

Impacts of research and development on manufacturing trade^{*1}

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Abstract

The basic aim of the research is to investigate the impacts of research and development (R&D) on manufacturing trade. Six hypotheses are tested. The focus is on possible non-linear effect of R&D on trade flows and whether R&D helps overcome the distance and the role of level of economic development on manufacturing trade. The panel unit root test and panel econometric methods are employed on the adapted gravity trade model using the panel data for Organisation for Economic Cooperation and Development (OECD) countries during the period 1995-2003. The results of the research indicate that R&D is positively associated with manufacturing trade for exporting countries, while results are mixed for importing countries. The results reject the non-linear relationship between R&D and manufacturing exports. Estimations suggest that R&D may contribute to overcoming the effects of distance on manufacturing exports and may strengthen import specialization. R&D is found as the way to foster exports of manufacturing products from developing to developed OECD countries.

Key words: manufacturing trade, research and development, distance, level of economic development, OECD countries, adapted gravity equation, panel data analysis

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1. Introduction

Literature explains various internal and external factors of technological sources, technology acquisition, research and development (R&D) intensity and innovation at firm, industrial sector, and nation levels (e.g. Bavec, 2009). The changing global competitiveness and trade patterns between the nations have generated a search for the determinants which are causing these changes. R&D intensity and innovation activities are seen as key factors in explaining the changes in technological gaps and in competitiveness in world trade (e.g. Freeman et al., 1991; Wakelin, 1998). There is a growing literature on the determinants of trade performance, either for one country (e.g. Özçelik and Taymaz, 2004), or for more or a group of countries (Roper and Love, 2002), in order to assess and point to a role for R&D intensity and innovation activities as factors influencing the trade performance of developed industrialized countries (Fagerberg, 1988; Greenhalgh, 1990) and developing countries (Montobbio and Rampa, 2005).

The purpose of this paper is to identify the determinants of manufacturing trade focusing on the role of the R&D expenditures in these processes. This is the challenging research and policy issue for the research policy with the managerial implications concerning the R&D expenditures and their affects to improve performance in the international manufacturing trade. More specifically, this paper investigates the impact of R&D intensity on trade by analysing the determinants of the bilateral manufacturing trade flows between eighteen Organisations for Economic Cooperation and Development (OECD) countries. Adapted gravity equations are employed to identify the effects of R&D on bilateral manufacturing trade using a panel data analysis. The paper aims to contribute to the literature in five significant directions. First, the starting point of our investigation is the relationship between R&D and manufacturing trade performance in the OECD countries using a panel data analysis by applying the baseline adapted gravity equation model. The Ghazalian and Furtan (2007) econometric approach is integrated in the estimation procedure. So far, there are few similar studies in the literature. Second, it is analysed whether the R&D intensities have mitigated the effect of distance on manufacturing trade, and therefore, the rationale for long-distance is checked on manufacturing trade. The paper employs the Freund and Weinhold (2002, 2004) and Bojnec and Fertő (2009, 2010) specification for the investigation of the effects of R&D on distance and long-distance into the adapted gravity equation model. Third, the paper investigates the impact of the level of economic development on manufacturing trade and check the sensitivity of the panel regression results to the choice of R&D by investigating the effects of R&D by the level of countries' economic development. Fourth, the robustness test is conducted by years and for non-linearity. Finally, the paper deals with the specific issue of the association of R&D intensity and export intensity with research, economic system and managerial policy implications.

The rest of the paper is organized as follows. The next section presents the literature review. In the next section after that the methodology and data used are presented by focusing on the R&D intensity in the adapted gravity regression analysis. After that, the paper presents and discusses the regression results for alternative specifications of adapted gravity models and for a robustness check. The final section summarises the main findings and gives conclusions upon hypotheses and contribution for economic science, presents the limitations during the research work and directives for the future research, and derives research, institutional and policy implications of the investigation and research results.

The following six hypotheses are tested:

Hypothesis 1 (H1): manufacturing export is positively associated with gross domestic product (GDP) as a measure of the economy size in exporting and importing countries, with GDP per capita as a measure of economic development in exporting in importing countries, with having a common border, speaking the same language, and having a free trade agreement, respectively, but negatively associated with distance between bilateral countries capitals.

H2: manufacturing export is positively associated with R&D expenditure in exporting and importing countries, respectively.

H3: manufacturing export is non-linearly associated with R&D expenditure in exporting and importing countries, respectively.

H4: manufacturing export is positively and increasingly associated with R&D expenditure over time in exporting and importing countries, respectively.

H5: manufacturing export is positively associated with long distance when R&D mitigates the effect of long distance on manufacturing trade in exporting and importing countries, respectively.

H6: manufacturing export is positively associated with joint effect of the level of economic developed measured by GDP per capita and R&D expenditure in exporting and importing countries.

2. Literature review

The literature provides a theoretical background for export and R&D relationship at both macroeconomic and microeconomic level. Since the study focuses on the macroeconomic level, the focus is mainly on the former literature. The macroeconomic research offers two main theoretical perspectives to account for the relationship between R&D and exports. First, the neo-endowment models which concentrate on trade specialisation on the basis of factor endowments, such as materials, labour

capital, knowledge and human capital (Wakelin, 1998). Second, the neo-technology models which predict innovative industries will be net exporters instead of importers. The latter type of models provides an extension of the conventional technology-based models such as the product life-cycle theory (Vernon, 1966) and technology gap theory (Posner, 1961).

Krugman (1979) showed that countries and products can be ranked by technological level and that economies ahead on this scale specialize in the technological intensive goods. Increasing returns to scale and product innovations generate trade specialization and first mover advantages. But in equilibrium, imitation reduces technological gaps between countries, and the monopolistic power of leaders is temporary. In addition, the causal chain ran from R&D and innovation to international trade and not the other way round.

Grossman and Helpman (1995) argued that, in a framework of monopolistic competition, a country could shift its export demand curve outwards by increasing the quality of goods it produces; meanwhile, it could shift its import demand curve inwards by increasing the quality of goods produced for the domestic market. These demand-shift factors can possibly be proxied by factors that represent improvements in product quality, i.e. R&D and technological innovation.

Eaton and Kortum (2002) developed a Ricardian model to explore the role of trade in spreading the benefits of technological innovation. Their theory delivers an augmented gravity equation for bilateral trade that identifies the underlying parameters affecting the relationship between technological innovation and trade. In a linear specification, their results indicate that foreigners benefit on average by only a tenth as much as the innovating country, but the benefits depend on the distance to trading partners. The benefits of close neighbours are similar to those of the innovator welfare benefits.

A wealth of literature provides evidence at the macroeconomic level on the linkage between a country's export performance and its R&D pertained with creativity/innovation. Various empirical studies confirm the importance of R&D, technology and innovation as one of the major factors contributing to facilitating entry into global markets and thereafter maintaining competitiveness and boosting export performance (e.g. Fagerberg, 1988, Greenhalgh, 1990; Wakelin, 1998; Montobbio, 2003; Narula and Wakelin, 1998; Leon-Ledesma, 2005; DiPietro and Anoruo, 2006).

The literature highlights three channels for R&D and innovation influencing the level of trade (Ghazalian and Furtan, 2007). First, R&D and innovation may foster the product differentiation, allowing for more product variety choices and higher quality products for consumers. Second, R&D and innovation may reduce the production costs, making firms more competitive on the international markets. Third, R&D and innovation may reduce the transaction costs along the supply chain and between trading partners, making exports more competitive. For example, the literature on

international trade emphasises the role of institutions and infrastructure in export growth (e.g. Anderson and Marcouiller, 2002; Dollar and Kray, 2002; de Groot et al., 2004; Francois and Manchin, 2007; Depken and Sonora, 2005; Levchenko, 2007).

3. Methodology and data

The gravity model is largely used in explaining world trade patterns across countries. Since mid seventies several theoretical developments have appeared in support of the gravity model. Anderson (1979) made the first formal attempt to derive the gravity equation from a model that assumed product differentiation. Bergstrand (1989) also explored the theoretical determination of bilateral trade where gravity equations were associated with simple monopolistic competition models. Helpman and Krugman (1996) used a differentiated product framework with increasing returns to scale to justify the gravity model. Deardorff (1998) has proven that the gravity equation characterises many models and can be justified from standard trade theories. More recently Anderson and van Wincoop (2003, 2004) provide a strong theoretical justification for gravity approach. For the purpose of this paper, adapted gravity approach is used to integrate the Ghazalian and Furtan (2007) econometric approach in the estimation with the specific focus on the R&D intensities and manufacturing exports, the effect of distance and level of economic development, respectively, on manufacturing trade. These applications are linked to similar empirical approaches by Freund and Weinhold (2002, 2004) and Bojnec and Fertő (2009, 2010) on the role of internet on trade. This paper adopted those previous applications to specification for the investigation of the effects of R&D on distance and long-distance into the adapted gravity equation model, and for the impact of the level of economic development on manufacturing exports. Following Estrada et al. (2006) in the empirical analysis the robustness test is also conducted by years and for non-linearity.

More specifically, this paper applies adapted gravity model variables including market size (real GDP) of host i and destination j countries, geographical factors like the distance between capital cities (Distance) and common border (Contiguity), common cultural linkage (Language), and a dummy variable for Regional Free Trade Agreement (RFTA) membership as explanatory variables. First, to test of set H1, the following baseline adapted gravity trade model is specified:

$$\ln X_{ij,t} = \alpha_0 + \alpha_1 \ln \text{GDP}_{i,t} + \alpha_2 \ln \text{GDP}_{j,t} + \alpha_3 \ln \text{GDPCAP}_{i,t} + \alpha_4 \ln \text{GDPCAP}_{j,t} + \alpha_5 \ln \text{Distance}_{ij} + \alpha_6 \text{Contiguity}_{ij} + \alpha_7 \text{Language}_{ij} + \alpha_8 \text{RFTA}_{ij} + u_t \quad (1)$$

where $X_{ij,t}$ is manufacturing export from country i to county j in current year t , GDPCAP is GDP per capita, \ln is natural logarithm, and u_t is a stochastic element.

The trade data used is supplied by the OECD Bilateral Trade Database at the two-digit level of the International Standard Industrial Classification (ISIC) in United States (US) dollars. Data for the manufacturing exports (X_{ij}) are used. The sample contains 18 OECD countries² between 1995 and 2003 resulting in 2,754 observations. GDP is a proxy for the market size, and GDPCAP is a general proxy for the level of economic development as an important demand factor for both exporter and importer countries. The source of data is the World Bank, World Development Indicators (WDI) database. The $Distance_{ij}$ variable measures the geographic distance between the countries' capitals i and j , whereas the other dummies reflect whether i and j share: a land border ($Contiguity_{ij}$), their primary language (Language), and membership in a RFTA. The source of these data is the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII): <http://www.cepii.fr/anglaisgraph/bdd/distances.htm> database.

The literature argues that richer and larger exporters and importers trade more, as do countries linked by regional trade agreements, a land border, or a common language; and landlocked and physically large countries do less trade, while that trade falls with geographic distance (e.g. Leamer and Levinsohn, 1995). Distance can have an influence on technology transfer (Eaton and Kortum, 2002; Kneller, 2005).

Second, to test of set H2, the specific interest is for investigation the role of R&D on manufacturing trade. The previous literature largely provides evidence on how R&D defined variables (R&D expenditures/inputs/innovation-related variables) is expected to directly raise export intensity (e.g. Wakelin, 1998; Montobbio-Rampa, 2005). A successful R&D application in the process of innovation may also provide positive spill-over effects on organization, human resource development, management and marketing skills, which lead to export growth. Thus, an adapted gravity model is employed with R&D expenditure variables:

$$\begin{aligned} \ln X_{ij,t} = & \beta_0 + \beta_1 \ln GDP_{i,t} + \beta_2 \ln GDP_{j,t} + \beta_3 \ln GDPCAP_{i,t} + \beta_4 \ln GDPCAP_{j,t} + \\ & + \beta_5 \ln Distance_{ij} + \beta_6 Contiguity_{ij} + \beta_7 Language_{ij} + \beta_8 RFTA_{ij} + \beta_9 R\&D_{it} + \\ & + \beta_{10} R\&D_{jt} + u_t \end{aligned} \quad (2)$$

The variables of particular interest are the expenditures on R&D. The data for governmental R&D outlays are collected from the OECD STAN R&D dataset. The R&D intensity is measured as the OECD R&D expenditure for total manufacturing (in million constant US\$ in 2000 purchasing power parity – PPP – prices). In the light of previous research, it is expected that the higher the R&D intensity, the higher would be the export activity performance.

² The list of countries included in the data sample: Australia, Belgium, Canada, the Czech Republic, Finland, France, Germany, Ireland, Italy, Japan, South Korea, the Netherlands, Norway, Poland, Spain, Sweden, the United Kingdom, and the United States of America.

The robustness of the results is checked in two steps using different specifications. First, recent research emphasises the existence of a possible non-linear relationship between R&D and exports (Estrada et al., 2006), because the effect of R&D and thus improved technological innovation on trade could vary according to the technological achievement in countries. To check of set H3 for a possible a non-linear relationship between R&D and manufacturing exports, two additional terms are included in the model:

$$\begin{aligned} \ln X_{ij,t} = & \beta_0 + \beta_1 \ln GDP_{i,t} + \beta_2 \ln GDP_{j,t} + \beta_3 \ln GDPCAP_{i,t} + \beta_4 \ln GDPCAP_{j,t} + \\ & + \beta_5 \ln Distance_{ij} + \beta_6 Contiguity_{ij} + \beta_7 Language_{ij} + \beta_8 RFTA_{ij} + \beta_9 R\&D_{it} + \\ & + \beta_{10} R\&D_{jt} + \beta_{11} R\&D_{it} + \beta_{12} R\&D_{jt} + u_t \end{aligned} \quad (3)$$

where the variables R&D2 describe the squared terms of the R&D variable.

Second, the panel regression specifications have been chosen to minimize the possibility of omitted variable bias and to capture some of the impact of the R&D on manufacturing trade. To test of set H4, cross-section estimation is more prone to these problems, as it is impossible to control for country-fixed effects while using country-specific variables. Nevertheless, cross-section estimation eliminates the possibility of co-trending variables over time and thus provides a useful robustness check of the results.

Third, R&D with pertaining innovation may also reduce the transaction costs fostering the exports. Thus it is checked of set H5 whether R&D intensity influences the distance effect between trading partners. Following Freund and Weinhold (2004) model (2) is re-estimated to check the effect of R&D intensity on distance:

$$\begin{aligned} \ln X_{ij,t} = & \beta_0 + \beta_1 \ln GDP_{i,t} + \beta_2 \ln GDP_{j,t} + \beta_3 \ln GDPCAP_{i,t} + \beta_4 \ln GDPCAP_{j,t} + \\ & + \beta_5 \ln Distance_{ij} + \beta_6 Contiguity_{ij} + \beta_7 Language_{ij} + \beta_8 RFTA_{ij} + \beta_9 R\&D_{it} + \\ & + \beta_{10} R\&D_{jt} + \beta_{11} R\&D_{it} * Longdistance_{ij} + \beta_{12} R\&D_{jt} * Longdistance_{ij} + u_t \end{aligned} \quad (4)$$

where $Longdistance_{ij}$ is a dummy variable, which equals one if the distance between countries i and j exceeds the average distance between all countries. The rationale for use of the interaction effect of R&D and $Longdistance$ is that with more R&D intensity it would be possible to overcome the greater distance. If a particular R&D variable has reduced (increased) the effect of distance on manufacturing trade, then the regression coefficient on the interaction $R\&D * Longdistance$ term should be positive (negative).

Fourth, Barrios *et al.* (2003) argue that the effects of R&D do matter more for exports to technologically advanced countries, such as the European Union and other OECD countries where exporters have to improve technology in order to be able to compete on those markets successfully. Thus to test of set H6 the effects of the R&D variables are empirically tested in association with the level of economic development:

$$\begin{aligned} \ln X_{ij,t} = & \beta_0 + \beta_1 \ln GDP_{i,t} + \beta_2 \ln GDP_{j,t} + \beta_3 \ln GDPCAP_{i,t} + \beta_4 \ln GDPCAP_{j,t} + \\ & + \beta_5 \ln Distance_{ij} + \beta_6 Contiguity_{ij} + \beta_7 Language_{ij} + \beta_8 RFTA_{ij} + \beta_9 R\&D_{it} + \\ & + \beta_{10} R\&D_{jt} + \beta_{11} R\&D_{it} * GDPCAP_{it} + \beta_{12} R\&D_{jt} * GDPCAP_{jt} + u_t \end{aligned} \quad (5)$$

The rationale for use of the interaction effect of R&D and GDPCAP is that more economically developed countries with higher GDPCAP invest more in R&D intensity and thus they can increase manufacturing exports through higher-valued product differentiation.

Finally, there are some issues that have to be addressed when estimating such panel models (Ghazalian and Furtan, 2007). First, heteroskedasticity may occur because trade between two smaller countries or between a smaller and larger country is probably more volatile than trade between two larger countries (Frankel, 1997). The panel dataset is also subject to the existence of autocorrelation. Contemporaneous correlation across panels may occur because exporting to one country can take place as an alternative to exporting to another country. Similarly, adjacent exporter(s)/ importer(s)' time specific shocks result in larger correlated error terms of their trade with their partners. To deal with issues of contemporaneous correlation the panel corrected standard error model (PCSE) is applied which controls for heteroskedasticity and the AR(1) type of autocorrelation and contemporaneous correlation across panels (Beck and Katz, 1995, 1996).

4. Empirical results

The presentation of the empirical results is divided into the eight parts. The first one presents summary statistics on R&D expenditure and the second one time-series properties of the variables in the panel data analysis. The remaining parts present the empirical results testing of set hypotheses using regression analysis.

R&D expenditures

The impact of R&D on trade performance may vary by sectors in the economy which are either net users or net producers of R&D-based innovations. Some sectors in the economy might be characterized by high levels of R&D-based innovation, while some other sectors might be characterized by few R&D-based innovations. There might be also differences in production and use of R&D-based innovations by different sectors. Therefore, the starting point of the empirical analysis is presentation the analysis of the R&D expenditures for the analysed countries.

Table 1: The OECD research and development expenditure for total manufacturing
 – in million US\$ in 2000 PPP

Countries	1995	1996	1997	1998	1999	2000	2001	2002	2003	Mean	SDV
Australia	1817	1717	1676	1552	1557	1717	1907	2176	2442	1840	296
Belgium	2331	2472	2658	2670	2882	3146	3586	3282	3222	2917	418
Canada	4048	4173	4751	5441	5764	6915	7573	6545	6364	5731	1233
Czech Republic	624	600	727	803	730	737	797	815	863	744	88
Finland	1235	1477	1729	2019	2290	2722	2845	2938	3042	2255	674
France	15339	15817	15885	16220	17233	17961	19230	20523	20663	17652	2060
Germany	24898	25765	26843	28310	30441	33082	33650	35003	36431	30491	4243
Ireland	517	569	607	626	637	631	620	634	654	610	43
Italy	5490	5724	5622	5276	5546	6068	6301	6298	6105	5825	376
Japan	51517	55609	59913	60874	61677	66584	69468	73434	75263	63816	7986
South Korea	8407	9460	10064	8400	9200	11398	13354	14267	15817	11152	2723
Netherlands	2863	2942	3115	3058	3503	3658	3887	3751	4061	3426	442
Norway	544	579	583	560	594	703	801	781	853	666	119
Poland	539	612	651	773	832	651	653	408	464	620	136
Spain	1891	2138	2204	2678	2756	2934	3026	3618	3843	2787	658
Sweden	4090	4467	4595	4679	5204	6271	7027	6893	6800	5558	1181
United Kingdom	11481	11580	12194	12842	13967	14583	15689	16621	16796	13973	2082
United States	104237	116953	125902	125447	122565	129594	126340	117453	129126	121957	8034

Note: SDV – Standard Deviation

Source: OECD (2006). ANBERD database

Table 1 presents the R&D expenditures for total manufacturing by the analyzed eighteen OECD countries. Except for Poland, the analyzed OECD countries experience increasing R&D expenditures by manufacturing sectors. Particularly rapid increase is seen for Finland and South Korea.

Time-series properties of the variables in the panel

Before estimating the panel regression models, the main model variables are pre-tested for unit root tests. A number of panel unit root tests are available. Considering the well known low power properties of unit root tests, this paper employs a battery of unit root tests: Levin et al. (2002) method (common unit root process), Im et al. (2003) method (assuming individual unit root processes), ADF-Chi square, and PP-Chi square. Table 2 presents the results of four different panel unit root tests (Levin, Lin and Chu; Im, Pesaran and Shin; ADF-Fisher Chi square, PP-Fisher Chi square), with different deterministic specifications (with constant, and with constant and trend). Mixed results were obtained. The most important model variables such as

the bilateral trade flows and R&D expenditures in countries i and j do not have unit roots, i.e. are stationary, with individual effects and individual trend specifications. The panel unit root null hypothesis is also rejected with constant only deterministic specification for Levin, Lin and Chu and PP-Fisher Chi-square tests. Other variables such as GDP and GDPCAP are more ambiguous in terms of unit root in a panel context. It may be concluded that with the individual effects specification both variables of the panel dataset are stationary, while the majority of test results accept the panel unit root null hypothesis.

Table 2: Panel unit root test results

Panel unit root tests of variables	intercept and trend		intercept	
	Statistic	Probability	Statistic	Probability
<i>ln Exports</i>				
Im, Pesaran and Shin W-statistic	-1.72707	0.0421	2.75432	0.9971
ADF-Fisher Chi-square	859.801	0.0000	660.428	0.0856
PP-Fisher Chi-square	850.296	0.0000	672.915	0.0441
Levin, Lin & Chu t	-41.3195	0.0000	-5.79121	0.0000
<i>ln GDP exporter</i>				
Im, Pesaran and Shin W-statistic	1.50362	0.9337	-8.94086	0.0000
ADF-Fisher Chi-square	603.409	0.5900	952.174	0.0000
PP-Fisher Chi-square	315.447	1.0000	805.242	0.0000
Levin, Lin & Chu t	-41.3195	0.0000	-38.6387	0.0000
<i>ln R&D exporter</i>				
Im, Pesaran and Shin W-statistic	-5.44310	0.0000	2.91297	0.9982
ADF-Fisher Chi-square	1079.56	0.0000	595.969	0.6712
PP-Fisher Chi-square	875.020	0.0000	967.296	0.0000
Levin, Lin & Chu t	-55.4886	0.0000	-18.9092	0.0000
<i>ln GDPCAP exporter</i>				
Im, Pesaran and Shin W-statistic	0.21571	0.5854	-4.89430	0.0000
ADF-Fisher Chi-square	750.099	0.0001	850.260	0.0000
PP-Fisher Chi-square	434.234	1.0000	1263.93	0.0000
Levin, Lin & Chu t	-49.2143	0.0000	-32.5830	0.0000

Note: Lag length (1) was selected by Schwarz Bayesian Information Criteria

Source: Authors' calculations

To ensure that both variables are stationary $I(0)$ and not integrated of a higher order, unit root tests are applied on first differences of all variables. Table 3 presents unit root test results for the first differences with constant specification only (it is not likely that first differences are trended). All tests reject the unit root null hypothesis for the first differences. In sum, it may be concluded that panel is likely stationary.

Table 3. Panel unit root test results in first differences

Panel unit root tests in first differences of variables ln exports	intercept	
	Statistic	Probability
Null: Unit root (assumes individual unit root process)		
Im, Pesaran and Shin W-statistic	-16.1776	0.0000
ADF-Fisher Chi-square	1448.31	0.0000
PP-Fisher Chi-square	1587.28	0.0000
Levin, Lin & Chu t	-40.9337	0.0000
<i>ln GDP exporter</i>		
Im, Pesaran and Shin W-statistic	-8.94086	0.0000
ADF-Fisher Chi-square	952.174	0.0000
PP-Fisher Chi-square	805.242	0.0000
Levin, Lin & Chu t	-38.6387	0.0000
<i>ln R&D exporter</i>		
Im, Pesaran and Shin W-statistic	-16.8326	0.0000
ADF-Fisher Chi-square	1393.49	0.0000
PP-Fisher Chi-square	1283.29	0.0000
Levin, Lin & Chu t	-55.9749	0.0000
<i>ln GDPCAP exporter</i>		
Im, Pesaran and Shin W-statistic	-11.5627	0.0000
ADF-Fisher Chi-square	1132.94	0.0000
PP-Fisher Chi-square	935.235	0.0000
Levin, Lin & Chu t	-43.5799	0.0000

Note: Lag length (1) was selected by Schwarz Bayesian Information Criteria.

Source: Authors' calculations

The baseline adapted gravity model estimations

The starting point is to test of set H1 and to present regression results based on the adapted gravity model without R&D variables. The equation (1) in Table 4 shows the baseline adapted gravity model estimations for manufacturing trade. The empirical results largely confirm of set H1. The baseline adapted gravity models indicate that the size of GDP has a positive and statistically significant impact on bilateral manufacturing trade for exporting and importing countries. The size of the economy and its growth over time encourages bilateral manufacturing trade between the OECD countries. The level of development measured by GDPCAP has also a positive and statistically significant impact on bilateral manufacturing trade for exporting and importing OECD countries. As expected, the Distance between the countries' capitals has a negative and statistically significant impact on bilateral manufacturing trade between the OECD countries, indicating the importance of geographical proximity and trade costs in conducting international manufacturing trade business. The regression coefficients of the Contiguity, Language, and RFTA

are positive and statistically significant, confirming the importance of geographical and cultural proximity as well as the importance of the bilateral and multilateral trade liberalisation for increases in bilateral manufacturing trade between the OECD countries.

Table 4: The effect of R&D on manufacturing trade

Dependent variable: ln manufacturing export	(1)	(2)	(3)
ln GDP exporter	0.842 ^{***}	0.351 ^{***}	0.362 ^{***}
ln GDP importer	0.806 ^{***}	0.751 ^{***}	0.775 ^{***}
ln GDPCAP exporter	0.978 ^{***}	0.636 ^{***}	0.658 ^{***}
ln GDPCAP importer	0.659 ^{***}	0.465 ^{***}	0.436 ^{***}
ln Distance	-0.607 ^{***}	-0.676 ^{***}	-0.684 ^{***}
Contiguity dummy	0.745 ^{***}	0.617 ^{***}	0.679 ^{***}
Language dummy	0.204 ^{***}	0.237 ^{***}	0.191 ^{***}
RFTA dummy	0.901 ^{***}	0.786 ^{***}	0.739 ^{***}
ln R&D exporter		0.476 ^{***}	0.759 ^{**}
ln R&D importer		0.067 [*]	0.290 ^{**}
ln R&D2 exporter			-0.017
ln R&D2 importer			-0.014
Constant	-42.216 ^{***}	-26.044 ^{***}	-28.802 ^{***}
N	2754	2754	2754
R ²	0.9937	0.9937	0.9935
Rho	0.753	0.835	0.822

Notes: * p<0.1; ** p<0.05; *** p<0.01. Parameters are estimated by the Prais-Winsten estimator. The common AR(1) parameter is denoted by rho. The z values are computed from standard errors that are corrected for heteroscedasticity and contemporaneous correlation of error terms across panels.

Source: Authors' calculations

The effects of R&D on manufacturing trade

In the process of international trade and export expansion, R&D with innovation is a significant determinant for the development of competitive advantage (Krugman, 1979). In general, a positive relation between a country's export performance and its R&D intensity /creativity/innovation has been confirmed by previous studies (e.g. Greenhalgh, 1990; Verspagen and Wakelin, 1997; DiPietro and Anoruo, 2006).

To test of set H2, in the equation (2) in Table 4 the baseline adapted gravity model specification is extended with the R&D expenditure variables. The signs of the associations and statistical significance of the regression parameters have remained unchanged. Only the negative association for the Distance variable has been strengthened, whereas the absolute size for the other regression coefficient has declined. A significant decline of the regression parameter is seen for the GDP exporter variable, which implies some correlation between the level of R&D expenditures and the level of GDP in exporting OECD countries. The regression coefficients that are pertaining to the R&D expenditure variables are positive and statistically significant at the higher degree for exporting than for importing countries. Therefore, it is confirmed of set H2 on the importance of R&D for competitiveness in manufacturing exports, but to a lesser degree also for the manufacturing import specializations.

Robustness test for non-linear relationship

The robustness test of set H3 for non-linear relationship is included by the square of the R&D variable for exporter and importer countries. The regression (3) in Table 4 reinforces the findings that are consistent with the previous baseline adapted gravity regression, whereas the regression parameters for the square of the R&D exporter and importer countries' variables, respectively, are of a negative sign, but statistically not significant. This implies that it has not been confirmed of set H3 on a non-linear relationship for the R&D variables.

Sensitivity check: cross-section estimations for the baseline model

It is checked of set H4 for cross-section estimations stability for the baseline model by the analyzed years. The aim is to investigate the patterns in development of the regression coefficients over time.

As can be seen from Table 5, the regression coefficients that pertain to GDP exporter and importer countries variables, respectively, tend to increase, and after they get stabilized, they become statistically significant. These patterns confirm the importance of the economic size and economic growth of the exporting and importing OECD economies for manufacturing trade. There are diverging patterns in the importance that is seen for the GDPCAP for exporter OECD countries, which the regression parameters tend to decrease over time and vice versa for the GDPCAP for importer OECD countries, which the regression parameters tend to increase and after that stabilize. The importance of the Distance has increased over time. The importance of the Contiguity dummy and the RTFA dummy, respectively, on manufacturing exports between the OECD countries tends to decline, which is consistent with the ongoing process of manufacturing trade liberalization and advances that are arising from information and communication technologies (Bojnec and Fertő, 2009).

Table 5: Cross-section estimations for the baseline model

Dependent variable: ln manufacturing export	1995	1996	1997	1998	1999	2000	2001	2002	2003
ln GDP exporter	0.062	0.074	0.100	0.101	0.145**	0.203***	0.318***	0.330***	0.306***
ln GDP importer	0.576***	0.563***	0.673***	0.834***	0.796***	0.794***	0.808***	0.802***	0.778***
ln GDPCAP exporter	0.755***	0.603***	0.573***	0.624***	0.668***	0.526***	0.583***	0.412**	0.290
ln GDPCAP importer	0.671***	0.534***	0.642***	0.943***	0.887***	0.815***	0.842***	0.867***	0.830***
ln Distance	-0.628***	-0.676***	-0.706***	-0.735***	-0.731***	-0.763***	-0.797***	-0.813***	-0.834***
Contiguity dummy	0.713***	0.618***	0.550***	0.528***	0.530***	0.487***	0.478***	0.483***	0.442***
Language dummy	0.277**	0.317***	0.324***	0.354***	0.326**	0.329**	0.358***	0.319**	0.342**
RFTA dummy	0.768***	0.639***	0.613***	0.606***	0.565***	0.481***	0.459***	0.408***	0.421***
ln R&D exporter	0.678***	0.635***	0.637***	0.631***	0.595***	0.557***	0.451***	0.427***	0.445***
ln R&D importer	0.209**	0.210***	0.116*	-0.032	0.017	0.057	0.048	0.054	0.064
Constant	-19.918***	-16.187***	-19.718***	-26.171***	-26.398***	-25.561***	-28.773***	-27.118***	-24.152***
R ²	0.8428	0.8683	0.8705	0.8585	0.8616	0.8584	0.8595	0.8514	0.8449
N	306	306	306	306	306	306	306	306	306

Notes: * p<0.1; ** p<0.05; *** p<0.01

Source: Authors' calculations

The importance of the Language dummy tends to increase slightly and after that stabilize. The particular interest is in investigation of set H4 on the R&D variables: the importance of the R&D variables for manufacturing exporters tends to decline slightly, but has remained statistically significant, while the importance of the R&D variables for manufacturing importers has become insignificant. These findings only partly support of set H4 as they reinforce the importance of the R&D expenditures for exports to compete and sustain competitiveness in the exporting of manufacturing products, while it is becoming less important for manufacturing import specialization.

The effects of R&D on distance

This model specification assumes, and empirical estimates in regression (4) in Table 6 confirm, that the regression coefficient pertaining to the Distance is negative. However, the regression coefficients have changed or decreased only slightly when the R&D*Longdistance variables to test of set H5 are included in the models. The regression coefficients on R&D variables remain positive and statistically significant. These results indicate that R&D intensity has strong impacts on the distance and manufacturing trade, particularly for encouraging manufacturing trade by exporting countries. This is further confirmed by the regression coefficients for the interaction R&D variables. There is a positive and statistically significant association for the exporting countries, and a negative and statistically significant association for the importing countries. These results consistently with set of H5 imply that the R&D

variable has reduced (increased) the effect of distance on bilateral manufacturing trade for exporting (importing) OECD countries. The OECD countries, which have invested more in R&D have also expanded and strengthened their manufacturing exports on longer distances, while the manufacturing import specialization by importing OECD countries has become weaker.

Table 6: The effect of R&D on distance

Dependent variable: ln manufacturing export	(4)
ln GDP exporter	0.327***
ln GDP importer	0.774***
ln GDPCAP exporter	0.693***
ln GDPCAP importer	0.408**
ln Distance	-0.654***
Contiguity dummy	0.698***
Language dummy	0.237***
RFTA dummy	0.700***
ln R&D exporter	0.454***
ln R&D importer	0.090***
ln R&D exporter * ln Longdistance	0.061***
ln R&D importer * ln Longdistance	-0.068**
Constant	-26.155***
N	2754
R ²	0.9936
Rho	0.826

Notes: * p<0.1; ** p<0.05; *** p<0.01. Parameters are estimated by the Prais-Winsten estimator. The common AR(1) parameter is denoted by rho. The z values are computed from standard errors that are corrected for heteroscedasticity and contemporaneous correlation of error terms across panels.

Source: Authors' calculations

The effects of the level of economic development

The effect of the level of economic development is included in the adapted gravity regression model to test set of H6 by the interaction effect of the R&D variables and GDPCAP variables, which is presented in regression (5) in Table 7. The negative absolute size of the Distance variable on bilateral manufacturing trade has increased, and particularly substantially has increased the impact of the R&D variable on manufacturing trade. This clearly confirms the important and statistically

significant role of the R&D variables for increases of bilateral manufacturing trade in exporting OECD countries, and for import specialization by reduction in manufacturing trade in importing OECD countries. However, unlike to set of H6, the regression coefficients that are pertaining to the interaction R&D*GDPCAP variables are negative and statistically significant for exporting countries and positive and statistically significant for importing countries, indicating the increasing importance of developing OECD countries in competitive manufacturing exports and successful import specialization in bilateral trade between the OECD countries. Among ‘developing OECD countries’ are included the Czech Republic, Finland, Ireland, South Korea, Poland, and Spain. These countries experienced also different successes in R&D intensive manufacturing trade structures.

Table 7: The effect of R&D and economic development on manufacturing trade

Dependent variable: ln manufacturing export	(5)
ln GDP exporter	0.420 ^{***}
ln GDP importer	0.717 ^{***}
ln GDPCAP exporter	3.666 ^{***}
ln GDPCAP importer	0.481 ^{***}
ln Distance	-0.745 ^{***}
Contiguity dummy	0.532 ^{***}
Language dummy	0.316 ^{***}
RFTA dummy	0.702 ^{***}
ln R&D exporter	5.751 ^{***}
ln R&D importer	-0.890 [*]
ln R&D exporter * ln GDPCAP exporter	-0.528 ^{***}
ln R&D importer * ln GDPCAP importer	0.102 ^{**}
Constant	-57.257 ^{***}
N	2754
R ²	0.9942
Rho	0.845

Notes: * p<0.1; ** p<0.05; *** p<0.01. Parameters are estimated by the Prais-Winsten estimator. The common AR(1) parameter is denoted by rho. The z values are computed from standard errors that are corrected for heteroscedasticity and contemporaneous correlation of error terms across panels.

Source: Authors' calculations

5. Results and discussion

Liberalization and globalization of international manufacturing trade has brought pressure on manufacturing industries to be competitive both in exports and to succeed in their domestic markets. Additional pressures for restructuring have also been created by economic recession (e.g. Sever, 2009). The paper focuses on manufacturing trade and export performances between the eighteen OECD countries.

GDP as a measure for the economy size and GDPCAP as a measure for the level of economic development in exporter and importer countries, respectively, positively and statistically significantly affect manufacturing trade. While richer and larger exporters and importers may trade more, generally larger countries have a lower level of trade openness than small countries, and thus degree of trade openness differs from the quantity of goods traded. The distance between the capital cities negatively affects manufacturing trade, implying that trade costs do matter for manufacturing trade, but can be mitigated by R&D intensity for transportation and communication costs. As expected, a common border, cultural linkage and common language, and regional free trade agreement membership positively affect manufacturing trade. There are possible barriers and policy restrictions to international manufacturing trade due to the economic and strategic importance of these products concerning the competitiveness of national industries in the continuous increase in global competition. In addition to the importance of geographical proximity, trade barriers and policy restrictions cause trade costs in conducting international manufacturing trade businesses, but raising the importance of the bilateral and multilateral trade liberalisation for increases in international manufacturing trade between the countries. Specific attention has been given to the association between manufacturing export and R&D expenditure. The R&D variable for exporting countries increases manufacturing exports. The OECD countries, which invest more in R&D, have higher manufacturing export, but this varies for manufacturing imports.

Possible non-linear effects of R&D expenditure on manufacturing trade flows in exporting and importing countries, respectively by including the square of the R&D expenditure variable, have not been confirmed. This does not confirm manufacturing export variation according to the R&D and improved technological achievement in countries.

With a sensitivity test with the cross-section estimates by years it has been confirmed that manufacturing export is positively associated with R&D expenditure, but not increasingly over time in exporting countries. In addition, it has not been confirmed that manufacturing export is positively associated with R&D expenditure for importing countries.

The emphasis has been on test whether R&D expenditure may help overcome the distance barriers among the countries. The evidence has been found in favour

of the effect that the OECD countries, which have invested more in R&D have also expanded and strengthened their manufacturing exports on longer distances and improved manufacturing import specialization. Therefore, the greater R&D expenditure mitigates the importance of the distance for exporters by expanding their export opportunities, and reduces the distance for importers' countries. This is consistent with Martínez-Zarzoso and Márquez-Ramos (2005) that the impact of distance on technology transfer (geographic factor) does still exist, but its relevance has been weekend during the last decade as confirmed by China's export to Germany vis-à-vis the neighbouring countries.

These findings have important policy implications to consider concerning R&D and pertaining innovation activity on the importance of the R&D as a factor of export growth and for reduction of transaction costs, and thus for fostering manufacturing trade between the OECD as well as other countries. Manufacturing international supply-chain management focuses on export competitiveness strategies and innovative developments to be and sustain competitive in regional and global markets. These performances are influenced by macro-economic and economic development variables, R&D and innovation, cultural, distance, and similar explanation factors for merchandise export performances by delivering quality merchandise at a low price and ability to prosper innovatively and sustain internationally competitive.

In addition, the role of the interaction effect between level of economic development measured by GDPCAP and R&D expenditures on manufacturing export has been rejected. These econometric results provide an important policy finding that the developing OECD countries with the R&D expenditures have successfully catching-up in manufacturing export and import specialization as a lesson learnt for some other developing countries. This finding gives support for the importance of differences in R&D intensity and pertained innovation in influencing international manufacturing competitiveness, which is of importance to domestic government science, technology, and research and innovation policy with a positive impact on manufacturing trade performance. The R&D expenditures in the economically most developed OECD countries have not been sufficient to sustain a competitive position in manufacturing exports as well as in manufacturing import specialization, which has resulted in an increase of their manufacturing imports from developing OECD countries. The results imply structural changes that are caused by the R&D expenditure intensity with pertaining innovation in some developing OECD countries that improve their export competitiveness in more technological advanced manufacturing products, which are exported worldwide, particularly to the most developed OECD countries. Due to this, the results that are pertaining to the R&D variables and their interaction effects, particularly with the level of economic development (GDPCAP), in successful import specialization are mixed, but the R&D expenditures with successful innovations make domestic manufacturing more competitive particularly in technologically advanced some developing OECD countries. As a result, some developing OECD countries, for example South Korea, have successfully entered into the international

manufacturing trade between the OECD countries, but only partly valid for example for Ireland and the Czech Republic due to the strong linkage between imported and exported R&D intensive manufactured products with strong integration into the global manufacturing network of transnational companies (TNCs) (Wei et. al, 2007). Unlike some previous micro-level studies (e.g. Özçelik and Taymaz, 2004; Roper and Love, 2002) it has not been investigated possible role of subsidiaries of TNCs in R&D intensity, global vertical production and manufacturing exports, which would require survey data.

A justification of the choice of different samples of countries and time periods might be also useful to explain the changing and current global trading environment. The global R&D related manufacturing trade has been reshaped considerably during the last decade as a consequence of the emerging markets' trade, particularly China, India and some other countries mostly as a result of the activities of TNCs. In the current global environment they play an important role in R&D intensity, bilateral country-to-country trade and trade structures (e.g. Ambos 2005, Figueiredo, 2008). Therefore, an issue for future research is investigation of possible roles of TNCs play in R&D intensity and international merchandise trade by separation of manufacturing exports on the domestic and TNC contents. In addition, different specifications of variables and their interaction effects can be used.

Yet, opportunities for further research are on the model specification of the key indicators and specific measures of R&D values such as measurement of innovation, intensity and creativity. In addition to the use of the interaction effects in the adapted gravity equation trade model, there are also opportunities to use the ratio of variables such as the ratio of R&D expenditures on manufacturing value added, then to use time lags for R&D expenditures, the intensity of international patents, and the growth rates of exports vs. export levels. Finally, among unaddressed issues and thus issues for future research is the role of outsourcing as one of the means by which the boundary of the firm can be adjusted. Among various other means are also the role of the conglomeration, horizontal and vertical integration, and the role of joint ventures and foreign direct investments and international corporations in the international manufacturing trade in different cultures, traditions and value systems and their research, business, managerial and policy implications.

6. Conclusions

The paper provides conceptual, methodological, empirical, and policy insights and innovative approaches into the effects of R&D on the bilateral manufactured goods trade between OECD countries in the panel data analysis. It provides a systematic study on the manufacturing trade and its determinants. The six hypotheses have been tested. The set of H1 has been confirmed. The econometric results that are pertaining to the

adapted gravity equation variables are largely consistent with theoretical expectations. The set of H2 has been confirmed that manufacturing export is positively associated with R&D expenditure in exporting countries, while the regression coefficients for the R&D variables for importing countries are mixed. The results have not confirmed the set of H3 for non-linear effects of R&D expenditure on manufacturing trade neither for exporting nor for importing OECD countries. Only partly has the set of H4 been confirmed that manufacturing export is positively associated with R&D expenditure over time in exporting countries, but not in importing countries. The set of H5 has been confirmed that manufacturing export is positively associated with long distance when R&D mitigates the effect of long distance on manufacturing trade in exporting and importing countries, respectively. Finally, the set of H6 it has not been confirmed that manufacturing export is positively associated with joint effect of level of GDPCAP and R&D expenditure in exporting countries.

The contributions of the paper's results to the economic science and literature are both empirical and policy nature. The paper provides new empirical evidence on the relationship between R&D expenditure intensity and manufacturing trade between OECD countries using a large panel data sample. The results show a positive relationship between R&D intensity and manufacturing exports.

The empirical novelty in this paper is the adapted gravity model with tests for the interaction effects between R&D expenditure and long-distance on manufacturing trade on one hand, and between R&D expenditure and GDPCAP on manufacturing trade on the other.

Among limitations to be found during research, this is how to specify the adapted gravity model and to compile a proper variable to measure the impact of R&D on manufacturing trade. The justification of the validity of the adapted gravity model and the use R&D (and specific measures as R&D values) variables in the model in terms of concepts and definition for measurements of innovation, intensity, and creativity, which may affect bilateral trade in manufacturing goods and the strategic decisions for R&D efforts.

Among implications for research, in addition to the panel data analysis, we have conducted a cross-section sensitivity test and a test for a non-linear relationship by the square of the R&D variable for exporter and importer countries, respectively, but it has not been confirmed a non-linear relationship for the R&D variables. Among directions and opportunities for the future research are to apply an adapted gravity trade model to other products and services, different other groups of countries and thus to investigate other possible comparisons. One of the issues for the future research is to investigate the level of trade volatility by the country size (between small countries or between small and large countries).

Important are the institutional implications of the investigation and research results for the system and recommendations to economic policy implementation and

decision makers for implementations of manufacturing trade. Export performance is particularly linked to the R&D expenditures as a way for innovation approaches and attitudes to advanced manufacturing technology and improvement methods in pursuit of competitive advantage and sustain competitive. These findings provide the system and economic policy implementation implications for R&D and manufacturing international supply-chain management with practical implications for managers and policy makers for a better understanding over the issues that are affecting R&D and international manufacturing trade with relevant insight on current challenges.

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Utjecaj istraživanja i razvoja na trgovinu proizvodima prerađivačke industrije¹

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Sažetak

Osnovni cilj ovoga rada je istražiti utjecaj istraživanja i razvoja na trgovinu proizvoda prerađivačke industrije. Testira se šest hipoteza. Fokus je na mogućim nelinearnim učincima istraživanja i razvoja na trgovinske tijekomove te pomažu li istraživanje i razvoj prevladati udaljenosti i ulogu razine gospodarskog razvoja na trgovinu proizvodnje. Panel test jediničnih korijena i panel ekonometrijske metode su primijenjene na prilagođeni gravitacijski trgovački model pomoću panel podataka Organizacije za ekonomsku suradnju i razvoj (OECD) u vremenskom razdoblju od 1995.-2003. godine. Rezultati istraživanja pokazuju da su istraživanje i razvoj pozitivno povezani s trgovinom proizvodnje za zemlje izvoznice, dok su rezultati mješoviti za zemlje uvoznice. Rezultati odbijaju nelinearnu vezu između istraživanja i razvoja i izvoza proizvodnje. Procjene nagovještavaju da istraživanje i razvoj mogu doprinijeti prevladavanju učinaka udaljenosti izvoza proizvodnje i mogu ojačati izvoznu specijalizaciju. Istraživanje i razvoj se vidi kao način poticanja izvoza proizvoda iz zemalja u razvoju u razvijene zemlje članice OECD-a.

Ključne riječi: trgovina proizvoda prerađivačke industrije, istraživanje i razvoj, udaljenost, razina gospodarskog razvoja, zemlje članice OECD-a, prilagođena gravitacijska jednadžba, panel analiza podataka

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