# Technological Imitation and Innovation in New European Union Markets

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Abstract

We analyze the role of imitation and innovation in promoting technological progress in new members of European Union: the Czech Republic, Hungary, Poland and Slovakia. The two modes of technological development—innovation and imitation—are distinguished from one another by identifying the dominant orientation of innovation efforts at the industry level. Specific industry features and the origin, structure and size of foreign direct investments in these countries are utilized for this purpose. The empirical relationship between intra-industrial bilateral trade flows, which proxy the level of technological progress, and innovation expenditures is analyzed using a gravity model. During the estimation stage, we use appropriate instruments to account for the potential endogeneity of innovation to trade. The results reveal the important role of foreign direct investment and multinationals in the technological progress of the region. Specifically, technological progress that is due to innovation is driven mainly by affiliates of foreign firms and multinationals.

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

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## 1. Introduction

In making 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 (Demekas et al. 2007; Lansbury et al. 1996; Landesmann and Stehrer 2006). Wide-ranging policies on economic reforms along with the privatizing of state-owned enterprises helped to establish private companies and bring foreign competition, foreign capital and advanced corporate-governance practices to the region (Estrin et al. 2009; Moudatsou 2003; Roland 2001; Landesmann and Dobrinsky1995; Lefilleur and Maurel 2010). 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 the modes of technological development—imitation and innovation—relate to overall progress and competitiveness. In this paper we contribute to the literature by analyzing imitation and innovation in Central Europe, a region that recently underwent an unprecedented economic transformation. We show that the technological progress that is due to innovation is driven mainly by affiliates of foreign firms and multinationals.

Imitation and innovation were investigated as modes of technological development in many instances (e.g. Bottazzi and Peri 2003; Jaffe and Trajtenberg 2002). Theoretical studies within the framework of technology diffusion and international technology transfer (e.g. Currie at al. 1999; 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 through the imitation of foreign ideas and techniques,[2] less developed countries promote technological change to help them catch up to developed countries. This is evidently true in a globalized world economy with a rapid integration of economic processes and an increasing number of converging clubs, including the EU (Grossman and Helpman 1991). Because of the effect of the economic transformation of Central European countries, there is a lack of research on this phenomenon for economies that have recently joined the EU. Firstly, learning through imitation itself is relatively new in these countries where markets have just been established. Secondly, an adequate data set on innovation at a reasonable level of disaggregation and quality is still not available for many of these countries. Consequently, issues associated with the lack of data and, thus, adequate tools cause difficulties in analyzing the issue properly. Finally, a common innovation measure that is based on either R&D or patents has been criticized for unrealistic underlying assumptions for analyzing innovation.[3]

The purpose of this paper is to analyze the role of imitation and innovation in the technological development in four new EU members: the Czech Republic, Hungary, Poland and Slovakia. In

[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).
[2]For example, Japanese firms made huge progress from borrowing, modifying and successfully commercializing foreign technologies and ideas during the post-war period (Okimoto and Saxonhouse 1987).
[3]The assumption of perfectly rational behavior of firms is seen to be unrealistic for analyzing innovation processes.

order to distinguish innovation from imitation, we identify the dominant orientation of innovative efforts at the industry level, using R&D expenditures as a measure of innovative effort. 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 especially strong. The innovative performance of firms is defined in the broadest possible sense in this study, following Ernst (2001) and Freeman and Soete (1997). That is, it 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 (Ernst 2001). Hence, our approach focuses on specific industries only, often referred to as leading-edge and high-tech-level 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.

The progress effect of innovation effort is analyzed further with a 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; Leamer and Levinsohn 1995; 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 model 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, as argued by Grupp (1998). The choice of intra-industrial bilateral flows is justified by the fact that they give rise to trade within similar commodity markets between the countries as stressed in Grubel and Lloyd (1975) and Greenaway and Milner (1986). The potential endogeneity of innovation with respect to trade in the dynamic panels is treated with instruments obtained from the Community Innovation Survey (CIS).[4] The data used in this study, consequently, cover CIS- and non-CIS-based innovation indicators for two groups of countries, including four new and 16 old EU members for the period from 1995 to 2006.[5] The sources of the data are the Main Science and Technology Indicators (MSTI) of the Organization for Economic Cooperation and Development (OECD) of the United Nations Industrial Development Organization (UNIDO) and Eurostat databases.

This study contributes to the literature by focusing (apart from the innovation indicators) on the origins and direction of FDI and its role in the technological progress of the selected new EU members. FDI is an important means of technological and knowledge transfer. The case of the new EU countries is of particular interest since they received a substantial amount of FDI during the transformation period (Carstensen and Toubal 2004; Disdier and Mayer 2004).[6] The results reveal the important role of FDI and multinationals in the technological progress of the region and complement the recent results of Lefilleur and Maurel (2010) that show the key role of FDI in integrating Central European (CE) countries into the European production process. In

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

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

[6]During the period from 1990 to 2007, the four new EU members received $271.6 bln. FDI in total. The breakdown for each country is as follows: the Czech Republic ($69.9 bln.), Hungary ($62.5 bln.), Poland ($114.1 bln.), Slovakia ($25.2 bln.). For more details see OECD Statistics: 2008.

particular, we show that technological progress that is due to innovation is driven chiefly by affiliates of foreign firms and multinationals. Our results are in line with the experience of countries in other regions of the world, like the US and China. Nowadays, China is the largest recipient of foreign capital among developing countries, particularly receiving money from the US[7]. As a percentage of the gross inflow of capital coming from abroad, the total size of FDI in China increased from 6% to about 70% during 1980–2000 (Fung et al. 2004).[8] The direct technology transfers from multinational corporations to local subsidiaries played a very important role in advancing technologies as well as promoting rapid economic growth in China (Yao and Wei 2007). The rest of the paper is organized as follows. Section 2 presents the theoretical and empirical background. Section 3 describes the gravity model of bilateral trade. Section 4 reviews the innovation and trade flows measures. The empirical model specification and data are presented in Section 5. The conclusion follows.

## 2. Theoretical and empirical background

Imitation and innovation are important modes of technological development. Their nature, characteristics, interdependence and/or evolution over time are frequently discussed in the economic literature, usually focusing on a single country (Barro and Sala-i-Martin 1997; Bottazzi and Peri 2003; Glass and Saggi 1998; Grossman and Helpman 1991; Jaffe and Trajtenberg 2002; Jones 1995; Segerstrom 1991). In the endogenous growth literature (Barro and Sala-i-Martin 1997, Glass and Saggi 1998 and Grossman and Helpman 1991), imitation and innovation cannot coexist within a single country. Namely, North-South models with technology transfer between rich and poor regions distinguish the South as a region of countries that are either not innovators or are only innovators after being imitators initially. Many researchers have argued, however, that an equilibrium with both imitation and innovation within a single country can exist (e.g. Currie et al. 1999; Jones and Williams 2000; Segerstrom 1991).

According to Segerstrom (1991), the prospect of collusion between firms provides incentives to engage in costly imitation. Models with catching-up features, in which equilibrium with imitation and innovation within specific countries depends on a cross-country assimilation effect and the ease of imitation, are provided in Currie et al. (1999). The reasons and factors for R&D over- and underinvestment as well as the conditions under which an optimal allocation of imitation and innovation can co-exist were explored further by Jones and Williams (2000) and Segerstrom (2000, 2004). Perez-Sebastian (2007) incorporated into these models transitional dynamics along the development path and arrived at the conclusion that imitation possibilities change over time. To be more specific, the policy intensity of imitation decreases as initially poor countries develop and integrate with more advanced ones. As a consequence, the early stages of convergence are characterized by a high intensity of imitation activities, while in later stages innovation dominates.

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[7]The US is the second largest investor with about 9% in total FDI after Hong-Kong (48%).

[8]The number of foreign-invested enterprises in China increased by 11% between 1995 and 2000, including half of the total number of firms operating in the electronics and telecommunication industry, for example (Fung et al. 2004).

The economic reasons for the high intensity of imitation are covered in Poyago-Theotoky (1998). In particular, under weak patent protection and strong technological spillovers, private firms underfund R&D and innovative activities. Then, they reap the benefits of innovation through easy imitation once a new invention has been made. Thus a free-rider aspect of R&D can cause an underinvestment problem that can be corrected, initially, by policy measures through government subsidies to R&D expenditures, R&D tax credits and cooperative ventures in R&D.

New EU members constitute one group of countries where the above-mentioned processes are at the very heart of their transformation and integration development. In particular, the countries managed to replace on a 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 in terms of the real economy (Kočenda 2001) as well as in terms of nominal (Kočenda et al. 2006) and fiscal (Kočenda et al. 2008) indicators.

Aside from specific issues that are relevant for these new EU members, the relationship between innovation and technological progress has been studied empirically using exogenous North-South models (e.g. Krugman 1979) and endogenous growth models (e.g. Grossman and Helpman 1990; Young 1991). According to North-South models, the North innovates and exports newly invented goods to the South. Then, the South initially imitates these goods and, as soon as it becomes mature, exports them to the rest of the world. In this respect, the North ought to continually innovate in order to keep its exports high. Different aspects of structural transformation and the competitiveness of countries are covered in Fagerberg et al. (2007), Landesmann and Stehrer (2006), using a growth model based on Schumpeterian logic. The authors emphasize technology, capacity and demand as of greater importance for growth and development than price competitiveness. Endogenous growth models recognize the open-economy effect by endogenizing innovation so that the impact of international trade on innovation can be predicted. Progress indicators depicting innovation progress that are frequently used in the empirical literature 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 progress effect of innovation 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 pattern and magnitude of the impact caused by innovation on progress connect innovation with foreign trade indicators (e.g. Bleaney and Wakelin 2002; Buxton et al. 1991; Fagerberg 1988; Smith et al. 2002).

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 (see e.g. 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.

There are several ways to measure innovation. Commonly used measures include R&D inputs, patent counts and citations, new product and process announcements and survey-based measurements. Many studies use single indicators, while some studies use composite measures. The usefulness of these indicators in measuring innovation, as a single or a composite index, depends on the specific nature of the industries (Hagedoorn and Cloodt 2003). Differences in the nature of industry activities determine why certain innovation indicators are better (Brouwer and Kleinknecht 1999; Devinney 1993; Ernst 2001; Griliches 1998). The more an industry is characterized by high R&D, high patenting intensity and/or 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).

The innovative performance of companies can be defined in a narrow or broad sense, according to Ernst (2001) and Freeman and Soete (1997). The narrow sense refers to innovation as a result of a company's activity in terms of the degree to which it introduces newly invented products, process or devices. Innovation occurs when a company first markets a new product or introduces a new process. This enables followers to imitate or adopt these newly invented goods and processes. According to Grupp (1998) and Pianta (2003), the distinction between innovation and imitation at this level can be made in two ways. First, a distinction can be made through examining the evolution of particular technologies by their development stages. Second, it can be made through clear identification of innovating firms and industries. Both ways of distinction require conducting detailed surveys at the firm level since the usual innovation measures (i.e. R&D and patent indicators) do not clearly distinguish between the two modes of technological development. The main problem comes from the fact that the 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). In addition, since imitators do not have to know the first innovators within the industries or countries they operate in, imitation can be as resource- and R&D-intensive as if it was the first innovation. Therefore, distinguishing innovation from imitation on the basis of the existing firm-level CIS surveys and the MSTI data set is difficult.

A broader understanding of the concept of innovation performance assumes innovation as a chain process 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). This study relies on a broader understanding of innovation, viewing the impact of innovative efforts on the technological and innovative performance of companies as especially strong in high-tech industries (Baysinger and Hoskisson 1989; Griliches 1998; Hagedoorn and Cloodt 2003). Having in mind the above-mentioned complexities in distinguishing innovation from imitation, we select specific high R&D-intensive and science-based industries with a dominant orientation towards innovation activities. These industries are referred to as high-tech-level Schumpeterian industries and very often include the aerospace, electronic, office machinery and computer, pharmaceutical and instrument-producing branches. Hence, following the approach of Grupp and Maital (2000) and Hagedoorn and Cloodt (2003), we distinguish between innovation and imitation by assuming that R&D expenditures in high-tech industries represent the dominant orientation of innovative efforts in generating new ideas, the largest part of which leads to new inventions.[9] The progress effect of innovative efforts is analyzed further with a gravity model, which is introduced in Section 3.

## 3. The gravity model of bilateral trade

In its simplest form, the gravity model of bilateral trade, which was used 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 costs. Initially, gravity models lacked a strong theoretical background, but still were widely and successfully used to empirically analyze bilateral trade flows. Later studies have been increasingly showing that gravity models can have a solid theoretical foundation, such as Ricardian, Heckscher-Ohlin, and increasing–returns-to-scale (IRS) models (Anderson 1979; Bergstrand 1990; Deadorff 1984, 1998; Eaton and Kortum 2002; Helpman 1987). The key assumption behind these models is product specialization with a single commodity produced in only one country. That is, as an exporting country increases the supply of its product, the importing country will increase its consumption proportionally, which will result in larger volumes of trade between the two countries (e.g. Evenett and Keller 2002).

A more detailed theoretical and empirical explanation for the bilateral trade between countries is reflected in new trade theories (e.g. Deardorff 1984, 1998; Helpman 1981, 1987, 1998; 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 basic theoretical foundation of international trade. In particular, in the presence of economies of scale, production is located in one country, where producers differentiate their product. The larger the country in terms of GDP, the wider the variety of goods is offered. Thus, product differentiation causes trade between similar countries in such 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 their findings, models with imperfect specialization are better candidates for matching trade volumes with GDP compared to perfect specialization models. This is because the former models provide more realistic predictions where the factor proportionality of trade with GDP is less than one, while the latter models over-predict the volume of trade. Moreover, in imperfect specialization models the degree of specialization is a function of relative factor abundance, a key exogenous variable. Consequently, the authors suggest that trade among the industrialized countries can be partially captured by a

[9] We acknowledge, however, that patenting behavior can be explained by potential imitation due to the protection of imitation by patents or technological restrictions as in, for example, the pharmaceutical, software and computer and semiconductor industries (see e.g. Bessen and Maskin 2000). Illegal imitations are still possible, though.

model that combines trade in perfectly specialized, differentiated and homogeneous goods. Trade between less developed and industrialized countries can be quite well explained by imperfect specialization models. The basic theoretical assumptions for the use of gravity equations are, therefore, balanced trade between two identical countries,[10] zero trade and transport costs and no trade in intermediate goods. Evenett and Keller (2002) considers first an 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:

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

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

The gravity equation with imperfect specialization of production, which is seen as a better candidate for matching trade volumes with GDP, 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:

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

$\gamma^j$ is the share of good *z* in country *i*'s GDP, presented in equation 3.

(3) $$\gamma^i = \frac{z^i}{(p_x x^i + z^i)}, \text{ where}$$

$p_x$ is the relative price of good *x*. Country *i* exports only capital-intensive *x* goods 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 product (*z*) and the extent of the shortfall depends on the size of the differentiated goods sector (*x*) in GDP.

Most gravity applications include other variables in addition to the output and distance measures. Recent studies cover a wide range of economic relationships. These include, for example, the impact of natural disasters and catastrophic events (Gassebner et al. 2006) and internet connections (e.g. Freud and Weinhold 2004) on bilateral trade flows. The impact of institutions

[10] The two countries are identical in terms of production technology and homothetic consumer preferences.

and opening of embassies in transition economies is analyzed in Koukhartchouk and Maurel (2004) and Afman and Maurel (2009). 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. In particular, the larger the trade volume of similar products between two countries, the higher the probability that innovators at one end reach the technology knowledge at the other (Grupp 1998).

## 4. The empirical specification of the gravity model.

The gravity model in the current study is based on the assumption that technology diffusion mimics the geographical pattern of intra-industrial trade, which gives rise to trade within similar commodity markets between two countries. In particular, the larger the trade volume of similar products between two countries, the higher the probability that innovators in one country reach the level of technology knowledge in the other. The main question of interest is, then, how the two modes of technological development (i.e. innovation and imitation) affect bilateral trade flows at the industry level. Since most new EU countries have recently been experiencing 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 effect firm performance. Therefore, both contemporaneous and lagged time frames are considered in this study, covering the years 1996, 2000, 2004 and 2006.[11]

We formulate the gravity model for three different dependent variables as follows:

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

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

(4.3) $log(F_{ijt}) = \gamma_0 + \gamma_1 log(Y_{it}/Y_{jt}) + \gamma_2 log(E_{it}/E_{jt}) + \gamma_3 log\,(Dist_{ij}) + \gamma_4 log(I_{it-1}) + \gamma_5 log(I_{jt-1}) + \gamma_6 D + e^3_{it}$.

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 that the industry grouping is included in the specification in order to distinguish innovation from imitation in the broadest possible sense. In particular, the trade flow variables in equation (4.1) include only specific, research-intensive or science-based Schumpeterian industries.[12] According to Baysinger and Hoskisson (1989), Griliches (1998) and Hagedoorn and Cloodt (2003), 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. Therefore, we assume that R&D expenditure in high-tech industries represent

[11] The most recent Community Innovation Surveys are available for 2006.

[12] We focus on industrial production in specific high-tech industries that are considered 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 (see e.g. Grupp and Maital 2000).

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. Following this, we use the second specification, equation (4.2), which includes the remaining manufacturing industries, as a proxy for trade in imitated goods.

Nominal export values are converted into real values 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 term *D* is assigned as a dummy for the new EU members, where the share of multinationals in R&D and innovation expenditures is high. In the third specification, equation (4.3), instead of bilateral trade flows, we use the aggregate FDI flows between the pair of countries denoted by *F*, since FDI is an important means of technology transfer. 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 $t=1,2,3,4$.[13] Finally, the parameters to be estimated by the gravity model are $\alpha_0,..., \alpha_5$, $\beta_0,...,\beta_5$ and $\gamma_0,..., \gamma_6$ , and $e^{1,2,3}_{it}$ as the error terms.

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 at al. 1998). Hence, several methods were used for correcting for endogeneity issues, including Granger-causality tests, a time-sequence analysis of firms' performance with respect to exports and simultaneous equation systems. Lachenmaier and Woessmann (2004) note, however, that some of these methods might not be as suitable, such as, the Granger-causality concept due to its forward-looking nature. Specifically, high diffusion rates within industries do not necessitate incorporating the lagged innovation variables. They argue that innovation proxies and exogenous variation in the innovation indicators (e.g. impulses and obstacles that hinder innovation at the firm level) are more sensible in treating these issues. Therefore, following Lachenmaier and Woessmann (2004), the impulses and obstacles which impact firm innovativeness are used as an instrument for innovative activity in two-stage least squares estimation (2SLS) of equations (4.1) and (4.2).

The instruments are obtained from the CIS where economic activities are broken down by NACE division (see Table 1). 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, the way of 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.

[13] By using the ratios of variables between pairs of countries we account for different degrees of openness.

## 5. Data and empirical results

This section describes 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 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 specific high-tech and science-based industries. These industries include the aerospace, electronic, office machinery and computer, pharmaceutical and instrument-producing branches. The data for these industries, which are very often referred to as leading-edge and high-tech Schumpeterian 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 FDI flows between the country pairs and 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.

We now present a brief descriptive overview of comparative statistics on the main innovation indicators in terms of R&D activities (see Table 2). Clearly, there is a notable difference in the magnitude, structure and main source of finance in the R&D expenditures of the new and old EU members. As shown in Figure 1, for example, the gross domestic expenditure on R&D (GERD),[14] measured in terms of EUR per inhabitant, are significantly lower in the new EU members. For new EU countries, the size of these R&D expenditures as a percentage of GDP decreased in 2006 relative to 1996 by about 0.65% of GDP on average, while in the old members it increased by about 0.89%.

Figure 2 demonstrates further the main sources of finance, including the four main institutional sectors: the business enterprise sector, the government sector, the higher education sector, the private non-profit sector and the foreign sector. The largest part of R&D activities is financed by the government sector in the new members of the EU with the exception of the Czech Republic, where business enterprises have a large share (57%); this is slightly above the average level of the old EU members (53%). Poland and Slovakia are characterized by a very large portion of research projects supported by government funds (about 58% and 56%, respectively). According to Poyago-Theotoky (1998), governments overinvest while the private sectors underinvest into R&D activities when the free-rider aspect of R&D is especially strong. In particular, in the environment of imperfect patent protection and strong technological spillovers, with easy access to research results, private firms leave R&D activities to their rivals. Then, when a new invention has been made, the private firms reap the benefits of innovation through easy imitation. Consequently, there is an important reason for governments to correct the underinvestment problem by active policy measures through R&D subsidies, tax credits and cooperative joint ventures, which may be the case in these new EU members.

[14] 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.

The R&D expenditures of the business sector increased greatly in the Czech Republic and Hungary over time (see Figure 3), especially between 2001 and 2006, while Poland and Slovakia show a clear declining trend. There was a large increase in the size of business R&D expenditures financed from abroad in the new EU members. This was especially the case in Poland and Slovakia, where expenditures increased by 4.4% and 8.5%, respectively. For the old members there is a declining trend during 2001–2006 (see Figure 4).[15] The overall data demonstrate that the business sectors of the new members are still much less R&D-intensive than those of the old members. Besides, a relatively large part of the R&D activities in the new member group is financed from outside of the business sector.

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 3 provides comparative statistics on these industries, separately for the new and old EU members. 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.

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 imitation using trade flows between all the remaining manufacturing industries, taken as a proxy for imitated products. Finally, the estimates of both equations are compared to the gravity regression with bilateral FDI flows.

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 OLS residuals is rejected at the 5% level. Both the White and Housman specification tests suggest that the RE model is the preferred option. The hypothesis test is that the individual country-specific effects are uncorrelated with the other regressors in the model. The reported $\chi^2$ value is smaller than the critical value, so the $H_0$ cannot be rejected at the 5% significance level.[16] 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 4 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

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[15]The data for Austria and the UK are missing in this computation.

[16] The results of the tests are not reported but they are available upon request. Detailed results from the estimations of the three models are reported in Table A1 in the Appendix.

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 and FDI flows decrease. As for the impact of innovation, the effect is positive and significant at the 5% significance level.

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 5. Multinationals appear to be the main driving force of growth, 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 FDI inflows to the research-incentive manufacturing sectors is also high, ranging from 60% to 70% on average during the period from 2001 to 2006 (see Table 6). Most of the R&D-related projects in the region are initiated and performed by multinationals. All in all, indicators presented in the above-mentioned tables suggest that the dominant orientation toward innovation efforts is concentrated mostly in the foreign firms' affiliates in the region. In this respect, in the new EU countries, bilateral trade in research-intensive or innovative products between similar industries decreases by about 3.64 times (the exponent of the coefficient on the dummy variable [1.29] on new EU members countries).

With respect to the potential role of imitation in technological development, which refers to the second model specification, taken as trade flows between the remaining manufacturing industries, 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 imitated goods 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 export of goods produced in less R&D-intensive manufacturing industries, which is taken as a proxy for the export of imitated goods, increases by about 1.17 times (the exponent of the dummy variable is 0.16).

Finally, the third specification—where the aggregate FDI flows from exporting to importing countries are taken as a proxy of technological diffusion—explains 21% of the variation. The variable based on the size of research-intensive industries positively affects the flow of FDI at the 1% significance level. The number of employees in the high-tech branches has the expected sign, however, the estimated parameter is not significant. In the case of the new members, furthermore, the outflow of FDI is systematically lower by about 7.5 times, which is reasonable since these countries are receivers of FDI. Besides, there was 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 3). Presumably, these technologies were transferred further for supporting domestic R&D efforts concentrated mostly in the public (e.g. government and education) sectors, as demonstrated in Table 2. 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 6). 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 led by foreign–affiliated companies and multinationals in the new EU members.

## 6. 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 from imitation in these countries. Then we analyze at the industry level the origins and size of FDI as well as the main sources and direction of innovation expenditures in the science-based industries of the new EU members versus the group of old members. The comparative analysis reveals that the orientation towards innovation efforts is concentrated chiefly in corporate affiliates of foreign firms in these countries. This finding is consistent with the experience of other countries, particularly the US and China. In China, the large inflows of FDI in the last two decades and the direct technology transfers from multinational corporations to local subsidiaries played a very important role in advancing technology as well as promoting rapid economic growth (Fung et al 2004).

Finally, we estimate the potential progress effects of innovation and imitation on the basis of a gravity model on the sample of 20 countries while treating endogeneity issues using CIS-based instruments. Our 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. Furthermore, the bilateral trade flows of the remaining, or less research-intensive, industries proxy the potential progress effect of imitation in our analysis. The size of and innovation within the science-based industries do not seem to promote the trade of imitated products. On the contrary, the effect is negative and significant, while in the case of new EU members the effect is positive and significant. The bilateral flows between less science-based industries increase by about 1.17 times in this group. All in all, the findings suggest that innovation-driven technological change and growth in the region is caused, to a large extent, by multinationals and foreign firms' affiliates operating in local industries.

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*Table 1: Innovating firms 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 fibres | Basic metals and fabricated metal products | Transport equipment |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 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 |
| Old EU members | | | | | |
| Austria | 1996 | 658 | 60 | 474 | 36 |
| | 2004 | 1511 | n/a | 715 | n/a |
| | 2006 | 1164 | 703 | 725 | 103 |
| Belgium | 1996 | 413 | 132 | 390 | 62 |
| | 2004 | 616 | 441 | 721 | 183 |
| | 2006 | n/a | n/a | n/a | n/a |
| Denmark | 1996 | 1002 | 93 | 383 | 29 |
| | 2004 | 399 | 62 | 197 | n/a |
| | 2006 | n/a | n/a | n/a | n/a |
| Finland | 1996 | 509 | 105 | 114 | 50 |
| | 2004 | 569 | 40 | 334 | 65 |
| | 2006 | n/a | n/a | n/a | n/a |
| France | 1996 | 5701 | 1781 | 2822 | 778 |
| | 2004 | 5786 | 1405 | 4517 | 986 |
| | 2006 | n/a | 1453 | 755 | n/a |
| Germany | 1996 | 8784 | 972 | 3365 | 371 |
| | 2004 | 8456 | 1248 | 3970 | 1538 |
| | 2006 | 10939 | 1830 | 3262 | 1152 |
| Ireland | 1996 | 340 | 94 | 98 | 72 |
| | 2004 | n/a | n/a | n/a | n/a |
| | 2006 | 403 | n/a | 243 | 58 |
| Italy | 1996 | 1470 | 233 | 813 | 138 |
| | 2004 | 12713 | 1214 | 9937 | 1246 |
| | 2006 | n/a | n/a | n/a | n/a |
| Luxembourg | 1996 | 18 | 3 | 18 | n/a |
| | 2004 | 39 | 1 | 11 | n/a |
| | 2006 | 32 | 20 | 20 | n/a |
| Netherlands | 1996 | 1462 | 381 | 557 | 269 |
| | 2004 | 978 | 204 | 644 | 134 |
| | 2006 | n/a | n/a | 346 | n/a |
| Portugal | 1996 | 413 | 237 | 100 | 10 |
| | 2004 | 1597 | 489 | 1498 | 351 |
| | 2006 | 1077 | 1742 | 1609 | 336 |

| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| Spain | 1996 | n/a | n/a | n/a | n/a |
| | 2004 | 5274 | 1917 | 7162 | 1528 |
| | 2006 | 5310 | 6553 | 5494 | 1143 |
| Sweden | 1996 | 1294 | 121 | 589 | 192 |
| | 2004 | 955 | 180 | 961 | 289 |
| | 2006 | n/a | n/a | n/a | n/a |
| United Kingdom | 1996 | 5522 | 1646 | 2608 | 555 |
| | 2004 | 3097 | 518 | 2136 | 467 |
| | 2006 | n/a | n/a | n/a | n/a |

*Note: Sign "n/a" denotes that data are not available*

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

*Table 2: Gross research and development expenditure (GERD) in selected countries*

| *R&D ( EUR per inhabitant)* | Czech Republic | Hungary | Poland | Slovak Republic | EU 16 (min) | EU 16 (average) | EU 16 (max) |
|---|---|---|---|---|---|---|---|
| 1996 | 45.70 | 22.40 | 20.90 | 28.30 | 52.90 | 345.59 | 515.40 |
| 2001 | 81.00 | 53.70 | 34.60 | 27.80 | 77.90 | 529.57 | 1179.80 |
| 2006 | 171.80 | 89.40 | 39.60 | 40.20 | 109.90 | 719.41 | 1328.60 |
| *GERD by sources, 2006 (% of total by sources):* | Czech Republic | Hungary | Poland | Slovak Republic | EU 16 (min) | EU 16 (average) | EU 16 (max) |
| 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 and private-non-profit sector | 1.00 | 0.60 | 2.40 | 0.30 | 0.40 | 2.28 | 5.90 |
| *Expenditures by business enterprises, 2006 (% of total by countries):* | Czech Republic | Hungary | Poland | Slovak Republic | EU 16 (min) | EU 16 (average) | EU 16 (max) |
| 1996 | 0.47 | 0.17 | 0.55 | 0.14 | 0.20 | 5.88 | 28.62 |
| 2001 | 0.44 | 0.19 | 0.41 | 0.09 | 0.13 | 6.66 | 31.68 |
| 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)** | Czech Republic | Hungary | Poland | Slovak Republic | EU 14 (min) | EU 14 (average) | EU 14 (max) |
| 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 (2006), Science and Technology Indicators.*

*Table 3: 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 |
| 2004 | 13.66 | 21.92 | 2.73 | 4.68 | 14.55 |
| 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 products are defined as the sum of the following products: aerospace, computers, office machinery, electronics, instruments, pharmaceuticals, electrical machinery, and armament.*
*Source: OECD (2008), Science and Technology Indicators.*

*Table 4: The main estimation results (by Random Effect model)*

| Dependent variables: | | | $log(T^{innov}_{ijt})$ | $log(T^{imit}_{ijt})$ | $log(F_{ijt})$ |
|---|---|---|---|---|---|
| Independent variables: | | | Model 1 | Model 2 | Model 3 |
| Constant term | C | $\alpha_0$ | 21.58 (1.33)*** | 4.07 (0.43)*** | 17.49 (1.66)*** |
| Value added of the industry in country *i*/ Value added of the industry in country *j* | $log(Y_{it}/Y_{jt})$ | $\alpha_1$ | 0.22 (0.06)** | -0.07 (0.02)*** | 0.23 (0.07)*** |
| The number of industry's employees of country *i* (exporter)/ The number of industry's employees of country *j* (importer) | $log(E_{it}/E_{jt})$ | $\alpha_2$ | -0.09 (0.09) | -0.04 (0.03)* | 0.05 (0.12) |
| Distance between the capital cities of countries *i* and *j* | $log\ (K_{ij})$ | $\alpha_3$ | -1.22 (0.17)*** | -0.03 (0.05) | -1.16 (0.19)*** |
| Innovation expenditure in country *i* / Innovation expenditure in country *j* at time *t-1* | $log(I_{it-1}/ I_{jt-1})$ | $\alpha_4$ | 1.06 (0.47)** | -0.39 (0.21)** | -4.01 (0.77)*** |
| Dummy for new EU members | *D* | $\alpha_5$ | -1.29 (0.31)*** | 0.16 (0.09)* | -2.01 (0.35)*** |
| Number of observations | | | 463 | 477 | 743 |
| R-squared | | | 0.25 | 0.20 | 0.21 |

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

*Table 5: Inward activity of multinationals (%, share in national total manufacturing)*

| | | 2001 | | | | 2006 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Czech Republic | Hungary | Poland | Slovak Republic | Czech Republic | Hungary | Poland | Slovak Republic |
| ISIC 3 | Variables | | | | | | | | |
| Manufacturing (total) | Number of establishments | 3.1 | 8.3 | 13.9 | n/a | 4.3 | 1.9 | 16.9 | 10.2 |
| | Turnover | 43.3 | n/a | 35.2 | n/a | 55.9 | 61.9 | 45.5 | 70.5 |
| | R&D expenditures | 60.1 | n/a | 6.6 | 33 | 71.6 | n/a | 32 | 64.1 |
| Chemical products | Number of establishments | 4.7 | 18.1 | 19 | n/a | 7.7 | 7.7 | 24.1 | 15.4 |
| | Turnover | 31 | 43.3 | 40.6 | n/a | 67.1 | 47.8 | 47.5 | 55.4 |
| | R&D expenditures | 37.4 | n/a | 1.4 | 38.3 | 89.6 | n/a | n/a | 90.7 |
| Drugs and medicines | Number of establishments | n/a | n/a | 25.9 | n/a | n/a | n/a | 24.8 | n/a |
| | Turnover | n/a | n/a | 26.6 | n/a | n/a | n/a | 58.2 | n/a |
| | R&D expenditures | 41.5 | n/a | n/a | n/a | 96.5 | n/a | n/a | n/a |
| Fabricated metal products | Number of establishments | 3.3 | n/a | 13.9 | n/a | 5.6 | 1.0 | 18.3 | 9.2 |
| | Turnover | 33.8 | n/a | 22.9 | n/a | 38.6 | 27.3 | 34.7 | 38.3 |
| | R&D expenditures | 10.8 | n/a | 0.9 | n/a | 33.8 | n/a | 5.8 | n/a |
| Total machinery and equipment | Number of establishments | 2.4 | n/a | 13.3 | n/a | 3.8 | 2.8 | 17.1 | 13.7 |
| | Turnover | 49.6 | 83.5 | 45.8 | n/a | 63.9 | 81.1 | 55.1 | 77.6 |
| | R&D expenditures | 30.8 | n/a | 10.4 | n/a | 51.8 | n/a | 15.1 | n/a |
| Office, accounting and computing machinery | Number of establishments | 5.5 | n/a | 16 | n/a | 5.2 | 4.4 | n/a | 9.8 |
| | Turnover | 93.9 | n/a | 20.7 | n/a | 95.9 | 35.3 | n/a | 25.9 |
| | R&D expenditures | n/a | n/a | n/a | n/a | n/a | n/a | 29.4 | n/a |
| Electrical machinery and electronic equipment | Number of establishments | 1.7 | n/a | 20.1 | n/a | 2.7 | 5.0 | 25.1 | 16.3 |
| | Turnover | 62.1 | n/a | 65.7 | n/a | 70.5 | 94.1 | 68.7 | 86.8 |
| | R&D expenditures | 35 | n/a | 19.8 | 55.7 | 60.5 | n/a | n/a | n/a |
| Transport equipment | Number of establishments | 10.1 | 19.1 | 24.9 | n/a | 22.5 | 11.0 | 30.7 | 28.5 |
| | Turnover | 83.5 | 91.7 | 70.1 | n/a | 88 | 93.9 | 77.2 | 92.8 |
| | R&D expenditures | 85.6 | n/a | 6.3 | n/a | 83.8 | n/a | 52.4 | n/a |
| Aircraft and spacecraft | Number of establishments | n/a | n/a | 31.6 | n/a | n/a | n/a | 61.1 | n/a |
| | Turnover | n/a | n/a | 15 | n/a | n/a | n/a | 50.7 | n/a |
| | R&D expenditures | 7.6 | n/a | 2.6 | n/a | 4.2 | n/a | n/a | n/a |
| Total business enterprise | Number of establishments | 4 | n/a | 8.8 | n/a | 5.4 | n/a | 12.0 | n/a |
| | Turnover | 30.1 | n/a | 25 | n/a | 41 | n/a | 34.3 | n/a |
| | R&D expenditures | 45.3 | n/a | 4.6 | 19 | 58.6 | n/a | 30.1 | 30.2 |

*Note: Sign "n/a" denotes that data are not available*

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

*Table 6: FDI inflows to the 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 | 5645 | 5465 | 38332 | 3936 | 20027 | 40556 | 5712 | 19591 | 57303 | 1451 | 4700 | 16141 |
| Manufacture (ISIC 3) | 1654 | 1696 | 8912 | 2098 | 1477 | 9527 | 1204 | 4680 | 16435 | 249 | 2029 | 5905 |
| | | | | | | | | | | | | |
| *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* |
| -pharmaceuticals, medicinal chemical and botanical products | 0.00 | 7.29 | 2.82 | 0.00 | 22.94 | 5.18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *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* |
| -metal products | 5.21 | 19.13 | 20.75 | 2.95 | 14.25 | 7.94 | 5.55 | 19.86 | 15.28 | -0.44 | 28.45 | 24.85 |
| -mechanical products | 4.02 | 15.68 | 12.29 | 1.93 | -17.64 | 2.11 | -5.11 | 4.58 | 5.77 | 2.85 | 2.16 | 3.12 |
| *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* |
| -office machinery and computers | 0.00 | 11.70 | 3.30 | 4.02 | -2.21 | 0.06 | 4.48 | 0.50 | 0.93 | 0.05 | -0.07 | 0.05 |
| -radio, TV, communication equipments | 14.65 | -3.52 | -0.52 | 8.11 | -13.90 | 9.92 | 19.73 | 6.03 | 4.71 | 4.84 | 12.96 | 5.83 |
| -medical, precision and optical instruments, watches and clocks | 0.00 | -0.76 | 0.42 | 0.00 | -1.32 | 0.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.24 | 0.22 |
| *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* |
| -motor vehicles | 17.08 | 3.66 | 12.65 | 31.02 | 53.69 | 33.82 | 4.58 | 12.85 | 19.10 | 54.55 | 30.35 | 28.75 |
| -other transport equipments | 6.59 | 0.90 | 1.31 | 0.04 | 0.83 | 0.59 | 3.54 | 5.09 | 1.75 | 0.02 | 0.06 | -0.07 |
| -manufacture of aircraft and spacecraft | 0.00 | 1.44 | 0.39 | 0.00 | 0.51 | 0.14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *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 incentive 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: Science and Technology Indicators.*

Appendix

*Table A1: Estimation results (full results)*

**Regression 1**: $log(T^{innov}_{ijt}) = \alpha_0+\alpha_1 log(Y_{it}/Y_{jt})+\alpha_2 log(E_{it}/E_{jt})+\alpha_3 log\ (Dist_{ij})+ \alpha_4 log(I_{it-1}/I_{jt-1})+ \alpha_5 D + e_{it}$ [1]

| Variables | | | Coefficients obtained on | | |
|---|---|---|---|---|---|
| Dependent variable | | | OLS | Fixed effect (FE) | Random effect (RE) |
| **Intra-industrial trade flows from country *i* to country *j* at time *t*** | $log(T^{innov}_{ijt})$ | | | | |
| Independent variables: | | | | | |
| Constant term | C | $\alpha_0$ | 25.32 (2.50)*** | 32.81 (21.54)* | 21.58 (1.33)*** |
| Value added of the industry in country *i*/ Value added of the industry in country *j* | $log(Y_{it}/Y_{jt})$ | $\alpha_1$ | 0.24 (0.05)*** | 0.62 (0.24)** | 0.22 (0.06)** |
| The number of industry's employees of country *i*/ The number of industry's employees of country *j* | $log(E_{it}/E_{jt})$ | $\alpha_2$ | 0.05 (0.13)** | 1.99 (0.42)*** | -0.09 (0.09) |
| Distance between the capital cities of countries *i* and *j* | $log\ (Dist_{ij})$ | $\alpha_3$ | -1.27 (0.25)*** | -2.86 (3.05) | -1.22 (0.17)*** |
| Innovation expenditure in country *i* / Innovation expenditure in country *j* at time *t-1* | $log(I_{it-1}/ I_{jt-1})$ | $A_4$ | -2.08 (1.65)* | 0.90 (0.50)** | 1.06 (0.47)** |
| Dummy for new EU members | *D* | $\alpha_9$ | -2.08 (0.35)*** | dropped | -1.29 (0.31)*** |
| Number of observations | | | 463 | 463 | 463 |
| R-squared | | | 0.26 | 0.19 | 0.25 |
| Hausman test: $\chi^2$ (4) = (b-B)'[(V_b-V_B)^(-1)](b-B) | | | | | |
| Comparison with OLS | | | # | 2.38 | 36.82 |
| Between FE and RE | | | # | # | 38.17 |

| **Regression 2:** $log(T^{imit}_{ijt}) = \beta_0+\beta_1 log(Y_{it}/Y_{jt}) + \beta_2 log(E_{it}/E_{jt}) + \beta_3 log\ (Dist_{ij}) + \beta_4 log(I_{it-1}/I_{jt-1})+ \beta_5 D+e_{it}$ [2] | | | | | |
|---|---|---|---|---|---|
| Variables | | | Coefficients obtained on | | |
| Dependent variable | | | OLS | FE | RE |
| Intra-industrial trade flows from country *i* to country *j* at time *t* | $log(T^{imit}_{ijt})$ | | | | |
| Independent variables: | | | | | |
| Constant term | C | $B_0$ | 7.06 (0.87)*** | -5.77 (10.39) | 0.06 (1.87) |
| Value added of the industry in country *i*/ Value added of the industry in country *j* | $log(Y_{it}/Y_{jt})$ | $B_1$ | 0.01 (0.03) | -0.48 (0.11)*** | -0.18 (0.04)*** |
| The number of industry's employees of country *i*/ The number of industry's employees of country *j* | $log(E_{it}/E_{jt})$ | $B_2$ | 0.15 (0.08)** | -0.39 (0.19)** | -0.14 (0.07)*** |
| Distance between the capital cities of countries *i* and *j* | $log\ (Dist_{ij})$ | $B_3$ | -0.12 (0.04)*** | 0.77 (1.35) | 0.08 (0.12) |
| Innovation expenditure in country *i* at time *t-1* | $log(I_{it-1})$ | $B_4$ | -0.32 (0.09)*** | 0.28 (0.19)* | 0.17 (0.09)** |
| Innovation expenditure in country *j* at time *t-1* | $log(I_{jt-1})$ | $B_5$ | 0.14 (0.06)*** | 0.00 (0.02) | 0.02 (0.01)* |
| Dummy for accession countries | *D* | $B_6$ | -0.59 (0.26)** | dropped | 0.79 (0.32)** |
| Hausman test: $\chi^2$ (5) = (b-B)'[(V_b-V_B)^(-1)](b-B) | | | | | |
| Number of observations | | | 477 | 477 | 477 |
| R-squared | | | 0.23 | 0.18 | 0.14 |
| Hausman test: | with OLS | | | 45.45 | 25.03 |
| | between FE and RE | | | | 24.43 |

**Regression 3**: $log(F_{ijt}) = \gamma_0 + \gamma_1 log(Y_{it}/Y_{jt}) + \gamma_2 log(E_{it}/E_{jt}) + \gamma_3 log\ (Dist_{ij}) + \gamma_4 log(I_{it-1}) + \gamma_5 log(I_{jt-1}) + \ \gamma_6 D + e^3_{it}$

| Variables | | | Coefficients obtained on | | |
|---|---|---|---|---|---|
| Dependent variable | | | OLS | FE | RE |
| **FDI flows country *i* to country *j* at time *t*** | $log(F_{ijt})$ | | | | |
| Constant term | C | $\alpha_1$ | -3.85 (2.19)** | -52.46 (11.85)*** | -5.45 (2.67)** |
| Value added of the industry in country *i* | $log(Y_{it})$ | $\alpha_2$ | 0.15 (0.07)** | 1.04 (0.39)*** | 0.33 (0.10)*** |
| Value added of the industry in country *j* | $log(Y_{jt})$ | $\alpha_3$ | -0.09 (0.07)* | 2.22 (0.41)*** | -0.05 (0.08) |
| The number of industry's employees of country *i* | $log(E_{it})$ | $\alpha_4$ | 0.47 (0.12)*** | 0.79 (0.93) | 0.49 (0.16)*** |
| The number of industry's employees of country *j* | $log(E_{jt})$ | $\alpha_5$ | 0.10 (0.11) | -0.70 (1.19) | 0.34 (0.15)*** |
| Distance between the capital cities of countries *i* and *j* | $log\ (K_{ij})$ | $\alpha_6$ | -0.84 (0.15)*** | dropped | -0.75 (0.18)*** |
| Innovation expenditure in country *i* at time *t-1* | $log(I_{it-1})$ | $\alpha_7$ | 0.00 (0.09) | 0.05 (0.17) | -0.10 (0.11) |
| Innovation expenditure in country *j* at time *t-1* | $log(I_{jt-1})$ | $\alpha_8$ | 0.71 (0.07)*** | -0.18 (0.09)** | 0.47 (0.07)*** |
| Dummy for accession countries | $D$ | $\alpha_9$ | -1.37 (0.30)*** | dropped | -1.68 (0.41)*** |
| Number of observations | | | 743 | 743 | 743 |
| R-squared | | | 0.41 | 0.16 | 0.39 |
| Hausman test: $\chi^2(5)$ = (b-B)'[(V_b-V_B)^(-1)](b-B) | | | | | |
| Comparison of FE and RE with OLS: | | | | 268.63 | 75.96 |
| Comparison between FE and RE: | | | | | 138.48 |

Notes: Huber-White heteroskedasticity-consistent standard errors: ***,**,* denote 1%, 5% and 10% significance level, respectively. The $H_0$ hypothesis of "instruments are correlated with error terms" (based on NR2~ $\chi$2) is rejected in favour of valid instruments.

*Figure 1: Gross R&D expenditures (EUR per one inhabitant)*

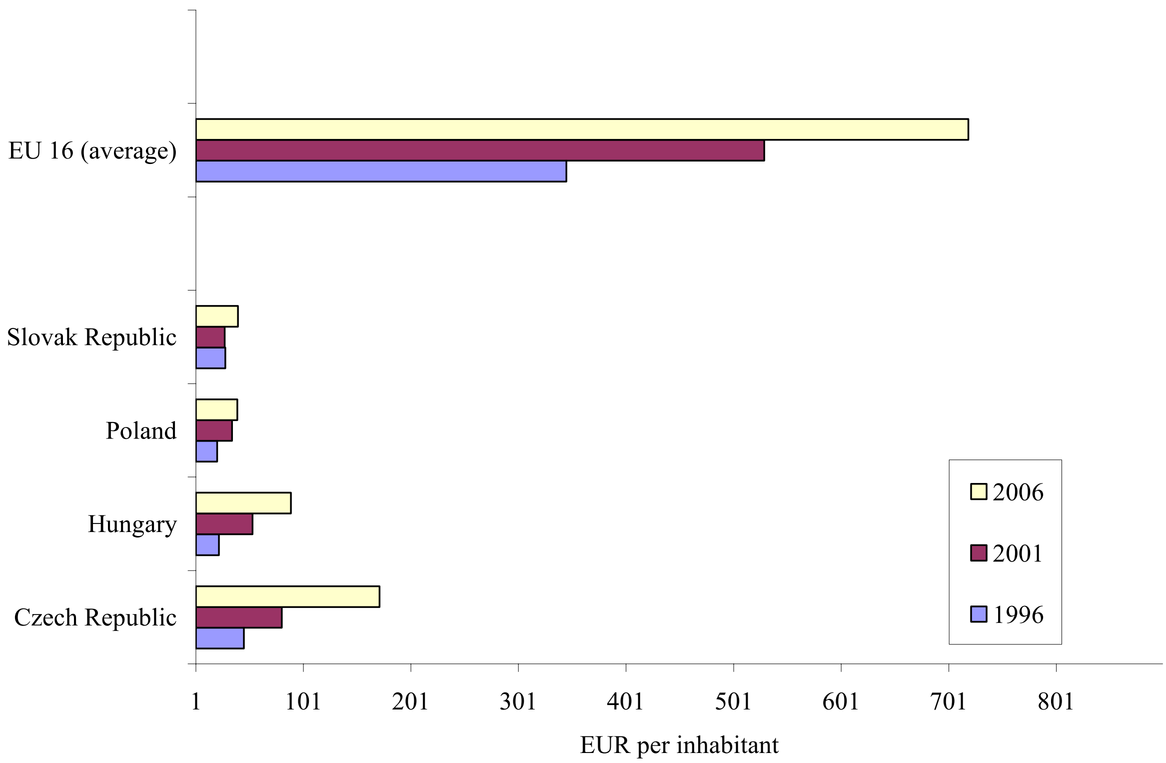


*Figure 2: The size of GERD in 2006: by the sources of finance*

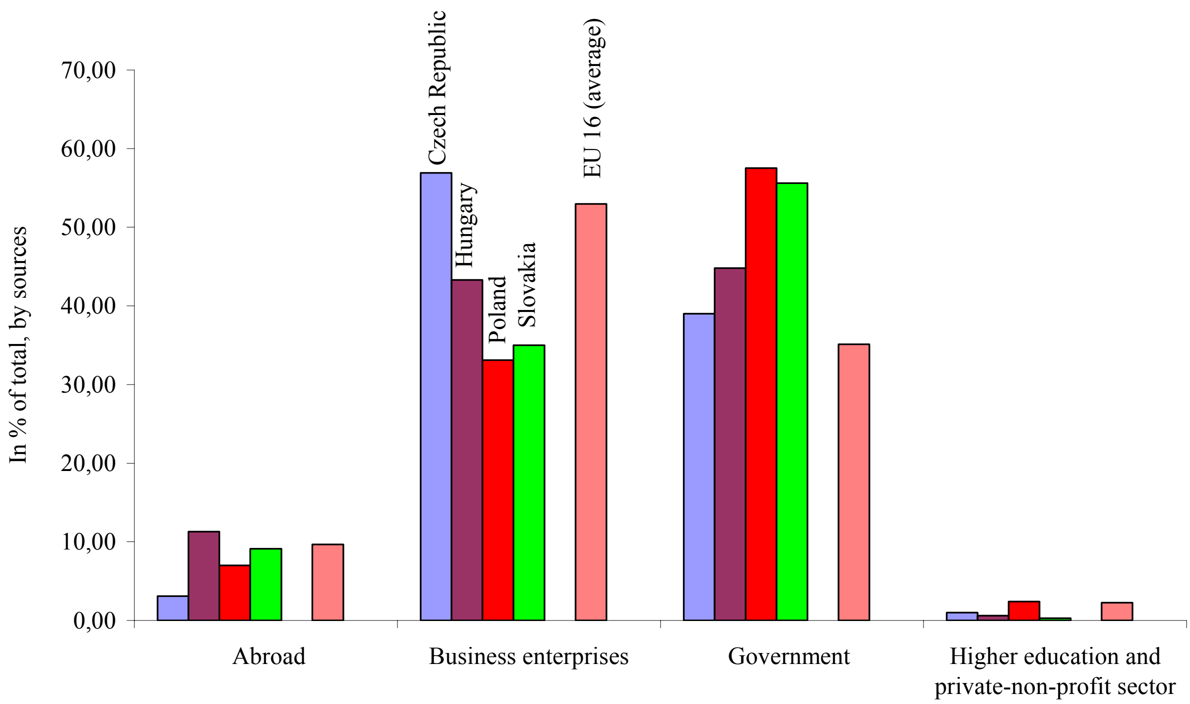

*Figure 3: R&D expenditure by business enterprises, % of total by countries*

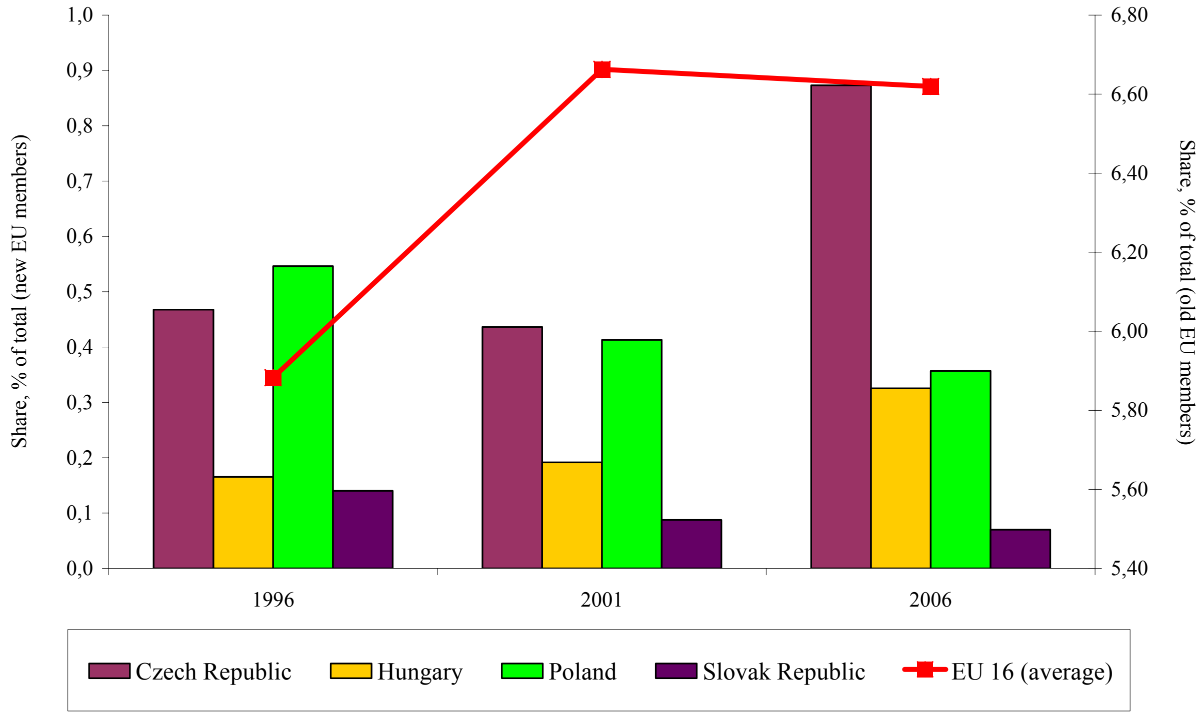


*Figure 4: R&D expenditure by business enterprises financed from abroad*