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Technological Innovation in New European Union Markets

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Contents

List of Tables

Abstract

We analyze the role of innovation in the technological development of four new EU members: the Czech Republic, Hungary, Poland and Slovakia. For that purpose, we use a novel approach by modeling the empirical relationship between intra-industrial bilateral trade flows, which proxy the level of technological progress, and innovation expenditures within the context of a gravity model with a set of appropriate instrumental variables to account for the potential endogeneity of innovation to trade. We show that innovation efforts in high-tech industries exhibit a strong effect on the technological progress of the region and they are closely linked to foreign direct investment and multinationals. As foreign-owned subsidiaries become a part of the innovation systems and industrial structure of the host country they promote overall technological growth in the region.

JEL-Classification: C51, F14, F21, O31

Keywords: foreign direct investment, innovation, imitation, international trade, European Union

1 Introduction

When designing regional and national policies early in the 1990s, Central European countries recognized western-style market strategies and techniques as important channels for promoting economic transformation and growth (Lansbury et al. 1996). Early trade liberalization helped these emerging economies to be successfully involved in import-led growth strategies (Frensch, 2010). Further, wide-ranging policies on economic reforms along with the privatization of state-owned enterprises helped to establish private companies and bring foreign competition, capital and advanced corporate-governance practices to the region (Brada and Tomšík, 2009; Estrin et al. 2009; Lefilleur and Maurel, 2010; Moudatsou, 2003). These policies promoted gradual economic growth and determined a basis for innovative behavior in local firms and industries (Welfens, 1999).

With accession to the European Union (EU) in 2004, the policy priorities in new EU members have been increasingly devoted to research and development (R&D) and innovation as the key drivers of productivity growth.[1] This raises the important question of whether and how innovation relates to overall progress and competitiveness in the region. The purpose of this paper is to analyze the role of innovation in the technological development in four new EU members: the Czech Republic, Hungary, Poland and Slovakia. In order to distinguish innovation, we identify the dominant orientation of innovative efforts at the industry level, using R&D expenditures in specific industries as a measure of innovative efforts. Following Baysinger and Hoskisson (1989), Griliches (1998) and Hagedoorn and Cloodt (2003), we expect that particularly in high-tech industries, the impact of innovative (or R&D) efforts on the technological and innovative performance of firms is strong.

When defining the innovative performance of firms in its broadest sense we follow Ernst (2001) and Freeman and Soete (1997). That is, innovative performance refers to all innovation stages, including the birth of a new idea resulting from R&D activities, the introduction of new inventions (patenting), and the marketing of new products

[1] The EU Lisbon strategy of 2005 stresses that “knowledge transfer via researcher mobility, foreign direct investments (FDI) and imported technology is of particular importance for lagging countries and regions” http://ue.eu.int/ueDocs/cms_Data/docs/pressData/en/ec/84335.pdf).

(Ernst 2001). Hence, our approach focuses on specific industries only, often referred to as leading-edge and high-tech Schumpeterian manufacturing sectors. We assume that innovative efforts undertaken by companies in these industries are a very important part of their technological performance in generating new ideas, a large part of which eventually leads to new patents and products. As demonstrated in Table 1, the share of firms generating and introducing new processes and products (new to the market and new to the firm) is larger in high-tech industries than in traditional manufacturing sectors.

Table 1 The distribution of "Innovators" (b) versus "Imitators" (a) (shown as % proportions)

		New EU members	Old EU members	Total
2006	*Enterprises that have new or significantly improved products that are only new to the firm*			
	Total manufacturing, including:	100.00	100.00	100.00
	a) traditional manufacturing	31.96	27.59	28.22
	b) science-based sectors	68.04	72.41	71.78
	Turnover of new or significantly improved products that are only new to the firm			
	Total manufacturing, including:	100.00	100.00	100.00
	a) traditional manufacturing	13.99	10.07	10.40
	b) science-based sectors	86.01	89.93	89.60
	Enterprises that have new or significantly improved products that are new to the market			
	Total manufacturing, including:	100.00	100.00	100.00
	a) traditional manufacturing	28.90	19.65	21.00
	b) science-based sectors	71.10	80.35	79.00
	Turnover of new or significantly improved products that are new to the market			
	Total manufacturing, including:	100.00	100.00	100.00
	a) traditional manufacturing	12.32	7.44	7.92
	b) science-based sectors	87.68	92.56	92.08

Source: Eurostat (2006), Community Innovation Surveys

Innovation activities were investigated in many instances (e.g. Bottazzi and Peri, 2003; Jaffe and Trajtenberg, 2002). Theoretical studies focusing on technology diffusion and international technology transfer (e.g. Jones and Williams, 2000; Perez-Sebastian, 2007) emphasize the importance of imitation at the earlier stages of economic convergence, while innovation dominates at later stages. By learning foreign ideas and techniques, less-developed countries promote technological change and catch up with developed countries. This becomes evident in a globalized world economy with rapid integration and an increasing number of converging clubs such as the EU (Grossman and Helpman, 1991). Technological advancements have been studied from the national innovation system approach that accentuates the non-linear flows of technology and information among people, enterprises and institutions as being instrumental to the innovative process (Borrás, 2004). In this framework innovation and technology development are the result of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutions. The four basic knowledge flows between these institutions in a national innovation system are: 1) interactions among enterprises; 2) interactions among enterprises, universities and public research laboratories; 3) diffusion of knowledge and technology to enterprises; and 4) the movement of personnel (OECD, 1997; p. 7). The national innovation system approach closely links industrial and innovation policies to foreign direct investment (FDI). Costa and Filippov (2008; p. 388) argue that “once established in a host economy, foreign-owned subsidiaries become a part of its innovation systems and industrial structure. Therefore, the evolution and development of these firms are expected to benefit their host economies.”

The research of the innovation activities in Central European countries is far from complete. First, learning about innovation itself is relatively new in these countries where free markets have been established as part of the transformation process. Second, an adequate data set on innovation at a reasonable level of disaggregation and quality is still not available for many of these countries. Consequently, the lack of data causes difficulties in analyzing the issue properly. Finally, and on more general level, common innovation measures based on either R&D or patents are criticized for the unrealistic assumption of the perfectly rational behavior of firms for analyzing innovation processes.

We contribute to the literature by analyzing innovation in the region that recently underwent an unprecedented economic transformation. We use a novel approach in modeling the empirical relationship between intra-industrial bilateral trade flows, which proxy the level of technological progress, and innovation expenditures within the context of a gravity model. A distinctive contribution of this study is the evidence of the innovative efforts of firms in high-tech industries and their role in promoting overall technological growth in the region. The role of innovation in technological progress is analyzed with the gravity model, which is based on the assumption that technology diffusion mirrors the geographical pattern of trade (Eaton and Kortum, 2002; Grossman and Helpman, 1991; Rivera-Batiz and Romer, 1991).

In the gravity model, intra-industrial bilateral trade flows are taken as an approximate measure of technological progress. The basic intuition behind this view is that the larger the volume of intra-industrial trade between two countries, the higher the probability that innovators in the country with less technological knowledge converges to the country with more technological knowledge (Grupp, 1998). The mechanisms linking trade and industrial restructuring in the Central and Eastern European countries through learning and industrial upgrading were covered in Hotopp et al. (2005). The authors argued that trade-based learning mechanisms have strong effects on differences in industrial upgrading between Central and Eastern European economies.

Differentiation in industrial trade patterns with a clear distinction between the trade patterns of advanced OECD countries and less advanced regions in terms of the skill intensity of export industries is shown in Worz (2005). Our model is based on the assumption that technology diffusion mimics the geographical pattern of the intra-industrial trade that gives rise to trade between two countries within similar commodity markets (Grupp, 1998). The choice of intra-industrial bilateral flows in our study is justified by the fact that they give rise to trade within similar commodity markets between the countries as stressed already in Greenaway and Milner (1986) and Grubel and Lloyd (1975).

The potential endogeneity of innovation with respect to trade in the dynamic panels is treated with instruments obtained from the Community Innovation Survey (CIS).[2] The data used in this study, consequently, cover the innovation indicators for two groups of countries: four new, 15 old EU members and Iceland for the period from 1995 to 2006.[3] The sources of the data are the Main Science and Technology Indicators (MSTI) of the Organization for Economic Cooperation and Development (OECD) supplemented by the United Nations Industrial Development Organization (UNIDO) and Eurostat databases.

[2] The CIS is a survey on innovation activity in enterprises covering EU Member States, EU Candidate Countries, Iceland and Norway.

[3] The group of old EU members includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, the Netherlands, Portugal, Spain, Sweden, and the UK.

2 Theoretical and empirical background

Innovation is a very important mode of technological development and the nature, characteristics, and evolution of innovation over time are frequently discussed in the economic literature (Barro and Sala-i-Martin, 1997; Jones and Williams, 2000). In simple aggregate endogenous growth models (Barro and Sala-i-Martin, 1997), innovation and imitation cannot coexist within a single country. Many researchers argued with these findings, exploring reasons and factors for R&D over- and under-investment as well as conditions for the optimal allocation of innovation and imitation coexisting within a single country (Jones and Williams, 2000; Perez-Sebastian, 2007; Segerstrom, 2000). According to Perez-Sebastian (2007), for example, the policy intensity of innovation increases, as initially poor countries develop and integrate with more advanced ones. As a consequence, the early stages of convergence are characterized by low innovation intensity, while in later stages it dominates.

New EU members constitute the group of countries where the above-mentioned processes are at the very heart of their transformation and integration development. In particular, in the early 1990's the countries embarked on a transformation journey and managed to replace on large scale outdated equipment and machinery in their factories, improve their infrastructure, and adopt new technologies. They have also progressed in their integration process and economic convergence towards the EU, including their convergence in terms of nominal as well as fiscal indicators (Kočenda et al., 2006, 2008). Quite importantly, these countries managed to attract considerable FDI inflows and successfully tapped into the existing FDI pool. For these reasons the gravity model in relation to innovation seems an appropriate tool to use.

Different aspects of structural transformation and the competitiveness of countries are covered in Fagerberg et al. (2007) and Landesmann and Stehrer (2007), using a growth model based on Schumpeterian logic. The authors emphasize that technology, capacity and demand have greater importance for growth and development than price competitiveness. Indicators depicting innovation progress include total factor productivity variables, production indexes, technology-dependent employment and foreign trade indices. According to Grupp (1998), any indicator that is meant to capture the impact of innovation on technological development should identify international markets, in which the domestic economy is competitive. In this respect, foreign trade variables are traditionally considered the best progress indicators since they are closely related to the product specialization of countries as well as import-substitution sectors within countries. Besides, they can allow a structural comparison between national economies with different sizes and geographic locations. For these reasons, empirical studies investigating cross-country variations in the relationship between innovation and technological progress use foreign trade indicators (e.g. Bleaney and Wakelin, 2002; Buxton et al., 1991; Fagerberg, 1988).

The competitiveness of tradable goods can also be achieved through low prices rather than high quality. Undervalued currency and exchange rate regimes that have been relaxed only around the turn of the century enabled this development in price competitiveness in several Central European countries during the early transformation period (Kočenda and Valachy, 2006). With trade liberalization during the 1990s, however, many Central European countries began to experience an increase in prices as well as quality (Morada-Gonzalez and Viaene, 2005). For this reason, the present study employs deflated data, using the deflator at 2000 prices, when nominal exchange rates and domestic output stabilized in many of these countries. In light of the above-mentioned studies, this paper focuses on the potential effect of innovation on bilateral trade flows between country pairs drawn from a sample of 20 EU countries: four new and 16 old EU members.

With respect to the measure of innovation, this study relies on a broad concept of innovation. This concept assumes that innovation is a chain process, ranging from the birth of a new idea—generally measured by R&D efforts—to the introduction of a new invention through patenting and the final announcement of new products and processes (Ernst, 2001). Innovation in a narrow sense refers to the result of firms when they first market new inventions. This enables followers to imitate or adopt new inventions. According to Grupp (1998) and Pianta (2005), the distinction between innovation and imitation at this level can be made in two ways. First, it can be made through examining the evolution of technologies by their development stages. Second, it can be made through the identification of innovating firms and industries. Both ways require conducting detailed surveys at the firm level, because the usual innovation measures (i.e. R&D and patent indicators) do not clearly distinguish innovation. The main reason for this is that product and process innovations contained in the existing surveys (e.g. firm-level CIS surveys) are not necessarily new to the market and firms are not necessarily the first ones to have introduced these inventions (Eurostat, 2004). Therefore, distinguishing innovation from imitation on the basis of the existing firm-level CIS surveys and the MSTI data set is difficult. Having in mind these complexities, the innovation measure chosen for this paper is based on industry differences.

Industry differences determine why certain innovation indicators are more appropriate (Brouwer and Kleinknecht, 1999; Devinney, 1993; Ernst, 2001; Griliches, 1998). The more an industry is characterized by high R&D, high patenting intensity and a high ratio of new product introduction, the better the quality of the corresponding indicator. It is well known that particularly in high-tech industries, R&D expenditures, patents and new products play an important role in indicating the innovative performance of companies (OECD, 1997). These industries are referred to as high-tech Schumpeterian industries and very often include the aerospace, electronic, office machinery and computer, pharmaceutical and instrument-producing branches. As stressed by Baysinger and Hoskisson (1989), Griliches (1998), Grupp and Maital (2000) and Hagedoorn and Cloodt (2003), the impact of innovative efforts on the technological and innovative performance of companies in these industries is especially strong. Hence, following these studies, we distinguish innovation by assuming that R&D expenditures in high-tech and science-based industries represent the dominant orientation of innovative efforts in generating new ideas, the largest part of which leads to new inventions.

The role of innovative efforts and imitation is analyzed further with the gravity model. In its simplest form, the gravity model of bilateral trade introduced by Linneman (1966) relates trade between country i and country j to the proportion of the product of both countries' GDP (Y_i by Y_j) and the distance between them (D_{ij}) as a proxy for transaction and transport costs. A more detailed theoretical and empirical explanation for bilateral trade between countries is reflected in new trade theories (e.g. Deardorff, 1998;

Helpman, 1981; Krugman, 1979). These studies are based on an assumption of monopolistic competition and economies of scale and link empirical facts (e.g. trade between similar countries) with a theoretical foundation of international trade. In particular, in the presence of economies of scale, production of each type of product is located in one country. The larger the country in terms of GDP, the wider the variety of goods supplied. Thus, product differentiation causes trade between similar countries in a way that the more similar two countries are, the larger the volume of their bilateral trade. Consequently, the volume of trade depends largely on the size of a country in terms of GDP. The standard gravity model predicts that the trade flow between two countries is positively related to the product of their outputs and negatively related to the distance between them.

Evenett and Keller (2002) evaluate gravity equations within the framework of perfect and imperfect specialization production models. According to these authors, trade among the industrialized countries can be partially captured by a model that combines the exchange of perfectly specialized, differentiated and homogeneous goods. Trade between less-developed and industrialized countries can be explained by imperfect specialization models. Namely, Evenett and Keller (2002) consider first an increasing-return-to-scale (IRS) model with two countries (*i*, *j*) and two goods (*x*,*z*) of differentiated varieties. Since the IRS model leads to the perfect specialization of production for each variety, the flow of trade can be presented in a very simple way as the following equation:

$$M^{ij} = \frac{Y^i Y^j}{Y^w}, \qquad (1)$$

where M^{ij} is country *i*'s imports from *j*, Y^i and Y^j are the GDPs of the two countries and Y^w denotes the GDP of the world. Therefore, imports are strictly proportional to GDP.

The gravity equation with the imperfect specialization of production is a more general version of equation (1) and incorporates a broader set of assumptions. These are: two countries (*i*,*j*) with capital (*k*) and labor (*l*) and two sectors (*x*,*z*). One sector (*z*) produces a homogeneous good under constant returns to scale, while the second sector (*x*) produces a differentiated good under increasing returns to scale (Helpman, 1981).

The homogeneous good (z) is more labor-intensive in production and country (i) is capital abundant. In this setup, the gravity equation is as follows:

$$M^{ij} = (1-\gamma^{i})\frac{Y^{i}Y^{j}}{Y^{w}}, \qquad (2)$$

where γ^{j} is the share of good z in country i's GDP, presented in equation (3),

$$\gamma^{i} = \frac{z^{i}}{(p_{x}x^{i} + z^{i})}, \qquad (3)$$

where p_x is the relative price of good x.

Country i exports only capital-intensive goods x and its share in GDP is equal to $(1-\gamma^{i})$ so that the production value on which country j draws for its imports is $(1-\gamma^{i})Y^{i}$. According to the assumption of homothetic preferences, country j buys good x from abroad according to its share in world GDP, which is equal to Y^{j}/Y^{w}. Thus, for any level of $\gamma^{i} > 0$, the level of bilateral imports is lower than in the case where both goods are differentiated. The higher the volume of trade, the lower the share of homogeneous goods in GDP. Imports are less than proportional to the product (z) and the extent of the shortfall depends on the size of the differentiated goods sector (x) in GDP. Combining this logic with the above-mentioned results of Grupp (1998), which suggest that technology diffusion mimics the geographical pattern of the intra-industrial trade, we assume that an increase in the trade volumes of similar commodities between two countries leads to a high probability that innovators at one end reach the technology knowledge at the other end.

3 Empirical specification of the gravity model

The main question of interest in this paper is how innovation affects bilateral trade flows at the industry level. Since most new EU countries experienced rapid growth, one can assume that innovation activity has been increasing. This is because firms accelerate the introduction of new export products in order to remain competitive with both domestic and foreign competitors. We take into account the fact that certain types of innovation may require a longer time to affect firm performance. Therefore, both contemporaneous and lagged time frames are considered in this study, covering the years 1996, 2000, 2004 and 2006.

We formulate a gravity model for two different dependent variables as follows:

$$log(T^{high\text{-}tech}_{ijt})=\alpha_0+\alpha_1 log(Y_{it}/Y_{jt})+\alpha_2 log(E_{it}/E_{jt})+\alpha_3 log\,(Dist_{ij})+\alpha_4 log(I_{it-1}/I_{jt-1})+\alpha_5 D+e^{1}_{it}, \quad (4.1)$$

$$log(T^{low\text{-}tech}_{ijt})=\beta_0+\beta_1 log(Y_{it}/Y_{jt})+\beta_2 log(E_{it}/E_{jt})+\beta_3 log\,(Dist_{ij})+\beta_4 log(I_{it-1}/I_{jt-1})+\beta_5 D+e^{2}_{it}. \quad (4.2)$$

The dependent variable *T* in equations (4.1) and (4.2) denote intra-industrial trade flows from country *i* to country *j* at time *t*. The main difference between equation (4.1) and equation (4.2) is in industry grouping to distinguish innovation activities in the broadest possible sense. In particular, the trade flow variables in equation (4.1) include only research-intensive or science-based Schumpeterian industries. We group high-tech industries separately based on Grupp and Maital (2000), who found high-tech sectors highly innovative compared to traditional manufacturing sectors, such as food, drink, tobacco, metal, construction products, paper and textiles. Firms in these sectors are considered more heterogeneous in terms of their innovative performance. Companies in the service sector are even less innovative than those in traditional manufacturing. Consequently, the impact of innovative efforts on the technological and innovative performance of companies in generating new ideas, patents and products is especially strong in high-tech industries compared to other branches (Baysinger and Hoskisson, 1989; Griliches, 1998; Hagedoorn and Cloodt, 2003). We assume that R&D expenditure in high-tech industries represents the dominant orientation of innovative efforts in generating new ideas, which leads to more inventions, in terms of new patents, products and processes, than in other industries. The second specification, equation (4.2), which applies to trade flows between low-tech industries, includes the remaining manufacturing industries, estimating the magnitude of impact caused by R&D efforts.

Nominal export values are converted into real values in both specifications by using the harmonized GDP deflator of the euro zone to neutralize price differences across the countries included. The term *Y* denotes the constant value-added and *E* stands for the number of employees in the manufacturing sectors of the countries considered. The term *Dist* stands for distances (in kilometers) between the countries' capitals, and *I* indicates innovation (or R&D) expenditures. The terms *i* and *j* denote exporting and importing countries such that i=1,.., 20, j=1,.., 20 and *t* stands for years such as t=1,2,3,4. Finally, the parameters to be estimated by the gravity model are $\alpha_0,\ldots,\alpha_5$ and $\beta_0,\ldots,\beta_5$, and $e^{1,2}_t$ is the error term.

In addition to these variables, we incorporate a dummy variable that proxies policies towards FDI in the new EU members. According to Hanousek et al. (2011, p.320), "local firms in transition countries experience efficiency gains if they supply industries with a higher share of foreign firms or if foreign firms sell to them". These results support the policy implication in the new EU members that FDI is beneficial and should be promoted when intersectoral spillovers are expected to appear. Since these policies are very likely to affect the direction of bilateral trade flows, *D* represents a policy dummy in our model, which is equal to 1 if national policies encourage FDI inflows actively and 0 otherwise. In the new EU members, the national innovation system approach closely links industrial and innovation policies to FDI (Costa and Filippov, 2008). Therefore, we assigned a dummy for new EU members, where the share of multinationals in R&D and innovation expenditures is very high. During the period from 1990 to 2007, for example, the four new EU members received $271.6 bln. FDI in total (OECD, 2008).[4]

The policy dummy for the new EU members in our model is expected to have a negative sign ($\alpha_5<0$, $\beta_5<0$) in the case of a backward spillover effect of FDI. That is, if multinationals invest in new EU members, they would probably also buy some parts and components on the local market to contain costs. This would create a demand for higher

[4] The breakdown of FDI by four new EU members is the following: the Czech Republic ($69.9 bln.), Hungary ($62.5 bln.), Poland ($114.1 bln.) and Slovakia ($25.2 bln.).

quality inputs and encourage local suppliers to produce products with higher quality standards. As a result, the demand for imported products in the new EU markets would decrease, while the international competitiveness of the products produced locally would increase. This is a pull effect, improving the performance of local firms. On the contrary, if the dummy variables have a positive sign ($\alpha_5>0$, $\beta_5>0$), a forward linkage spillover effect takes place, increasing the bilateral trade flows to the new EU states. This may be the case when intermediate inputs with higher quality due to foreign investment affect the productivity of local sectors employing these inputs. By buying high quality intermediate inputs, local firms would benefit from foreign firms (Hanousek et al., 2011). Since the innovation proxy is likely to be correlated with the error term due to the endogeneity of innovation to trade, the variation in innovation that is exogenous to exports needs to be identified (Bernard and Jensen, 1999; Clerides et al., 1998). Lachenmaier and Woessmann (2004) suggest that innovation proxies and exogenous variation in the innovation indicators (e.g. impulses and obstacles that hinder innovation at the firm level) are sensible instruments to address these issues. Therefore, we use these variables for instrumenting innovative activity in the two-stage least squares estimation (2SLS) of equations (4.1) and (4.2).

Table 2 Innovating firms that experienced obstacles for innovation: four industries (number of firms)

Countries	Years	Manufacture of machinery and equipment n.e.c., electrical and optical equipment	Coke, refined petroleum products and nuclear fuel, chemicals, chemical products and man-made fibers	Basic metals and fabricated metal products	Transport equipment
New EU members					
Czech Republic	2004	1509	225	1116	220
	2006	1395	975	612	235
Hungary	2004	593	178	217	63
	2006	442	568	415	119
Poland	2004	2730	742	1988	600
	2006	2005	1855	1182	429
Slovakia	2004	156	34	136	47

Source: Eurostat (2004, 2006), Community Innovation Surveys

The instruments are obtained from the CIS where economic activities are broken down by NACE division (see Table 2). The major impeding factors that firms experience under innovation activity are classified as “hampered innovation activities” in the CIS databases. These factors include excessive economic risks, high innovation costs, a lack of appropriate sources of finance and qualified personnel, organizational rigidities and a lack of customer responsiveness to new products. Since these factors are assumed to be uncorrelated with the error term, identification using the instruments ensures that the innovation estimates are solely affected by the variation of innovation activities, which are exogenous to the export performance of firms. The formal test of the H_0 hypothesis that instruments are correlated with error terms, based on $NR^2 \sim \chi^2$, is rejected in favor of valid instruments. Consequently, the estimates of the 2SLS can be interpreted as the causal effect of innovation on exports.

4 Data and empirical results

This section describes the innovation-related indicators in the new as well as old EU members, along with empirical results. The data is obtained through the OECD and Eurostat MSTI databases and broken down by the main economic activities and sources of investment at the industry level. As mentioned in the sections above, based on a broad definition of innovative performance, we assume that the dominant orientation of innovative activities and efforts takes place in high-tech and science-based industries. These industries include the aerospace, electronic, office machinery and computer, pharmaceutical and instrument-producing branches. As shown in Table 1, the share of innovative firms in these high-tech industries is larger than in traditional manufacturing sectors, which include food, drink, tobacco, metal, construction products, paper and textiles. The comparison of indicators presented in Table 1 is based on the number and turnover of firms that introduced significantly improved products/processes that were new to the firm and new to the market, within each industry and for all countries included in our sample.[5]

The data for high-tech industries cover constant exports and value-added variables, the size of employment, and the CIS-based indicators. R&D expenditures are taken as innovative efforts; factors hampering and obstacles to innovation come from the micro-aggregated CIS databases for 1996, 2000, 2004 and 2006. The share of multinationals and FDI in innovation expenditures are taken at the aggregated level for each country for the period from 1995 to 2006. A brief descriptive overview of the main innovation indicators in terms of R&D activities shows a notable difference in the structure and main sources of finance in the R&D expenditures of the new and old EU members. For example, the gross domestic expenditures on R&D (GERD),[6] measured as a share of GDP, are significantly lower in the new EU members, where they decreased by about 0.63% of GDP on average between 1996 and 2006 (in the old members they increased by about 0.50%).

[5] Firms that, for the first time, introduced a product or process that was new to the firm are roughly identified as “imitators”, while firms that introduced products that are new to the market are considered “innovators”. We computed the shares of these two firm types with their total turnover and turnover per firm within each industry. Then, all industries were compared based on the shares that are provided in Table 1.

[6] GERD is composed of business enterprise expenditure on R&D (BERD), higher education expenditure on R&D, government expenditure on R&D and private non-profit expenditure on R&D.

Table 3 Gross research and development expenditure (GERD) in selected countries

	Czech Republic	Hungary	Poland	Slovak Republic	EU 16 (min)	EU 16 (average)	EU 16 (max)
R&D (EUR per inhabitant)							
1996	45.70	22.40	20.90	28.30	52.90	345.59	515.40
2006	171.80	89.40	39.60	40.20	109.90	719.41	1328.60
GERD by sources, 2006 (% of total by sources):							
Abroad	3.10	11.30	7.00	9.10	3.80	9.67	18.40
Business enterprises	56.90	43.30	33.10	35.00	40.40	52.98	68.10
Government	39.00	44.80	57.50	55.60	25.10	35.11	48.30
Higher education	1.00	0.60	2.40	0.30	0.40	2.28	5.90
Expenditures by business enterprises, (% of total by countries):							
1996	0.47	0.17	0.55	0.14	0.20	5.88	28.62
2006	0.87	0.33	0.36	0.07	0.16	6.62	30.82
*Business enterprise R&D expenditure financed from abroad (% of R&D expenditures of enterprises)**							
2001-2005, average	3.60	19.66	2.21	2.37	1.77	8.10	14.92
2006	2.62	15.88	6.64	10.88	3.31	8.03	11.62

Note: * Austria and the UK are excluded from computations due to missing data
Source: OECD (1996, 2006), Science and Technology Indicators.

In terms of the sources of finance, the largest part of R&D activities is financed by the government in the new members of the EU (with the exception of the Czech Republic). The overall data demonstrated in Table 3 suggest that the business sectors of the new members are still much less R&D-intensive than those of the old members.[7] Besides, a relatively large part of the R&D activities in the new member group is financed from abroad. Since R&D is an important but not the only input of innovative activities, we review other indicators as well—for example, patents, the technology balance of payments (TBP) and international trade—especially for R&D-intensive and science-based industries (Table 4). The TBP indicators characterize the commercial transactions related to international technology transfers. They show that the net amount of payments for the acquisition and use of patents, licenses and various kinds of know-how containing industrial R&D carried abroad is generally high in the new EU member countries. On the contrary, in the old EU members, the net amount of payments is negative. The size of these payments, along with the R&D activities financed abroad directly and indirectly (through government funds), gives a basic indication of how large the magnitude of the imported technology to the new EU member countries is.[8]

Table 4 Selected innovation indicators

	Czech Republic	Hungary	Poland	Slovakia	EU-average
1. Technology balance of payments: net payments (mln. current dollars)					
1999	270	288	539	47	486
2001	213	440	618	35	793
2006	308	770	1694	224	-1550
2. Share of countries in triadic patent families (% of total by countries)					
1999	0.03	0.08	0.02	0.01	2.92
2005	0.11	0.28	0.09	0.02	6.25
2.1. Patent applications filed under the Patent Co-operation Treat (total number)[*]					
2005	120	180	104	36	2669
2.2. Foreign co-inventors in patent applications (% of total number of applications)					
2005	38.56	28.77	37.88	45.83	25.34
3. Export market share in high technology industries (%, of total exports)[*]					
1999	7.85	19.45	2.26	3.50	14.96
2001	9.10	20.61	2.71	3.17	16.52
2006	12.74	20.33	3.11	5.43	15.08

Notes: [*] applications at the international phase (EPO designations) are taken for 2005 at the aggregate level. According to OECD, high technology industries are: aerospace, computers, office machinery, electronics, instruments, pharmaceuticals, electrical machinery and armaments.
Source: OECD (2008), Science and Technology Indicators.

[7] The data for Austria and the UK are missing in this computation.
[8] Frensch (2010) shows that trade liberalization helped emerging European economies to be successfully involved in import-led growth strategies, which consist of importing intermediate and capital goods while paying for these imports by exporting final goods produced with these imports.

Our estimation steps include, first, the gravity regression where the trade flows between similar (science-based, research-intensive) industries are taken as a dependent variable to account for the potential progress effect of innovation. Second, we analyze the potential progress effect of R&D activities in traditional manufacturing sectors, using trade flows between all the remaining manufacturing industries. For pretesting purposes we use ordinary least squares (OLS), fixed effect (FE) and random effect (RE) models. The model selection is based on the properties of the residuals obtained for each model. The OLS and FE models do not satisfy the requirements for residuals being independently and identically distributed. The H_0 of no AR(1) serial correlation in the OLS residuals is rejected at the 5% level. Both the White and Housman specification tests suggest that the RE model is the preferred option.[9] The hypothesis test is that the individual country-specific effects are uncorrelated with the other regressors in the model. The reported χ^2 value is smaller than the critical value, so the H_0 cannot be rejected at the 5% significance level. Therefore we opted for the RE model that yields white noise residuals.

The summary of the estimation results from the RE model is reported in Table 5 and constitutes our main estimation results. The estimates from the first model suggest that with an increase in the size of research-intensive manufacturing sectors (proxied by the ratio of value-added) the flow of innovative products between countries increases, as expected. An increase in the ratio of employees in these industries contributes to a decrease in trade flows, however, the estimated parameter is not significant at the usual levels. With an increase in the distance between countries, the trade flows decrease. As for the impact of innovation, the effect is positive and significant at the 5% significance level.

[9] The intermediate results are not presented but they are readily available upon request.

Table 5 The main estimation results (from the Random Effect model)

Dependent variables:			$log(T^{high\text{-}tech}_{ijt})$	$log(T^{low\text{-}tech}_{ijt})$
Independent variables:			Model 1	Model 2
Constant term	C	α_0, β_0	21.58 (1.33)***	4.07 (0.43)***
Value-added of the industry in country *i* / Value-added of the industry in country *j*	$log(Y_{it}/Y_{jt})$	α_1, β_1	0.22 (0.06)**	–0.07 (0.02)***
The number of industry employees of country *i* (exporter) / The number of industry employees of country *j* (importer)	$log(E_{it}/E_{jt})$	α_2, β_2	–0.09 (0.09)	–0.04 (0.03)*
Distance between the capital cities of countries *i* and *j*	$log\ (K_{ij})$	α_3, β_3	–1.22 (0.17)***	–0.03 (0.05)
Innovation expenditure in country *i* / Innovation expenditure in country *j* at time *t-1*	$log(I_{it-1}/\ I_{jt-1})$	α_4, β_4	1.06 (0.47)**	–0.39 (0.21)**
Dummy for new EU members	*D*	α_5, β_5	–1.29 (0.31)***	0.16 (0.09)*
Number of observations			463	477
R-squared			0.25	0.20

Notes: Huber-White heteroskedasticity-consistent standard errors: ***, * and, * denote the 1%, 5% and 10% significance levels, respectively.

The first specification explains about 25% of the variation in the bilateral trade flows. In the new EU members, the share of foreign affiliates in innovation expenditures is very high, as documented by the FDI data presented in Table 6. As it was demonstrated in Section 3, the dummy variable *D* represents national policies towards FDI in the new EU members, where the share of multinationals in R&D and innovation expenditures is very high. For example, the FDI inflows to the research-intensive manufacturing sectors range from 60% to 70%, on average, during the period from 2001 to 2006. The sign of the coefficient on the policy dummy is negative in the first regression, implying that bilateral trade in research-intensive or innovative products between similar industries decreases by about 3.64 times (since the exponent of the coefficient on the dummy variable on new EU members equals to 1.29). This suggests a positive backward spillover effect. Namely, multinationals most likely encourage local suppliers to produce products with higher quality standards, which eventually leads to a decrease in the inflow of imported products to new EU markets. This is a pull effect, improving the performance of local firms.

Table 6 FDI inflows to research-intensive manufacturing sectors

	Czech Republic			Hungary			Poland			Slovakia		
	2001	2006	2001–2006	2001	2006	2001–2006	2001	2006	2001–2006	2001	2006	2001–2006
All industries, mln. USD	5645	5465	38332	3936	20027	40556	5712	19591	57303	1451	4700	16141
Manufacturing (ISIC 3), mln. USD	1654	1696	8912	2098	1477	9527	1204	4680	16435	249	2029	5905
Share of research-intensive sectors in manufacturing, %												
Chemical products:	*2.32*	*9.58*	*6.58*	*13.70*	*–4.57*	*7.01*	*1.06*	*14.35*	*9.83*	*9.08*	*3.41*	*6.27*
Metal and fabricated metal products:	*9.23*	*34.81*	*33.04*	*4.88*	*–3.39*	*10.05*	*0.44*	*24.44*	*21.06*	*2.41*	*30.61*	*27.96*
Machinery and equipment:	*14.65*	*8.18*	*2.78*	*12.14*	–16.10	*9.98*	*24.21*	*6.53*	*5.64*	*4.89*	*12.88*	*5.89*
Transport equipment:	*23.66*	*4.56*	*13.96*	*31.07*	*54.52*	*34.41*	*8.12*	*17.94*	*20.84*	*54.57*	*30.41*	*28.68*
Research and development	*0.88*	*–0.04*	*0.26*	*–0.27*	*–0.04*	*0.09*	*0.19*	*0.12*	*0.14*	*–0.03*	*0.00*	*0.10*
Total share of research-intensive sectors in manufacture, %	**50.75**	**64.37**	**59.43**	**61.52**	**53.36**	**66.72**	**34.02**	**63.38**	**57.51**	**70.91**	**77.32**	**68.90**

Source: OECD (2001, 2006), Science and Technology Indicators.

In the second model specification, where trade flows between the remaining manufacturing industries are taken as a dependent variable, the coefficient of the size of research-intensive industries has a negative sign. In particular, with an increase in the ratio of value-added in the science-based industries between two countries, the flow of trade decreases. Increases in the ratios of employees as well as R&D expenditures in research-intensive sectors contribute to a decrease in the trade flow of these products. The dummy variable for the new EU members in this specification is positive and significant at the 10% level. This suggests that the bilateral trade flows in less R&D-intensive manufacturing sectors increase by about 1.17 times in the new EU countries (the exponent of the dummy variable is 0.16). This clearly indicates the case when inputs with higher quality, due to foreign investment, are required in the traditional manufacturing sectors employing these inputs. This leads to the larger flows of trade.

In both regression specifications, multinationals appear to be an important driving force of technological progress, especially in the research-intensive branches of the manufacturing sector. Namely, the inward activity of multinationals is very important in the manufacturing sector of the new EU member states, with their shares in the turnover as well as R&D expenditure being more than 50%, on average. The indicators presented in the above-mentioned tables suggest a very close link between FDI and innovation efforts in new EU members. The results may be linked to a large inflow of funds to these countries in recent years for various kinds of technical services, assistance and consultancy work performed abroad, as indicated in the large and positive values of the TBP indicators (Table 4). Presumably, these technologies were transferred further for supporting domestic R&D efforts concentrated mostly in the public (e.g. government and education) sectors. In contrast, the share of the new EU members in the triadic patent variables is very low relative to the average level of the old EU members, while the size of foreign co-investors in patent applications is high (Table 4). This implies a relatively low innovation capacity of local industries, as our results suggest. All in all, the results confirm the view that the progress effect of innovation is strong in the new EU members.

5 Conclusion

This paper focuses on the origins and potential progress effect of innovation in a group of new EU member countries. First, we identify the sources and dominant concentration of innovative efforts to distinguish innovation-based technological growth in these countries. Then we analyze, at the industry level, the main sources and direction of innovation expenditures in the science-based industries of the new EU members versus the group of old members. Finally, we estimate the potential progress effects of innovation on the basis of a gravity model on a sample of 20 countries while treating endogeneity issues using CIS-based instruments. The results reveal that an increase in the size of the science-based manufacturing industries leads to higher intra-industrial trade between the countries, which proxies innovation-based technological growth. With an increase in distance the trade flows decrease, as expected.

The innovation expenditures of exporting countries have a positive and statistically significant effect on the progress indicator (i.e. bilateral intra-industrial trade flows between the science-based industries). In the case of the new EU members, where the share of multinationals in innovation expenditures is high, the bilateral trade flows between these industries decrease by about 3.64 times. This suggests a very close link between innovation efforts and corporate affiliates of foreign firms in these countries, supported by the national innovation systems in these countries. Furthermore, the bilateral trade flows of the remaining, or less research-intensive, industries decrease, with an increase in the ratio of value-added in the science-based industries between two countries. Increases in the ratios of employees as well as R&D expenditures appear to contribute to a decrease in the trade flow of these products.

We aggregate our findings on how local firms benefit from intermediate inputs from foreign firms (forward spillover) and how these may profit from the improvement of domestic firms (backward spillover). We show a negative and significant forward spillover effect, while backward spillover effects are positive and significant. Negative forward spillover decreases the effect of the foreign presence, while positive backward spillover increases the effect. The importance of forward and backward spillovers is strongly supported in our study. This is a key result, implying that local firms in the new

EU markets experience efficiency gains if they supply industries with a higher share of foreign firms or if foreign firms sell to them. The policy implication is that FDI must be encouraged where intersectoral spillovers are expected to materialize, as argued by Hanousek et al. (2011).

Our results indicate that the innovation process in new EU economies is dominated by foreign multinationals which we consider beneficial for national innovation systems. Foreign subsidiaries possess resources and capabilities that affect their survival in the long term (Hung and Chin, 2011) and due to this advantage they can pose a threat to smal- and medium-size firms. Subsidiaries can also capture parts of the market and squeeze out domestic producers. Still, once foreign subsidiaries are firmly established and become part of a country's innovation system the overall benefit is hard to dispute. We concur with Costa and Filippov (2008; p. 388) that national policy makers should "foster the development of the existing foreign-owned subsidiaries located in their countries" in order to reap the maximum benefits from their presence in domestic economies.

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