	Chile	South Korea
Iceland	Algeria	Argentina	Japan
Norway	Tunisia	Cyprus	Taiwan
Sweden	Egypt	Iran	Hong-Kong
Finland	Angola	Israel	Australia
Austria	Kenya	Jordan	New Zealand
Switzerland	South Africa	Saudi Arabia	
Andorra	United States	Kuwait	

Table A2

Variable description and source

Variable	Description	Source
$X_{ijt,k}$	The exports of manufactures with a technological content k (high or medium-low) from Spanish region i to economy j at time t (in thousands of EUR)	Ministerio de Industria, Comercio y Turismo [11].
GDP_{it}	The GDP for the Spanish regions at current prices (in thousands of EUR)	The Spanish Statistical Office (INE) [12].
GDP_{jt}	The GDP for the importing countries at current prices (in thousands of EUR)	United Nations Conference on Trade and Development (UNCTADstat) [13]
$DIST_{ij}$	The geodetic distance, expressed in kilometers, between region i and economy j	The Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) [14]
$OPENNESS_{jt}$	The degree of trade openness of the host country, measured as net export flows over GDP	United Nations Conference on Trade and Development (UNCTADstat) [13]
$R\&D/GDP_{it}$	The percentage of R&D over GDP in the Spanish regions	The Spanish Statistical Office (INE) [12]

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(Continued.)

Variable	Description	Source
$GFCF/POP_i$	The ratio of gross fixed capital formation over population in the Spanish regions	The Spanish Statistical Office (INE) [12]
$UNIVERSITY_i$	The percentage of the regional population with higher education	The Organization for Economic Co-operation and Development (OECD) https://stats.oecd.org/
FDI/GDP_i	The ratio of gross Investment (FDI) flows over regional GDP	The Spanish Statistical Office (INE) [12]
$High_k$	Dummy variable takes value of 1 if exports have a high technological content	Own elaboration
$EUEFTA_j$	Dummy variable takes value of 1 if the destination of the exports is a member country of the EU or EFTA	Own elaboration
$SPANISH_j$	Dummy variable takes value of 1 if the importing country is a Spanish-speaking country	Own elaboration
$BORDER_i$	Dummy variable takes value of 1 if the exporting Spanish region has an external border	Own elaboration
$ISLAND_i$	Dummy variable takes value of 1 if the Spanish region is an island region (Islas Baleares o Islas Canarias)	Own elaboration
$GDPPC_i$	The GDP per capita for the Spanish regions at current prices (in EUR)	The Spanish Statistical Office (INE) [12]
$GDPPC_j$	The GDP per capita for the importing countries at current prices (in EUR)	United Nations Conference on Trade and Development (UNCTADstat) [13]
$SURFACE_i$	The area of exporting regions (in square kilometers).	The Spanish Statistical Office (INE) [12]
$SURFACE_j$	The surface area of importing countries (in square kilometers)	World Bank (DataBank) [9]
POP_i	The population of exporting regions (in thousands)	The Spanish Statistical Office (INE) [12]
POP_j	The population of importing countries (in thousands)	United Nations Conference on Trade and Development (UNCTADstat) [13]

Table A3

Estimations of the Alternative Equation (I)

Denomination	Variables	PPML	
		(whole sample)	(just positive sign)
		(I)	(II)
Intercept	Intercept	–4.835* (0.365)	–4.832* (0.365)
	High	–26.584* (0.842)	–26.347* (0.850)
Variables measuring the size of the exporting region's economy	log (GDP_i)	0.812* (0.015)	0.811* (0.015)
	High x log ($GDP_{i,}$)	1.145* (0.036)	1.134* (0.036)
Variables measuring the size of the importing country's economy	log (GDP_j)	0.840* (0.010)	0.840* (0.010)
	High x log (GDP_j)	–0.008 (0.017)	–0.012 (0.017)
Distance between regions and countries	log ($DIST_{i,j}$)	–1.170* (0.026)	–1.170* (0.026)
	High x log ($DIST_{i,j}$)	0.456* (0.053)	0.459* (0.053)
Other relevant regional or international factors	EUEFTA	0.586* (0.039)	0.586* (0.039)
	High x EUEFTA	0.451* (0.080)	0.446* (0.081)
	SPANISH	0.926* (0.040)	0.926* (0.040)
	High x SPANISH	–0.145** (0.079)	–0.153** (0.078)
	BORDER	0.625* (0.028)	0.625* (0.028)
	High x BORDER	–0.919* (0.055)	–0.919* (0.055)
	ISLAND	–2.436* (0.056)	–2.434* (0.056)
	High x ISLAND	2.356* (0.131)	2.406* (0.131)
	Time dummies	Yes	Yes
	Test for equality of coefficients-Wald test (p value)	10,471.33 (0.000)	10,310.71 (0.000)
	R^2	0.686	0.685
	Observations	40,460	37,050

(Table continues on the next page.)

(Continued.)

Denomination	Variables	PPML		PPML	
		(whole sample)	(just positive sign)	(whole sample)	(just positive sign)
		(III)	(IV)	(V)	(VI)
Intercept	Intercept	–3.727* (0.448)	–3.722* (0.448)	–5.936* (0.474)	–5.923* (0.474)
	High	–24.931* (0.946)	–24.673* (0.950)	–22.171* (1.046)	–21.911* (1.052)
Variables measuring the size of the exporting region's economy	log ($GDPPC_i$)	1.783* (0.089)	1.782* (0.089)	3.952* (0.166)	3.949* (0.166)
	High x log ($GDPPC_{i,}$)	0.850* (0.161)	0.840* (0.161)	–1.926* (0.307)	–1.933* (0.308)
	log (POP_i)	0.730* (0.012)	0.730* (0.015)	0.725* (0.023)	0.725* (0.023)
	High x log ($POP_{i,}$)	1.060* (0.042)	1.049* (0.042)	1.035* (0.056)	1.025* (0.056)
	log ($Surface_j$)	0.010 (0.021)	0.010 (0.021)	–0.113* (0.033)	–0.113* (0.033)
	High x log ($Surface_j$)	–0.089** (0.051)	–0.090** (0.052)	0.129** (0.070)	0.126** (0.069)
Variables measuring the size of the importing country's economy	log ($GDPPC_j$)	0.683* (0.012)	0.683* (0.012)	0.680* (0.012)	0.679* (0.012)
	High x log ($GDPPC_j$)	0.231* (0.029)	0.226* (0.029)	0.242* (0.028)	0.237* (0.029)
	log (POP_j)	1.025* (0.012)	1.025* (0.012)	1.031* (0.012)	1.031* (0.012)
	High x log (POP_j)	–0.054** (0.030)	–0.058** (0.030)	–0.062* (0.030)	–0.066* (0.030)
	log ($Surface_j$)	–0.135* (0.009)	–0.135* (0.009)	–0.157* (0.010)	–0.157* (0.010)
	High x log ($Surface_j$)	–0.033 (0.022)	–0.032 (0.022)	–0.013 (0.026)	–0.013 (0.026)
Distance between regions and countries	log ($DIST_{i,j}$)	–1.197* (0.022)	–1.197* (0.022)	–1.189* (0.020)	–1.189* (0.020)
	High x log ($DIST_{i,j}$)	0.437* (0.051)	0.440* (0.051)	0.422* (0.050)	0.425* (0.050)

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(Continued.)

Denomination	Variables	PPML		PPML	
		(whole sample)	(just positive sign)	(whole sample)	(just positive sign)
		(III)	(IV)	(V)	(VI)
Drivers of sophistication level	OPENNESS			–0.002* (0.0004)	–0.002* (0.0004)
	High x OPENNESS			0.001 (0.0009)	0.001 (0.0009)
	R&D/GDP			–0.464* (0.078)	–0.463* (0.078)
	High x R&D/GDP			0.724* (0.157)	0.719* (0.158)
	GFCF/POP			–0.202* (0.020)	–0.201* (0.020)
	High x GFCF/POP			0.238* (0.025)	0.239* (0.025)
	% UNIVERSITY			–0.040* (0.005)	–0.040* (0.005)
	High x % UNIVERSITY			0.052* (0.008)	0.052* (0.008)
	FDI/GDP			–0.069* (0.033)	–0.069* (0.033)
	High x FDI/GDP			0.146* (0.039)	0.146* (0.039)
Other relevant regional or international factors	EUEFTA	0.666* (0.045)	0.666* (0.045)	0.672* (0.043)	0.672* (0.043)
	High x EUEFTA	0.059 (0.092)	0.056 (0.092)	0.006 (0.091)	0.003 (0.091)
	SPANISH	0.978* (0.037)	0.978* (0.037)	0.946* (0.036)	0.945* (0.036)
	High x SPANISH	–0.057 (0.079)	–0.066 (0.079)	–0.020 (0.078)	–0.030 (0.078)
	BORDER	0.676* (0.032)	0.676* (0.032)	0.686* (0.040)	0.687* (0.040)
	High x BORDER	–0.746* (0.066)	–0.745* (0.066)	–0.762* (0.076)	–0.760* (0.076)
	ISLAND	–2.819* (0.065)	–2.815* (0.065)	–4.047* (0.124)	–4.044* (0.124)
	High x ISLAND	2.283* (0.159)	2.329* (0.160)	4.036* (0.276)	4.075* (0.277)
	Time dummies	Yes	Yes	Yes	Yes
	Test for equality of coefficients-Wald test (p value)	12,945.26 (0.000)	12,744.89 (0.000)	12,970.76 (0.000)	12,784.27 (0.000)
	R^2	0.755	0.754	0.790	0.789
	Observations	40,460	37,050	40,460	37,050

Note: Values shown in parentheses are standard errors. (*) Significant at 5%. (**) Significant at 10%.

Table A4

Estimations of the Alternative Equation (II)

Variables	PPML (whole sample) (VII)	PPML (just positive sign) (VIII)
Intercept	–5.450* (0.476)	–5.446* (1.277)
High	–25.458* (1.225)	–25.230* (2.455)
log (GDP_i)	0.797* (0.019)	0.797* (0.051)
High x log ($GDP_{i,}$)	1.032* (0.054)	1.021* (0.110)
log (GDP_j)	0.842* (0.011)	0.842* (0.032)
High x log (GDP_j)	0.015 (0.019)	0.011 (0.048)
log ($DIST_{i,j}$)	–1.173* (0.028)	–1.173* (0.082)
High x log ($DIST_{i,j}$)	0.401* (0.056)	0.401* (0.056)
OPENNESS	0.0005 (0.0004)	0.0005 (0.001)
High x OPENNESS	0.003* (0.0008)	0.003** (0.0009)
R&D/GDP(5)	–0.003 (0.015)	–0.003 (0.019)
High x R&D/GDP(5)	0.241* (0.123)	0.006 (0.054)
GFCF/POP(5)	0.005 (0.004)	0.005 (0.010)
High x GFCF/POP(5)	0.021* (0.007)	0.021* (0.010)
% UNIVERSITY	0.016* (0.004)	0.020* (0.012)
High x % UNIVERSITY	–0.008 (0.006)	0.006 (0.014)
FDI/GDP(5)	–0.028 (0.016)	–0.028 (0.031)
High x FDI/GDP(5)	0.126* (0.019)	0.126* (0.035)
EUEFTA	0.549* (0.045)	0.549* (0.135)
High x EUEFTA	0.171* (0.086)	0.168* (0.211)
SPANISH	0.898* (0.044)	0.898* (0.123)
High x SPANISH	–0.138* (0.090)	–0.145* (0.218)
BORDER	0.682* (0.035)	0.682* (0.102)
High x BORDER	–0.597* (0.067)	–0.598* (0.173)
ISLAND	–2.355* (0.079)	–2.353* (0.202)
High x ISLAND	2.278* (0.204)	2.321* (0.380)
Time dummies	Yes	Yes
Test for equality of coefficients-Wald test (p value)	1,534.64 (0.000)	1,512.63 (0.000)
R^2	0.704	0.703
Observations	30,940	28,726

Note: Values shown in parentheses are standard errors. (5) It means that 5 years' worth of value is accumulated. (*) Significant at 5%. (**) Significant.

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