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Drivers of national innovative systems in transition. An Eastern European empirical cross-country analysis

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Abstract

Innovation plays a crucial role in determining today's economic growth patterns. But what enables some countries to innovate more than others? This paper employs in premiere a panel of sixteen Eastern European countries throughout their transition period exploring empirically the drivers of their national innovative capacity, a concept first developed in Furman et al. (2002). The significant disparities both within- and between Eastern Europe and its Western counterpart, in terms of innovational inputs, outputs and structure, provide an even more challenging task for analysis. As a proxy for the new to the world innovation I employ the number of international patent grants at the US patent office. The econometric analysis confirms the importance of R&D commitments and innovative tradition in the form of existing knowledge stock. Increased trade openness and intellectual rights protection determine higher international patenting, while the transition specific factors, such as structural industrial distortions or aggregated output drops, have a significant negative influence. Governmental funding and research performance of universities encourage more innovation at the technological frontier, while the business R&D funding in Eastern Europe is negatively correlated with it.

Keywords: National innovative systems; Transitional Economies; Patents; Eastern Europe
JEL codes: O3, O57, P20

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1. Introduction

In today's global and dematerialized economy, the ability of a country to develop, adapt and harness its innovative potential is becoming critical in terms of long term economic growth and competitiveness. This fact, widely confirmed in the recent literature, is starting to generate concrete results in policy terms as well; the most recent European innovation strategies of Lisbon (2000) and Barcelona (2002) reflect this trend, aiming to reduce the gap between EU and US in terms of innovation, productivity and ultimately, economic growth.

Since the 1980s, the concepts incorporated in the national innovation system (NIS) approach gained significant attention and have become a frequent framework for policy analysis dealing with innovation in a systemic approach. However, while most empirical cross-country analysis still focuses mainly on developed countries (OECD or newly industrialized countries), the opportunities and factors affecting the developing countries remain an area reserved for further research.

This study contributes to the existing literature by analyzing the innovation systems of 16 former centralized countries from Central and Eastern Europe, including the most important members of the former Soviet Union. Since early 1990s these countries experienced a painful transition from a closed centralized economy to a free market one that has impeded not only their economic performance but their innovational capacities as well. While the current macroeconomic successes have triggered a relapse of innovation output, the policy commitments still fall short from providing substantial support in most of these countries. Throughout the history there are a couple of extraordinary examples of "outsiders", like Ireland, Finland, Israel, South Korea or Taiwan, which have become major global technological players in matter of decades due to the right mix of policies and investments. Eastern Europe needs to take better advantage of their own comparative advantage and build solid innovational capacities which will ensure sustainable economic growth and regional competitiveness. The objective of this study is to identify and quantify the determinants of innovation in these transitional countries, their challenges and problems and provide policy pointers for developing countries towards achieving a more systemic and efficient NIS.

The paper is organized as follows. Section 2 discusses the theoretical background of national innovation systems and provides an overview of the empirical work dealing with these issues in a cross-country dimension. Section 3 presents the main facts concerning the Eastern European innovation making both historical and regional comparisons. Section 4 presents the empirical approach and the dataset employed for the analysis while Section 5 reports the results. Finally, Section 6 concludes, discussing the findings and policy implications.

2. Perspectives on national dimensions of innovation

Since the relationship between economic growth and technological development has been established, the question of analyzing the determinants of this capacity of countries to generate flows of new knowledge has been investigated by numerous scholars. Rather than focusing on few specific factors the concept of national innovative capacity (NIC) investigates the overall sources and sustainability of innovation systems at the country level (Hu and Matthews, 2005). Thus, the NIC concept, defined as the ability of a country to produce and commercialize a flow of innovative technology over the long run, is a comprehensive framework converging three main sets of ideas (Furman et al., 2002). The first source is the endogenous growth theory (Romer, 1990; Jones, 2001) where the flow of new ideas in the economy is modeled by a production function employing the existing knowledge stock and available skilled human. Secondly, Porter's (1990) microeconomic framework for the interaction between the private innovative sector and the environment of the national industrial clusters postulates that the level of national innovative output relies on the degree of private R&D spending, competition, demand conditions, clustering of local plus supporting industries and input availability. Finally, there is an extensive literature dealing with the systemic approach of this issue at the country level. This strain of works supports the idea that innovation is significantly affected by the interaction of institutions, including the nature of university systems, intellectual property, historical industrial organization and the R&D labor division, private industry structure, government, all together constituting a complex system at work (Freeman, 1982; Lundvall, 1992; Nelson, 1993)

Within the technological change literature, patents are a common measure of innovational output and a good way of tracking down the flows of knowledge across technologies, sectors and countries. Over the last decades there has been a tremendous increase in the number of patents issued worldwide, especially in developed countries reflecting the increasing importance of dematerialized property in today's knowledge based economy[1]. However, like any other proxy, they present both advantages and disadvantages, as discussed in the literature (Acs et al., 2002). Despite the latter, patents remain the best available source for assessing technological change and innovation since "nothing else comes close in quantity of available data, accessibility and the potential industrial organizational and technological details" (Griliches, 1990).

In empirical terms, most of the national innovation capacity literature focuses on OECD or developed countries due to issues of data availability and quality. Furman et al. (2002) find convergence patterns in their analysis among OECD countries. Moreover, the largest impact and differentiation source among different scale-type of innovators[2] is determined by two components, namely, the R&D expenditure and GDP levels (Furman and Hayes, 2004). Based on the assumption that innovation grows nationally within a national framework of institutions, Varsakelis (2006) incorporates in his analysis specific measures of governance (civil liberties, political rights, free press and corruption) and education (mathematics and science mean scores). When exploring the role of political institutions persistence, findings show that the institutional system tenure, regardless of the type, increases US patent applications from the foreigners[3], in this case the nationals of several Latin American and Caribbean countries (Waguespack, Birnir and Schroeder,

[1] Approximately 110,000 applications were filled at the European Patent Office (EPO) and almost 315,000 were registered by the US Patent and Trademark Office (USPTO) in 2000, compared with nearly 60,000 and 108,000, respectively, in 1991.

[2] Four types of countries (leading, middle-tier, third-tier and emerging innovators) of which the latter are, although not quite catching-up with the innovation at the frontier, vastly outperforming in terms of wealth and patents economies that historically have always exceed greatly their own.

[3] However, when looking at domestic patenting, institutional stability has either a weekly negative or an insignificant effect, which is interpreted by the authors as driven by the trend of increasing patenting standards over time

2005). Hu and Matthews (2005) analyze a sample of East Asian countries through the lens of the NIC approach and find that the latecomer countries seem to rely mostly on the accumulated knowledge capacity (patent stock), the strength of innovative infrastructure (R&D manpower) and cluster-specific factors (specialization and private R&D) along public R&D funding, which is indispensable in early stages of industrial development.

With regards to Eastern Europe, the existing NIC literature is confined to either descriptive analyses or case studies. Radosevic and Auriol (1999) depict six Central and Eastern European transitional in these terms and conclude that "although there was a marked downward shift in terms of 'stocks' of R&D spending and employment, CEECs have managed to maintain and intermediate position between developed and less developed OECD/EU economies", failing however to transform these large stocks in sources of growth. Performing a detailed description of patent activity in the US from seven countries, Radosevic and Kutlaca (1999) decide that income levels and growth rates are more important than past institutional arrangements for determining the amount of innovation originating from EECs, their technological specialization is very much path dependent and that there is significant heterogeneity in how R&D is undertaken between various countries. An extended historical analysis of EECs' patenting at USPTO by Marinova (2000) emphasizes the sharp transitional decline in technological achievements and reveals the regional strengths of the EECs as well as country specific ones[4]. Finally, using indexed rankings, Radosevic (2004) confirms that all EECs are below EU average in NIC terms and that they are giving a more homogeneous picture of a wider Europe considering the existing North-South differences among Western European states.

3. Stylized facts about Eastern European innovation

At the beginning of the 1990s a huge natural experiment began when Eastern European suddenly embarked on their way towards free market economies. This deep transformation was quite painful, with sharp falls in output, capital stocks shrinkages, labor force movements, trade reorientation, significant structural changes and institutional collapse. All these factors contributed to the U-shaped response of the GDP to this significant shock followed later by an overall regional relapse in late 1990s.

This hard road of transition has left its mark on innovational output as well. In this section we are going to explore some stylized facts about Eastern European innovation by looking in more detail and historical perspective at the international patenting done by these countries as a proxy for their national innovative output. Specifically, the number of USPTO patents which comprises only "la crème" in terms of innovative output, thus, constituting a measure of technologically and economically significant innovations at the

[4] There are several pitfalls to this type of approach. First, the use of aggregated former entities (e.g. Yugoslavia, USSR) after their official secession is hard to justify. Second, the methodological inconsistencies of the old patent counts from USPTO website (not corrected until 2006) yielded systematically downward biased counts for some EECs, the newly formed countries especially. Finally, there is no base for comparisons between two different structures (before and after the fall of communism).

world's commercial technology frontier[5]. This indicator should be consistent across countries and can be used successfully as a proxy one's national innovation capacity.

3.1 Historical technological divide in Europe

The technological difference between Eastern (EECs) and Western Europe (WECs) is quite significant. Moreover, it holds also in the historical context when comparing their international patenting (see Figure 1).

(Figure 1 here)

This fact is due to factors driving them in opposite ways. While the WECs increased their R&D commitments and their active business environment took its role in developing them further, the EECs during the communism persisted in their autarky and failed to diversify and keep the pace with the world's technology (Murrel, 1990). In terms of *patent intensity*, defined here as the stock of patents per capita, even the most successful EECs are still far away from the frontier but kept an intermediate position along the southern periphery of Western Europe (Spain, Portugal and Greece) while the emerging ones still struggle at the bottom of this classification (see Table 2). In terms of *patent assignees*[6], things have also substantially changed in transition, mainly due to the recognition of private property. As expected, the assigning percentage of patents to foreign entities experienced a significant increase after the 1989 regional change in political regimes. A more detailed analysis of this transformation is given in section 3.5.

3.2 Regional innovative heterogeneity

There is also significant differentiation within the regions. The usual North/South division applies to Western Europe, while for Eastern Europe the picture is more diverse (see Figure 2). The overall innovative leader in the communism was the former Soviet Union which had the vast majority of granted patents in the US between 1975 and 1995, counting for about 66 percent in the late 1970s, 50 percent in the early 1980s and about 40% between 1985 and 1990. Its heir, Russia, remained on top during the transition and it is still responsible for about half of the USPTO patents from Eastern Europe with 3,114 patents between 1990 and 2005. The rest of 15 countries in our sample[7] can be grouped in innovative terms into three categories. **First tier innovators** average patent stocks between 200 and 900 during 15 years of transition. Hungary (1,068) is the most consistent but in a slight regression comparative with the prior period, Czech Republic (546) and especially Poland (522) have shown remarkable improvements while Ukraine (394) just rebounded after a sharp drop in the early 90s. **The second tier** averaged between 50 and 200 first inventor patents in this interval and is divided into two subgroups: *improvers* like Slovenia (248), Croatia (157), Romania (97) and Lithuania (78) with lower starting points and significant growth and *laggards* such as Bulgaria

[5] More significant than the national patenting since one will pursue it only if it is truly confident in the quality (significance and commercial potential) of his invention and if the expected gains are higher than the expected costs.

[6] An assignee is the holder of the rights to use the patent for commercial purposes.

[7] Countries that have a total of 20 or more first inventor patents in this 15 year interval; the rest are two small to be taken into account and/or with a lot of zero counts.

(134), Belarus (93) or Slovakia (102) exhibiting higher initial starting points but an overall regressing trend. Finally, the **third tier** is formed from small countries with few USPTO patents that seem not to have improved much over time: Latvia (40), Estonia (46), Georgia (27) and Serbia and Montenegro (89), a shadow in terms of innovation of the former Yugoslavia.

(Figure 2 here)

3.3 Technological specialization (East vs. West)

To compare the technological paths of Eastern and Western countries I employ the NBER US Patent dataset by Hall, Jaffe and Trajtenberg (2001) and their classification into six broad technological categories[8]. The results confirm a significant decrease in EECs' innovational output over the last 30 years and a significant change in their innovational mix in the first transitional decade (see Fig. 3). However, limited by the time frame (1999) the ongoing relapse in the region is not captured by this dataset.

(Figure 3 here)

When comparing Western and Eastern Europe's innovative specialization, using a 14-industry level of detail, similarities are obvious (see Figure 4). Both are strong in heavy industry, textiles, chemicals, food and home products categories. It seems that the EECs have a comparative advantage in drugs and medicine, metallurgy and energy, while their Western neighbours are better, as expected, in newer industries with a higher value added and better development perspectives, like *Engines and Vehicles, Communications, Computers* and *Miscellaneous Structures*. There are also signs of possible complementarity within a wider Europe, with Eastern strengths in and possibilities in pharmaceuticals as well as heavy industries while Western Europe being more competitive in terms of hi-tech industries such as communications, IT or automobiles.

(Figure 4 here)

3.4 Commitments to innovation

There is an obvious correlation between the level of income and the national commitments to innovation (see Figure 5a). Overall, there was a significant regional reduction between 1990 and 2004 in terms of human resources employed in R&D driven especially by the economic fall of the former Soviet Union who had an impressive R&D sector before 1990 (see Figure 5b).

(Figure 5 here)

At the country level the picture is more diverse with some heavy reductions (Bulgaria – 70%; Ukraine – 64%; Georgia – 53%; Romania – 45% and Russia – 41%), constancy (Hungary, Serbia and Montenegro, Slovakia, Slovenia and the Baltic states) and even increases in the number of researchers (Czech Republic – 34% and Poland 22%). However, the differences between EECs and WECs are tremendous and the GERD figures, even in relative terms, are significantly below the OECD median level. The

[8] These are: *Chemical, Computers and Communication, Drugs and Medical, Electrical and Electronic, Mechanical* and *Other*.

government remains a major player in R&D funding in Eastern Europe, while the involvement of businesses and higher education is still quite limited (see Figure 6a, 6b).

(Figure 6 here)

3.5 Old vs. New players

Some interesting facts can be identified when looking at the distribution of main EEC patent holders along the transitional period (see Table 3). While virtually there was no foreign presence prior to mid 1990s, except the former Yugoslavia, this has dramatically changed in the last years especially for the first tier innovators in the region. Prior to 1990, individual holders and domestic entities (firms, governmental bodies or research institutions) were dominant (see Table 4). After 1990, the significant difference is represented by the emergence of global players in the EEC innovation arena such as General Electric, Samsung Electronics, Sun Microsystems, Ericsson or Bosch Siemens (see Table 5). Moreover, the orientation of dominant orientation of these patents has shifted from heavy and labour intensive industries towards today's "hot" fields (pharmaceutical and biotech, computers and semiconductors, communications). Despite this last positive trend, foreign assignees are usually confined in a handful of countries, with Hungary and Russia leading the way in absolute numbers and Czech Republic, Slovenia or Croatia trailing behind, while the others have little, or no foreign assignees to their international patents.

Historically, the EECs' innovative productivity has been declining since the late 1970s associated with growing inefficiencies of the communist regime. Moreover, transition made things worse through significant reductions in the research and development endowments and lack of incentives for the private sector. However, the EECs managed to retain an intermediate position between the core European countries and the less developed peripheral EU states. Their legacy in some key fields (e.g. chemicals, pharmaceuticals) and trained human resources available provides opportunities for a successful revival of innovation in Eastern Europe in which some the global R&D players are already involved.

4. Measuring the determinants of innovative capacity

4.1 Framework

Departing from Furman et al. (2002), this study employs a similar specification additionally taking into account the particularities of transition countries. The idea production function based on endogenous growth theory becomes in this case:

$$\mathring{A}_{j,t} = \delta_{j,t}\,(X_{j,t}^{INF},\ Y_{j,t}^{CLUS},\ Z_{j,t}^{LINK},\ T_{j,t}^{TRANS})\ H_{j,t}^{\ A\lambda}\ A_{j,t}^{\varphi}$$

where $\mathring{A}_{j,t}$ is the flow of new at the frontier technologies, $H_{j,t}^{\ A\lambda}$ is the total level of capital and labor resources devoted to the ideas sector of economy while $A_{j,t}^{\varphi}$ is the stock of knowledge for country j at time t. X^{INF} refers to factors constituting the innovational infrastructure and policies affecting it; Y^{CLUS} attempts to quantify the environment for innovation in the national industrial clusters; Z^{LINK}'s meaning is to capture the strength of existing linkages between the common infrastructure and these clusters while T^{TRANS} takes into account transition specific factors that overall, have deeply impacted these countries. This specification implies complementarity among its different components. The analysis is organized around a log-log specification (excepting the qualitative variables and percentages) which makes it less sensitive to outliers and easier to interpret. As $\mathring{A}_{j,t}$, proxied by the flow of patents originating from EECs, is observed with delay we employ a two year lag, following Furman and Hayes (2004), which takes into account the average processing time between patent application and grant at USPTO:

$$\log \mathring{A}_{j,t+2} = \delta_{INF} \log X_{j,t}^{INF} + \delta_{CLUS} \log Y_{j,t}^{CLUS} + \delta_{LINK} \log Z_{j,t}^{LINK} + \delta_{TRANS} \log T_{j,t}^{TRANS} + \lambda \log H_{j,t}^{A} + \varphi A_{j,t} + \varepsilon_{j,t}$$

4.2 Variables

In this section I will describe the variables used. Details on data sources and construction are provided in Appendix A. The data covers 16 EECs during the transitional period 1990 to 2007. More details are presented in Table 7, means and standard deviations in Table 8, while the pair-wise correlations are reported in Table 9. The main challenge was the availability and quality of data, some of these countries did not collect this type of data prior to mid 1990s while other adopted quite late the international classifications and norms[9].

Keeping in mind the pitfalls of ***patents*** as proxies for innovation, I employ in this analysis the number of patents at the USPTO which constitutes a good measure of technologically and commercially significant innovations at the world's frontier, especially useful for cross-country comparisons[10].

GDP per capita in constant 2000 US$ from World Bank's Edstat database and represents the aggregated national demand. ***Population*** data comes from CIA Factbook 2006. The mean value is about 20 million people and the size of countries in our sample varies a lot, from a really small ones (Estonia, Latvia and Slovenia) to medium (most of the countries), above medium (Romania, Poland and Ukraine) and a significantly big one (Russia).

The gross domestic expenditure on R&D (GERD) comes mostly from UIS S&T database, UNESCO Statistical Yearbooks and OECD Main Science and Technology Indicators 2006 augmented with compatible national statistics data. To reflect innovational orientation towards industrial clusters and the quality of linkages I use a couple of indicators in the literature (***GERD financed by business; GERD performed by universities***) and also for robustness, the ***GERD financed by government***, founded by Hu and Matthews (2005) to be more significant for the latecomers trying to catch-up.

Researchers represent the human capital involved in R&D activities within a country. Due to reduced availability of the data, desire to "let the data speak" and avoid extrapolations, the most prevalent indicator in the case of the EECs (the head-count number of researchers) is used for measuring the human input into innovative activities.

Another measure of a country's infrastructure is represented by its ***openness to trade*** which can be justified both as a proxy for technology transfer through imports (Coe

[9] Some data is truncated towards the beginning of the analyzed period since establishing new national statistical offices (the case of former Yugoslav or USSR republics) is a rather lengthy process.

[10] The great commercial potential for innovations attracted is also reflected in the largest number of patent applications and grants worldwide: 417,508 applications and 157,717 grants in 2005 almost half of which are foreign, fact that strengthens even more the above assumption (USPTO Patent Statistics Chart, 2006).

and Helpman, 1995) as well as an increasing competition in the market for the domestic EECs firms after1990 (Furman and Hayes, 2004).

A key variable in the analysis is represented by the ***intellectual property rights*** regime. The IPR index used in this paper takes into account both the formal (commitments to IP treaties – Park and Wagh, 2002) and informal (actual enforcement taking place- Smarzynska, 2002) dimensions of this issue.

The ***cost of doing business*** variable is used as a proxy for the country's ability to create and stimulate the business environment through regulations, which in turn affects the overall innovativeness. A bureaucratic country will fail to attract foreign innovative firms or encourage domestic entrepreneurs to undertake innovation related activities. Both the number of procedures required to start a firm and the costs associated with it vary significantly[11]. Such high entry costs are associated with significant corruption, larger black market and low quality public goods (Djankov et al., 2001) and it is expected to be negatively correlated with innovational output.

It is widely known that the countries of Eastern Europe and former Soviet Union faced in the early 1990s serious challenges in reallocating resources, a result of the communist heritage of a closed economic system[12]. These distortions have disruptive effects both on economic as well as innovation mechanisms (Srholec, 2007) and therefore need to be accounted for in our regressions. Therefore, I employ in this study an ***industrial distortion index*** which reveals the progress of the country towards an international benchmark (see Appendix A). This index captures the transition from an over-industrialized economy towards a more balanced one with a significant service sector that did not exist prior to 1990.

The ***cumulative output decline*** shows the percent difference between the end of transitional downturn (2000) and initial (1990) levels of GDP and is a proxy for the harshness of the transition affecting also the resource allocation towards innovative activities. Although most of the countries have surpassed the levels of development by 2004, exceptions can be found in the former Soviet republics and the war haunted Serbia and Montenegro.

In lines with the literature (Acs et al., 2002; Varsakelis, 2006) emphasizing the role of education in stimulating national innovation, an indicator for this ability is included in our analysis. Therefore I use the ***expenditure on tertiary and secondary education*** as a percentage of GDP in my regressions, under the assumption that a high educated labor force increases the amount of possible innovation undertaken in a country.

4.3 Research hypothesis

The main objective of this study is to reveal the main determinants of innovation for the EECs. Building on the strains of literature presented in Section 2 this study will also explore some pertinent research questions in the context of developing/transitional economies. These hypotheses are presented below.

[11] From the lowest 2 business days in Australia to 521 in Madagascar or a cost of 0.5percent of per capita GDP (USA) to 4.6 times per capita GDP in Dominican Republic.

[12] A distinctive feature of these economies was an oversized industrial sector as a part of the economic development strategy during the former regime. Most of the countries had to deal with this "legacy" throughout the 1990s in form of privatizations, restructurings or liquidation of industrial mammoths.

Hypothesis 1. *A stronger and effective the intellectual property rights regime increases the number of "new to the world" innovations that are produced in a country.* There is an ongoing debate whether developing countries should or shouldn't increase their legislative measures and enforce more vigorously in order to develop faster. One argument is that a strong IPR policy increases the incentives for producing local innovations and also attracts a larger amount of FDI with higher technological potential for spillovers (Smarzynska-Javorcik, 2002; Kanwar and Evenson, 2003). However, a multinational may invest only in labor intensive industries while the upstream R&D activities will still be reserved for the home office. Moreover, since IPR is applied equally over all sectors, the gains from attracting FDI in one industry may be offset by losses from the others that have benefitted through imitation (Léger, 2005; Glass, 2004).

Hypothesis 2. *The present EEC's ability to produce a stream of commercially relevant innovations relies more in present commitments rather than the existing stock of knowledge.* Thus, by this assumption, the current human capital and financial resources employed should have a greater impact on commercial innovations rather than the amount of previous knowledge. In the case of the EECs, these knowledge stocks are expected to be mostly outdated and concentrated in mature industries with a present low propensity to patent, another negative legacy of centralized economic systems (Radosevic and Kutlaca, 1999).

Hypothesis 3. *Transitional countries will rely more on public expenditure on R&D rather than their business sector, which usually is the main driver of innovation in developed economies.* Since the whole market economy system is still relatively new for the EECs, one could expect that the main push in innovative activities will come from publicly funded research institutions rather than private businesses which require time for building up competitiveness (Suarez-Villa and Hasnath, 1993; Hu and Matthews, 2005).

5. Empirical analysis and results

Most of the variables in the model specification enter in log form, yielding useful results in terms of subsequent interpretation (elasticities) and minimizing the influence of possible outliers. In this specification I cannot employ a fixed-effects estimation since it will discard all the information comprised in three key variables with only one time dimension[13]. Instead I use a GLS estimator and include various controls (year and regional dummies) to capture possible as much as possible from the unobserved heterogeneity among cross-sections (Wooldridge, 2002). Moreover, to make sure that my regressions are not spurious, I perform the most common two panel unit root tests involving regressions on lagged difference: Levin Lin and Chu (2002) which assumes a cross-sectional common unit root and Im, Pesaran and Shin (2003) that allows for individual unit root processes across sections. The outcomes of these tests are presented in the last two columns of Table 8 confirming that the variables employed are stationary.

In addition, I run a couple of diagnostic tests to make sure that the OLS assumptions are not violated and the estimates are efficient. The Breusch-Pagan Lagrange multiplier test for random effects tests if variances of groups are zero. The BP LM values reject the null only in the first and second model, suggesting that random effects should

[13] Effectiveness and enforcement of IPR, cost of doing business and cumulative transitional output drop.

be used in these cases against an OLS estimator. However, these two models are of no interest to the purpose of this study but presented to preserve similarities with previous studies presented in Sections 4 and 5. The results of the BP LM test confirm that an OLS estimator can be used for Models 3 and 4. Using a likelihood ratio test, homoskedasticity is firmly rejected in all models. Beyond this, serial correlation could also be biasing the estimates so I perform the test described by Wooldridge (2002). However, the null of no serial correlation can be rejected at 5 percent significance levels in all relevant models, proving that this is not an issue for these estimations.

As a result of the above and to accommodate all possible issues arising from the econometric estimation, I will use a FGLS (feasible generalized least squares) estimator that is robust to first-order panel-specific autocorrelation and panel heteroscedasticity. Table 10 presents the panel estimations. As a robustness check, I report in the last column of this table, the OLS estimation of the preferred model with Newey-West standard errors[14] which are both heteroskedasticity and autocorrelation consistent.

Model 1 estimates a simple production function for national innovations as suggested by Romer (1990) and Jones (2001) including the human resources devoted to the R&D sector and building on the stock of previous knowledge and technological capital proxied here by the GDP per capita levels, as in Furman et al. (2002). The results show that, the comparable level of GDP PER CAPITA and human resources devoted to R&D (RESEARCHERS) explain a good portion of the variance in the innovative output. Also, a 10 percent increase in the number of researchers is associated with a 7.44 percent increase in national patents at USPTO while a similar increase in GDP per capita levels will lead to a higher output by 8.70 percent, similar to previous studies.

Model 2 is meant to emphasize the impact of *current* and *previous* R&D efforts on national innovation. These are depicted, at a country level, by GERD and a direct measure of the existing knowledge stock (US PATENT STOCK), more appropriate than the one employed in Model 1. To avoid severe collinearity problems in the case of GERD TOTAL and RESEARCHERS (0.93), I divide the former in two components: human resources devoted to R&D (RESEARCHERS) and a R&D intensity measure (GERD PER RESEARCHER), which also varies a lot within the sample[15]. These three factors solely explain about 82 percent of the variation in patents (in the OLS estimation) and are highly significant statistically proving the importance of such commitments to the overall innovative capacity of a country.

Finally, **Model 3** comprises all variables from four postulated sources of NIC: the common innovative infrastructure, cluster specific factors and quality of inter-linkages along the year fixed effects to control for the variation in the annual rate of patenting. OPENNESS to trade is argued in the literature to play an important positive role as a channel for technology diffusion while DISTORTIONS synthesizes the structural distance of a former central planned economy from a free market benchmark. The intellectual property system and effective enforcement (IPR) comes positive and highly significant implying that one legislative and implementation efforts of tougher IPR will

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[14] Uses autocorrelations up to m=4 to compute the standard errors. For the truncation parameter I employ the usual rule of thumb and compute it as (0.75*(N^1/3)) which equals 3.92, rounded up to 4. The estimations for Models 1 to 3 are not reported here due to space constraints, but are available upon request.

[15] In 2002 the computed annual GERD per researcher ranged from $ 3,492 (Georgia) to $118,000 (Slovenia) in real PPP terms.

yield positive national outcomes as well. The regulatory and bureaucratic burden (COST OF DOING BUSINESS) acts as a break while the public support for innovation (GOVERNMENTAL R&D FUNDING) shows a positive influence over the number of international patents granted. As additional controls for the severity/adversity of economic transition in these countries, I use an aggregated CUMULATIVE OUTPUT DECLINE measure. The cluster specific factor (BUSINESS R&D FUNDING) shows the inefficiency of business driven R&D in these countries, where most of the firms are rather adopters and importers of technology rather than producers of new-to-the-world innovations. The quality of linkages proxied by the UNIV R&D PERFORMANCE emphasizes the importance of these connections for technology development, still underdeveloped in the Eastern European space. Consistent with Hu and Matthews (2005) the public finance of research (GOVERNMENTAL R&D FUNDING) has a positive effect over national patenting. This model explains about 90 percent of the variance in patents and most of the regressors remain statistically significant.

The last equation presents the preferred model (**Model 4**) which drops the statistically insignificant variables from the previous one. This yields similar estimates for all variables included and an overall fit, exploring also regional effects through regional dummies[16]. The results are robust and the OLS estimates with Newey West standard errors, reported in the last column, confirm the magnitude and significance of the FGLS estimates.

6. Discussion and conclusions

This study contributes to the developing empirical literature investigating the determinants of innovation at a national level in non-OECD countries, specifically the transitional countries of Eastern Europe. The approach undertaken builds on the theoretical grounds laid down by the national innovation systems literature and the eclectic combination of traditional economic modeling and qualitative approach shown in Furman et al. (2002).

From the results a number of interesting observations as well as policy recommendations emerge. When comparing the EECs to the OECD countries or the East Asian “tigers”, keeping in mind the methodological differences with these previous studies, one finds both important similarities and differences. The core common finding is that their variation in the rate of patenting is accounted by two variables, namely the past stock of R&D and the present commitments (expenditure and manpower). Similar to Western countries, the EECs’ output seems to be positively influence by stronger protection of intellectual property, trade openness and gross expenditure on research and development. The findings support the literature arguing for a better protection of intellectual right, especially in the case of the EECs who possess the human endowment but lack serious R&D investments. Such measures can attract foreign direct investment in high tech industries as well, breaking the usual pattern of shifting only the labor intensive industries from developed Europe East-wards. The increased openness to trade throughout the 1990s is positively correlated with the production of international patents acting both as a channel for technological infusion and a stimulus for domestic exporters

[16] For the former Soviet Union which have experienced the hardest transitional falls and the small Baltics.

in the few dynamic industries left in the EECs, such as pharmaceuticals. From the regression coefficients one can conclude that the emphasis in the EECs remains on the human commitments. This is probably due to the relative scarcity of funds contributing to GERD corroborated with an outdated stock of patents due to its regional specialization, yielding little potential for subsequent innovations. Different from OECD, but resembling the results for the Asian countries, I find that expenditure on tertiary and secondary education has little statistical impact, while public R&D funding increases the number of international patents, especially in the initial period when the private sector is still small in size. As expected, the macroeconomic transitional forces play an important role especially in the 1990s when the hard adjustments were taking place. The communist industrial legacy has left these countries with huge adjustment problems that have taken a high toll on social and economic development. However, by the year 2000 most of them have adjusted to a market type of economy and rebounded successfully from their transitional decline. Both the newly developed industrial distortions index and aggregated negative transitional shock (output decline) are influencing negatively and significantly the amount of new to the world innovation from EECs.

However, there are also aspects that are quite different from previous results. The impact of domestic business R&D spending over innovational output is negative and statistically significant in Eastern Europe, a robust result through various specifications and econometric estimations. This fact contradicts other findings pertinent to developed countries (OECD, NIC), where private R&D investment is an important driver of innovation[17]. In order to better understand this phenomenon, we have to take a closer look at Table 3 presenting the distribution of EEC's patent holders. There is an obvious concentration towards individuals and foreign entities in all countries in detriment of domestic ones, with Hungary having the most balanced mix, as a proof that only in this case all the channels are efficiently exploited[18]. However, the general trend is that domestic Eastern European firms are innovating less now than the in the past, fact confirmed also by the European Innovation Scoreboard (2006) in which with the exception of Slovakia and Czech Republic, all the listed EECs perform poorly in terms of business expenditures on research[19]. This reveals some structural weaknesses with firm level innovation identified in more detailed case studies of Poland (Kubielas et al., 2003), Hungary (Szalavetz, 2003), Slovenia (Bucar and Stare, 2003) or Romania (Gheorghiu and Turlea, 2003). With few notable exceptions[20], the domestic business environment has a low innovative potential which translates into a reduced international competitiveness, reliance on imports of technology and equipment and a predominant orientation towards trade and services. The current trend could have severe consequences in the near future and the importance of public policy in these matters is evident.

Another weakness of the EECs is represented by the linkages between business environment and higher education sector, virtually missing in terms of research and development. In a similar way, the importance of public R&D funding should remain a

[17] Moreover, the early EECs' statistics do not differentiate between private and public businesses and the later were predominant until the late 1990s (and still are in some countries).
[18] The notable exception being Slovenia, with a good domestic pharmaceutical industry but very low levels of FDI.
[19] Under 0.5 percent of GDP while the leaders (Sweden, Japan, USA) invest between 2.4 and 1.91 percent
[20] Countries like Hungary, Russia and Slovenia and only few industries (pharmaceutical, chemical, energy)

priority in many of these countries, which are now starting to explore the production of commercial innovations and lack a proper infrastructure to develop them. However, the recovery or development of such mechanisms does not take place in many of the EECs, which may explain their low international patenting rates.

To conclude, the overall findings fit the lines of previous literature. For the EECs as well, the R&D expenditure remains the most important factor in determining national innovative output, followed by the human resource commitment in form of researchers involved and to a lesser extent the existing tradition and knowledge stock ("standing on shoulders of giants" type of effect). Policy wise, better IPR protection and enforcement will probably attract both foreign investors in superior industries capable of locally creating new-to-the-world knowledge and motivate domestic firms and inventors. Trade openness functions successfully as a channel for technology diffusion but without the proper absorptive infrastructure (business financed R&D, high tertiary and secondary education, involvement of universities) cannot achieve the critical mass needed for domestic international patenting to become significant. The macro realities of transition have less and less of a negative effect in the present, when countries have improved and stabilized their economies through reforms and privatization. Overall, the analysis finds that both innovation oriented policies and a balanced innovation investment mix are, in the case of Eastern European countries, prerequisites to develop their national innovation capacities and ensure their competitiveness on international markets. Even though these countries are living proof that innovation takes place despite inefficient policies, the need for a sustained growth in the region through knowledge accumulation is obvious. This becomes even more important now, when the usual drivers (efficient reallocation of resources and comparative advantage in labor intensive industries) are slowly petering out through economic integration within a larger Europe.

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List of abbreviations

CEECs	Central and Eastern European countries including: Czech Republic, Hungary, Slovakia, Poland, Slovenia, Serbia, Estonia, Latvia and Lithuania.
CIS	Commonwealth of Independent States is the unofficial heir of the former Soviet Union (consists of 11 former Soviet Republics: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Ukraine, and Uzbekistan)
EECs	generically referring to all Eastern European countries; includes CEECs, SEEs (South Eastern countries: Albania, Bulgaria, Croatia, Romania, Bosnia-Herzegovina, Macedonia, Montenegro) and CIS countries
EU	European Union
FDI	Foreign Direct Investment
FGLS	Feasible Generalized Least Squares
GDP	Gross Domestic Product
GLS	Generalized Least Squares
IPR	Intellectual Property Rights
OECD	Organization for Economic Co-operation and Development
NBER	National Bureau of Economic Research
NIC	National Innovative Capacity
R&D	Research and Development
S & T	Science and Technology
WECs	Western European Countries
UIS	UNESCO Institute for Statistics
USPTO	United States Patent and Trademark Office

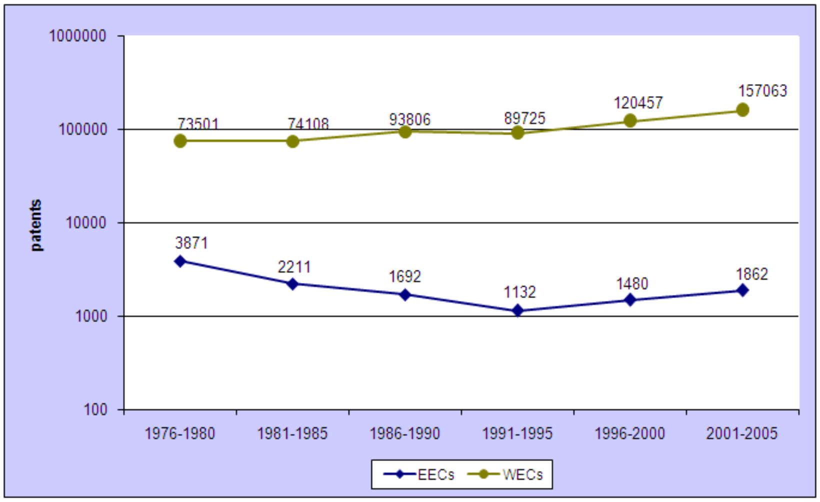

Figure 1 Trends in patenting in the USA. Eastern-Western European comparison

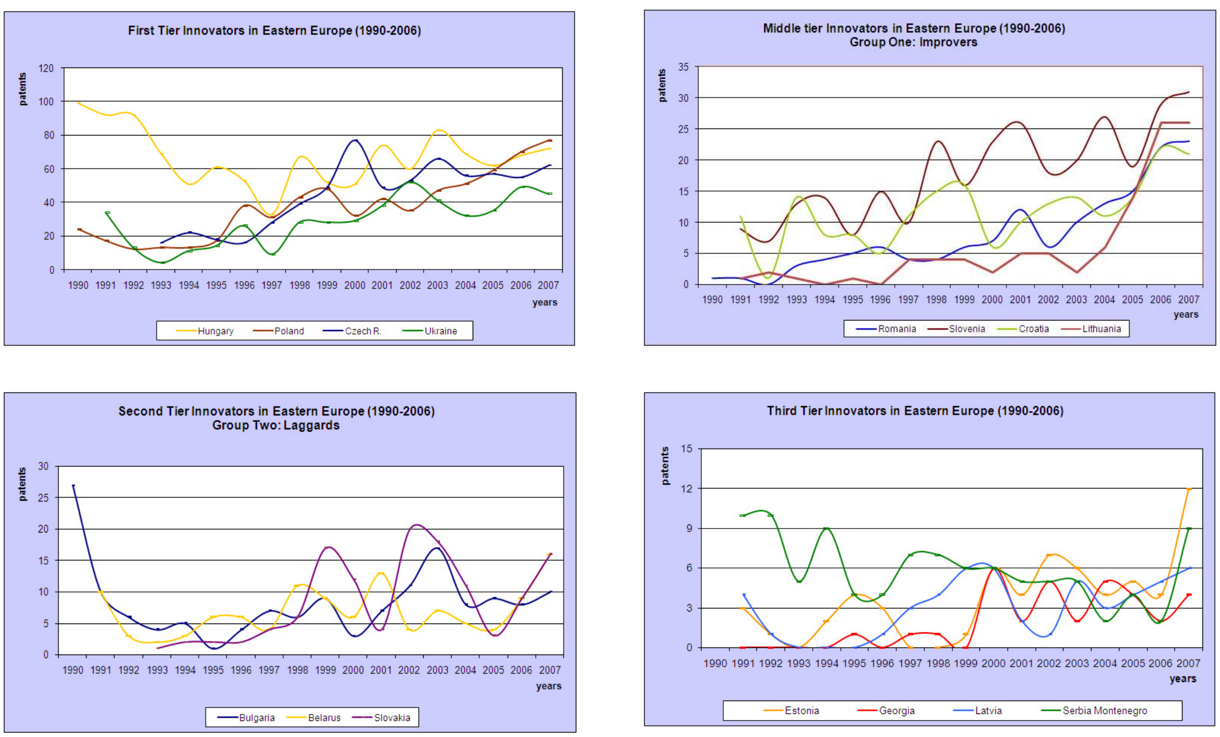

Figure 2 Innovators in Eastern Europe and conditional convergence (1990-2006)

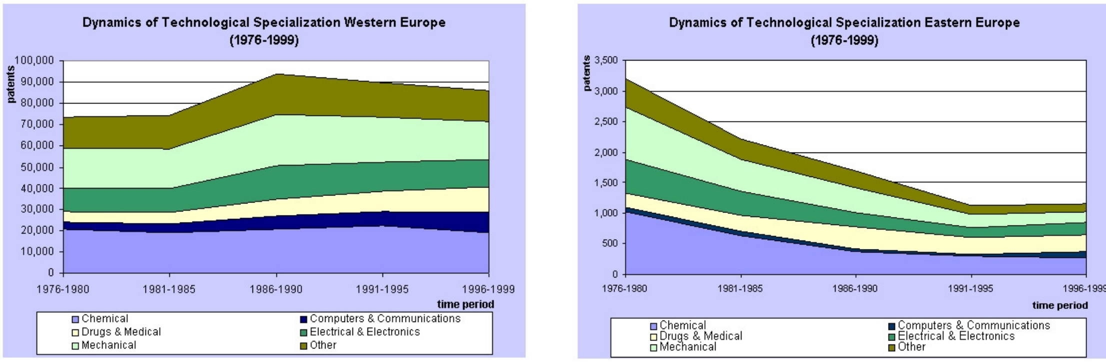

Figure 3 Technological specialization: East vs. West. Historical comparison

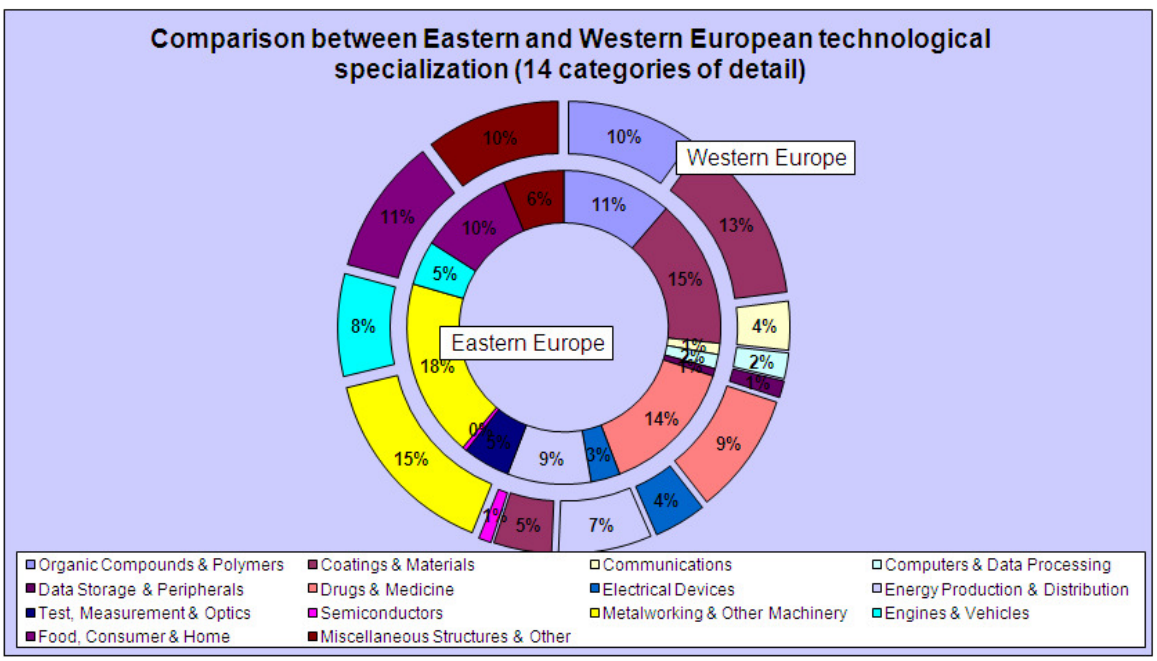

Figure 4 Detailed technological specialization comparison using USPTO patent stocks (1999)

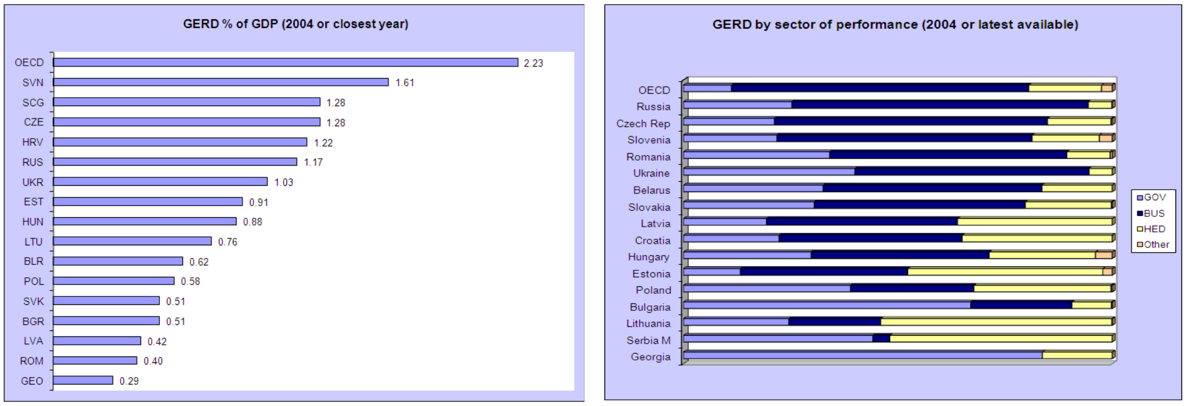

Figure 5a and 5b GERD in EECs as a percentage of GDP broken down by sources of funds
(GOV- Governmental, BUS- Business, HED- Higher Education)

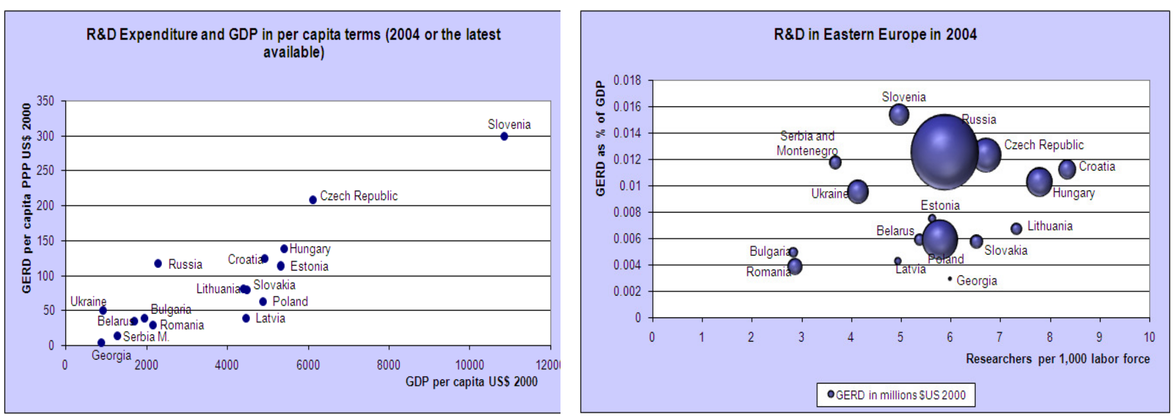

Figure 6a and 6b. R&D intensity, GDP per capita and researchers in Eastern Europe

Table 1 Variables employed for Eastern European countries in the sample (2004 or the latest available year)

Country	Population (millions)	GDP per capita ($ US 2006)	GDP per capita* ($ US PPP)	Recent real GDP growth (2001-05)	USPTO patents (90-06)	Researchers (thousands)	GERD (% GDP)	IPR index -	Trade Openness -	Cost Business (days)	Distortions -	Output decline (1990-2000)	Education spending (% GDP)	Public R&D (% GERD)	Private R&D (% GERD)	University R&D (% perf)
Bulgaria	7.7	3,683	9,975	4.9%	141	10.45	0.49%	5.14	141.47	32	0.296	-9.12%	2.40%	71.41%	18.52%	10.04%
Belarus	10.3	3,552	8,688	6.9%	101	18.56	0.62%	3.19	154.47	77	0.524	-9.72%	3.78%	32.60%	50.97%	16.43%
Czech Republic	10.2	13,035	20,563	3.2%	598	30.64	1.22%	9.57	154.13	36	0.274	3.31%	3.45%	22.97%	61.08%	15.63%
Estonia	1.3	9,882	17,672	6.2%	50	5.09	0.75%	5.72	178.04	47	0.261	5.52%	3.18%	16.97%	30.62%	47.82%
Georgia	4.7	986	3,277	7.2%	29	12.00	0.29%	3	87.8	22	0.184	-56.60%	1.85%	83.73%	-	16.27%
Croatia	4.5	8,422	13,186	4.3%	178	11.14	1.12%	3.71	115.39	48	0.167	-6.49%	3.25%	22.26%	42.66%	35.08%
Hungary	10.0	11,885	17,733	3.6%	1129	29.76	1.02%	11.25	164.03	45	0.266	12.52%	3.54%	32.85%	35.47%	25.16%
Lithuania	3.6	7,342	15,464	7.3%	77	9.52	0.67%	2.57	122.26	26	0.195	-24.77%	3.15%	33.39%	16.86%	49.75%
Latvia	2.3	7,175	13,938	7.4%	44	6.10	0.42%	5.76	99.71	16	0.242	-16.51%	3.45%	18.99%	40.88%	40.12%
Poland	38.5	8,602	14,137	3.0%	586	90.84	0.58%	9.69	66.46	31	0.143	41.14%	3.42%	45.46%	20.34%	33.92%
Romania	22.3	3,985	8,602	6.0%	118	24.64	0.38%	2.71	92.93	20	0.208	-12.92%	2.80%	24.17%	60.26%	15.56%
Russia	142.9	6,143	12,142	6.1%	3383	414.68	1.25%	6.08	75.23	35	0.425	-31.78%	1.68%	24.46%	69.88%	5.42%
Serbia and Montenegro	8.0	3,383	5,549	4.8%	91	10.86	1.17%	2.20	39.50	35	0.598	-37.86%	1.85%	44.19%	3.95%	51.86%
Slovakia	5.4	10,326	17,266	4.6%	111	15.39	0.57%	9.57	172.51	51	0.330	1.32%	2.92%	26.56%	64.33%	9.10%
Slovenia	2.0	18,816	23,102	3.4%	274	4.64	1.53%	10.56	123.47	60	0.108	19.77%	3.24%	23.06%	59.68%	15.55%
Ukraine	46.7	2,245	7,802	8.6%	437	85.21	0.95%	6.08	119.32	35	0.520	-54.15%	3.20%	40.00%	54.59%	5.41%

Table 2 Patent stock and intensity in Western and Eastern Europe as of 2005

Country	Patent stock*	Patent intensity**
Switzerland	44,471	5,937.88
Sweden	31,051	3,449.43
Germany	230,906	2,801.19
Finland	11,939	2,285.66
Netherlands	33,524	2,043.21
Denmark	10,161	1,870.47
France	95,830	1,579.89
Belgium	15,972	1,541.05
Austria	12,264	1,498.41
Norway	5,079	1,105.80
Iceland	244	822.28
United Kingdom	44,243	732.00
Italy	41,208	709.22
Ireland	2,537	631.77
Hungary	2,544	254.88
Slovenia	337	167.63
Spain	6,086	150.86
Czech Republic	1,344	131.31
Estonia	90	67.96
Bulgaria	461	62.42
Croatia	255	56.73
Greece	550	51.55
Russian Federation	5,743	40.19
Latvia	84	36.93
Slovakia	182	33.46
Belarus	303	29.44
Lithuania	97	27.05
Portugal	279	26.40
Ukraine	1,123	24.04
Poland	860	22.32
Serbia and Montenegro	161	20.12
Georgia	49	10.51
Romania	219	9.82

* USPTO patents between 1976 and 2005
** Current patent stock per million people

Note:
Patent stocks for countries with a different status prior to 1991 (USSR, Yugoslavia) or (1993) were estimated using the 5 year relative average percentage after they broke up.

Table 3 Main Eastern European patent holders*. Breakout by organizations**

	1990-1994			1995-1999			2000-2004		
	I	F	N	I	F	N	I	F	N
Bulgaria	4	0	7	5	0	0	13	0	0
Belarus	1	0	1	5	0	5	8	0	1
Czech Republic	..	..	..	10	5	10	32	22	8
Estonia	0	0	0	0	0	0	0	5	0
Georgia	1	0	0	3	0	0	2	8	0
Croatia	0	0	0	16	0	18	15	13	11
Hungary	49	0	237	49	27	70	66	59	48
Latvia	0	0	0	2	0	0	4	0	0
Poland	8	2	9	12	4	5	13	3	2
Romania	0	0	0	7	0	0	14	0	0
Russia	10	3	0	160	14	2	216	28	3
Slovakia	..	..	..	3	0	0	11	0	0
Slovenia	4	0	0	17	1	8	0	8	23
Ukraine	4	0	0	24	2	0	19	19	0

Source:

Based on a report from Patent Technology Monitoring Branch (PTMB) "Count of 1969 - 2005 Utility Patent Grants by calendar year of grant"
* Organizations receiving 5 or more utility patents during 1969-2004
** I - individuals; F - foreign entities (firms, universities); N - domestic entities (research institutes, institutions)

Table 4 Main organizations holding Eastern European patents in the communism (1969-1989)

No	Code	Name of the organization	Country	Patents	Main Field of Activity
1	N	CESKOSLOVENSKA AKADEMIE VED	Czechoslovakia	425	Education
2	N	RICHTER GEDEON VEGYESZETI GYAR RT *	Hungary	267	Pharmaceutical
3	N	CHINOIN GYOGYSZER ES VEGYESZETI TERMEKEK GYARA RT. *	Hungary	224	Pharmaceutical
4	N	ELITEX ZAVODY TEXTILNIHO STROJIRENSTVI GENERALNI REDITELSTVI	Czechoslovakia	121	Textiles
5	N	VYZKUMNY USTAV BAVLNARSKY	Czechoslovakia	105	Textiles
6	N	EGYT GYOGYSZERVEGYESZETI GYAR	Hungary	69	Pharmaceutical
7	N	SPOFA, UNITED PHARMACEUTICAL WORKS	Czechoslovakia	52	Pharmaceutical
8	N	ADAMOVSKE STROJIRNY, NARODNI PODNIK	Czechoslovakia	50	Polygraphic presses
9	N	VYZKUMNY A VYVOJOVY USTAV ZAVODU VSEOBECNEHO STROJIRENSTVI	Czechoslovakia	50	Metallurgy
10	N	INSTITUT ELEKTROSVARKI IMENI E.O. PATONA AKADEMII NAUK UKRAI	USSR	48	Metallurgy
11	N	ELITEX, KONCERN TEXTILNIHO STROJIRENSTVI	Czechoslovakia	36	Textiles
12	N	MEDICOR MUVEK	Hungary	30	Medical equipment
13	N	ESZAKMAGYARORSZAGI VEGYIMUVEK	Hungary	29	Chemical
14	N	INSTITUT GORNOGO DELA SIBIRSKOGO OIDELENIA AKADEMII NAUK SSS	USSR	25	Metallurgy
15	N	INSTITUTE PO METALOZNANIE I TECHNOLOGIA NA METALITE	Bulgaria	24	Metallurgy
16	N	MINISTERUL INDUSTRIEI CONSTRUCTIILOR DE MASINI	Romania	23	Government
17	N	VSESOJUZNY NAUCHNO-ISSLEDOVATELSKY I PROEKTNO-KONSTURKTORSKY	USSR	22	Constructions
18	N	POLITECHNIKA GDANSKA INSTYTUT CHEMII I TECHNOLOGII ORGANICZN	Poland	19	Education
19	N	POLITECHNIKA WARSZAWSKA	Poland	19	Education
20	N	LEK TOVARNA FARMACEVTSKIH IN KEMICNIH IZDELKOV, N.SOL.O.	Yugoslavia	17	Pharmaceutical

Source:

Based on a report from Patent Technology Monitoring Branch (PTMB) "Count of 1969 - 2005 Utility Patent Grants by calendar year of grant"
* Organizations receiving 5 or more utility patents during 1969-2004
** F - foreign entities (firms, universities); N - domestic entities (research institutes, institutions)

Table 5 Main organizations holding Eastern European patents in transition period (1989-2005)

No	Code	Name of the organization	Country	Patents	Main Field of Activity
1	N	RICHTER GEDEON VEGYESZETI GYAR RT	Hungary	79	Pharmaceutical
2	N	CHINOIN GYOGYSZER ES VEGYESZETI TERMEKEK GYARA RT.	Hungary	74	Pharmaceutical
3	N	EGIS GYOGYSZERGYAR	Hungary	63	Pharmaceutical
4	F	GENERAL ELECTRIC COMPANY	Hungary	51	Various
5	F	SAMSUNG ELECTRONICS CO., LTD.	Russia	36	Electronics
6	N	ELBRUS INTERNATIONAL LTD.	Russia	32	Computer Technology
7	F	LSI LOGIC CORPORATION	Russia	31	Communications; Semiconductors
8	F	GENERAL ELECTRIC COMPANY	Russia	30	Various
9	F	SUN MICROSYSTEMS, INC.	Russia	30	Computer Technology
10	N	BIOGAL GYOGYSZERGYAR RT.	Hungary	26	Chemicals
11	N	PLIVA FARMACEUTSKA, KEMIJSKA, PREHRAMBENA I KOZMETICKA	Croatia	24	Pharmaceutical; Cosmetics
12	N	LEK PHARMACEUTICAL AND CHEMICAL COMPANY D.D.	Slovenia	24	Pharmaceutical;Chemicals
13	F	AJINOMOTO COMPANY INCORPORATED	Russia	21	Food
14	F	CERAM OPTEC INDUSTRIES, INC.	Russia	21	Optical fiber; Lasers
15	N	OTKRYTOE AKTSIONERNOE OBSCHESTVO "NAUCHNO-PROIZVODSTVENNOE OBIEDINENIE "ENERGOMASH" IMONI AKADEMIKA KAKSOLMIKA V.P. GLUSHKO"	Russia	20	Energy; Engines
16	F	R-AMTECH INTERNATIONAL, INC.	Russia	19	Emerging Technologies
17	F	TELEFONAKTIEBOLAGET LM ERICSSON	Hungary	18	Telecommunications
18	N	TUNGSRAM RESZVENYTARSASAG	Hungary	18	Lighting
19	F	BOSCH SIEMENS HAUSGERATE GMBH	Slovenia	16	Household appliances
20	F	UNIVERSITY OF CHICAGO	Russia	16	Education
21	F	SEMICONDUCTOR COMPONENTS INDUSTRIES, LLC	Czech Republic	15	Semiconductors
22	N	GYOGYSZERKUTATO INTEZET KFT	Hungary	15	Pharmaceutical

Source:

Based on a report from Patent Technology Monitoring Branch (PTMB) "Count of 1969 - 2005 Utility Patent Grants by calendar year of grant"
* Organizations receiving 5 or more utility patents during 1969-2004
** F - foreign entities (firms, universities); N - domestic entities (research institutes, institutions)

Table 6 Index of Intellectual Property Protection Effective Enforcement

Score	Description
3	Close to adequate IPR legislation present by the end of 1995; some enforcement efforts undertaken
2	Close to adequate IPR legislation present by the end of 1995; no enforcement efforts undertaken
1	Lack of adequate IPR legislation at the end of 1995

Source:

Building on Smarzynska Javorcik (2002)

Variable	Full variable name	Definition	Source
PATENTS $_{j,t+2}$	USPTO patents to country j in year t+2	All patents granted to inventors from country j	USPTO Online Database; author's own calculations
GDP PER CAPITA $_{j,t}$	GDP per capita in US $ 2000 constant	Gross domestic product per capita in constant prices	World Bank Development Indicators 2007
US PATENT STOCK $_{j,t}$	USPTO patent stocks up to year t for country j	The stock of all patents granted to country j between 1976 and year t computed using perpetual inventory method	USPTO Online Database; author's own calculations
RESEARCHERS $_{j,t}$	The number of researchers	The total number of labor employed in R&D activities (head count)	UNESCO Statistical Yearbook 1999;UIS S&T database; Eurostat; various national statistics offices
R&D INTENSITY $_{j,t}$	Aggregated R&D expenditure per researcher employed	Total R&D expenditures (millions US$ 2000) per number of researchers	UNESCO Statistical Yearbook 1999;UIS S&T database; Eurostat; various national statistics offices
IPR $_{j}$	Intellectual property protection and enforcement index	The actual effective degree of protection and enforcement of intellectual property in country j	own calculations based on Ginarte and Park (1997); Park and Wagh (2002); Smarzynska (2002);
OPENNESS $_{j,t}$	Degree of openness to international trade	Exports plus imports divided by GDP in constant prices, expressed as a percent	own calculations
COST DOING BUSINESS $_{j}$	Cost of doing business in country j	Number of days necessary to start a business in country j (average of available years 2003-2006)	World Bank Doing Business database
EDUCATION $_{j,t}$	Spending on higher education as a % of GDP	Percentage of GDP spent on secondary and tertiary education	World Bank Edstat data
PUBLIC R&D FUNDING $_{j,t}$	Percentage of R&D funded by government	R&D expenditures funded by government divided by total R&D expenditures	UNESCO Statistical Yearbook 1999;UIS S&T database; various national statistics offices
DISTORTIONS $_{j,t}$	Structural distortion index	Industrial distortion index as the sum of deviations from the benchmark shares of employment in four sectors	own calculations
OUTPUT DECLINE $_{j}$	Cumulative output decline in transition	The percent difference between 2000 and 1990 GDP levels (US$ 2000)	WDI 2007; author's own calculation
BUSINESS R&D FUNDING $_{j,t}$	Percentage of R&D funded by private businesses	R&D expenditures funded by industry divided by total R&D expenditures	UNESCO Statistical Yearbook 1999;UIS S&T database; various national statistics offices; OECD MSTI 2007
UNIVERSITY R&D PERFORMANCE $_{j,t}$	Percentage of R&D performed by universities	R&D expenditures funded by higher education divided by total R&D expenditures	UNESCO Statistical Yearbook 1999;UIS S&T database; various national statistics offices; OECD MSTI 2007

Table 7 Variables, measures, definitions and sources

Table 8 Descriptive statistics of the variables employed and panel unit root tests

Variable	N	Mean	Std. Dev.	Min	Max	LL	IPS
Log Patents	257	2.480	1.364	0.000	5.841	-6.23***	-4.17***
Log GDP per researcher	209	2.173	0.908	-0.616	4.214	-11.57***	-4.92***
Log Researchers	220	9.987	1.288	8.218	13.808	-2.57***	1.22
Log Stock of USPTO patents	288	3.812	1.498	0.286	7.409	-5.84***	-3.90***
Log Openness to Trade	232	-7.195	0.585	-9.419	-5.960	-4.37***	-2.93***
IPR index	288	6.050	3.041	2.200	11.250	-	-
Cost business	288	38.449	15.272	16.000	76.500	-	-
Education share	196	0.031	0.007	0.013	0.048	-4.53***	-1.40*
Governmental R&D funding	165	0.700	2.760	0.200	35.900	-1083.1***	-170.98***
Log Distortion Index	236	-1.202	0.420	-2.253	0.202	-4.08***	-2.55***
Transitional output decline	288	-11.021	25.282	-56.598	41.140	-	-
Business R&D funding	167	0.423	0.149	0.077	0.728	-8.37***	-1.40*
University performed R&D	178	0.204	0.143	0.019	0.560	-8.19***	-0.89

Note:

All panel unit root tests include individual effects and individual linear trends;
Variables for which a value for this test is not available do not possess a time dimension in our data set;
The null hypothesis for these tests is non-stationarity (unit root);
*, ** and *** indicate parameters that are significant at the 10%, 5% and respectively 1%;

Table 9 Pair-wise correlations

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	log(US patents)	1.00												
2	log(gerd/researcher)	0.27	1.00											
3	log(researchers)	0.65	-0.25	1.00										
4	log(US patent stock)	0.89	0.31	0.68	1.00									
5	log (openness_trade)	0.18	0.38	-0.24	0.31	1.00								
6	IPR regime	0.50	0.55	0.09	0.48	0.27	1.00							
7	cost of doing business	0.08	0.35	-0.14	0.20	0.44	0.26	1.00						
8	education spending	-0.44	0.00	-0.43	-0.43	0.08	0.02	0.20	1.00					
9	GERD funded government	-0.02	0.11	-0.10	-0.08	0.02	0.08	0.10	-0.04	1.00				
10	log(industrial distortions)	-0.02	-0.42	0.35	0.05	-0.09	-0.23	0.12	-0.01	-0.03	1.00			
11	cummulative output drop	0.19	0.67	-0.23	0.23	0.23	0.67	0.36	0.08	0.09	-0.55	1.00		
12	GERD funded business	0.25	0.32	0.33	0.30	-0.17	0.34	0.07	-0.27	0.01	0.06	0.04	1.00	
13	GERD performed university	-0.28	0.08	-0.49	-0.32	0.11	-0.16	-0.10	0.47	0.06	-0.28	0.13	-0.61	1.00

Table 10 Determinants of new Eastern European innovations (FGLS estimation)

Dependent Variable = LN (PATENTS) $_{j,t+2}$						
MODELS		**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 4'**
Variables		Baseline model	R&D commitments	Full specifications	Preferred model	OLS Newey West †
Common innovative infrastructure						
A	LN GDP PER CAPITA	**0.870*** **				
		(0.086)				
A	LN US PATENT STOCK		**0.646*** **	**0.358*** **	**0.397*** **	**0.429*** **
			(0.058)	(0.094)	(0.081)	(0.075)
H_A	LN RESEARCHERS	**0.744*** **	**0.208** **	**0.527*** **	**0.576*** **	**0.636*** **
		(0.069)	(0.064)	(0.144)	(0.085)	(0.097)
H_A	LN GERD PER RESEARCHER		**0.257*** **	**0.477*** **	**0.441*** **	**0.588*** **
			(0.067)	(0.119)	(0.109)	(0.149)
X^{INF}	OPENNESS			**0.210**	**0.157**	**0.393***
				(0.201)	(0.187)	(0.198)
X^{INF}	IPR			**0.140*** **	**0.122*** **	**0.083** **
				(0.039)	(0.035)	(0.031)
X^{INF}	COST DOING BUSINESS			**-0.009**		
				(0.010)		
X^{INF}	EDUCATION SHARE			**1.77**		
				(7.488)		
X^{INF}	GOVERNMENTAL R&D FUNDING			**0.014**	**0.014**	**0.014*** **
				(0.012)	(0.010)	(0.005)
Transition specific Factors						
T^{TRANS}	DISTORTIONS			**-0.349** **	**-0.432*** **	**-0.491***
				(0.174)	(0.157)	(0.264)
T^{TRANS}	OUTPUT DECLINE			**-0.017*** **	**-0.018*** **	**-0.016*** **
				(0.005)	(0.004)	(0.005)
Cluster specific innovation environment						
Y^{CLUS}	BUSINESS R&D FUNDING			**-0.652**	**-0.837***	**-1.381** **
				(0.597)	(0.494)	(0.575)
Quality of linkages						
Z^{LINK}	UNIV R&D PERFORMANCE			**1.528** **	**0.801**	**0.707**
				(0.751)	(0.548)	(0.710)
Controls						
	CIS dummy			**0.586**	**0.245**	**0.201**
				(0.477)	(0.149)	(0.234)
	Baltics dummy			**-0.207**	**0.072**	**0.107**
				(0.359)	(0.225)	(0.269)
	Year fixed effects	no	yes	yes	yes	yes
Constant		**-11.744*** **	**-2.370*** **	**-4.270***	**-5.282*** **	**-4.915*** **
		(1.054)	(0.718)	(2.350)	(1.240)	(1.165)
Wald Chi square / F test		173.94***	590.18***	1578.72***	1482.01***	3713.92***
N		214	204	134	143	143
LR test: Ho no heteroskedasticity		226.04***	152.46***	101.97***	115.23***	115.23***
Breusch-Pagan LM test: Ho: OLS; Ha: GLS;		110.13***	40.42***	2.60	3.25*	3.25*
Woolridge test: Ho no serial correlation		7.091**	8.605*	5.241*	4.455*	4.455*

GLS estimation robust to heteroskedasticity and group specific autocorrelation of order one.
* P<0.1; ** P< 0.05; *** P<0.01; † Regression with Newey-West standard errors (maximum lags = 4)

Appendix A: Data note

Sample countries

The 16 countries considered for this study includes: Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Poland, Romania, Russia, Serbia and Montenegro, Slovakia, Slovenia and Ukraine.

Patent counts

Patent counts are drawn from the USPTO Full Text Database available online containing all patents issued in the USA to inventors originating in our sample countries. I use this measure instead of the usual "first inventor" utility patent measure for two reasons: first, the at the beginning of our analysis these countries were just getting started thus their patent numbers are very low and by using an "all inventor" approach the number of zero yearly totals is lowered; secondly, this measures allows for collaborative inventions which have an Eastern European inventors but not necessarily restricting us to the first one listed. The two aggregated counts are however very strongly correlated (0.9865) thus by doing this I gain a bit in terms of variance while taking into account all innovative output with origins in the EECs. Also, for accuracy, the early numbers have been corrected in the case of countries that have broken up during or at the beginning of the 1990s by individual patent assessment and reassignment of those emitted after the breakup point towards one of the former component countries based on the geographical location of the inventor. All null observations have been converted to 0.001 in order to make it possible to take logs.

Patent stocks

For computations of the patent stocks in year t, I use the perpetual inventory model and taking into account the number of patents flows between the initial year 1963 and t-1. The initial patent stock was computed using the method developed by Griliches (1990): $S_0 = P_0 / (g + \delta)$ where g is the average growth rate for the first ten years of available data and δ is the depreciation rate, set at 15%, the most common rate used in the literature for discounting patent flows. The subsequent stocks are computed as $S_t = (1- \delta)\ S_{t-1} + P_t$, where P_t equals the flow of patents from the current year.

Openness to trade

Data comes on imports, exports from the IMF Direction of Trade Database 2007 (DOTS). Openness to trade is computed as the total trade amount (imports plus exports) as a proportion of GDP.

Researchers

The total head count takes into account also a rather small percentage (usually between 5 and 10 percent of the total) of technicians and auxiliary personnel which are supporting the innovative activity of full time researchers.

Intellectual Property Rights (IPR) index

The most widely used in similar studies use the Ginarte and Park (1997) index of patent rights or its updated version by Park and Wagh (2002) which place Hungary and Croatia on top, while Lithuania and Bulgaria are on the opposite side of the spectrum[1]. However, in the case of the EECs as well as in many other developing countries, the "official" enforcement standard often differs significantly from the actual existing one. In order to control for this, a measure of the actual enforcement implemented in these countries is more appropriate (Radosevic, 2004). Thus, an IPR index like the one developed by Smarzynska Javorcik (2002) serves better our analysis[2] (see Table 6, Annex 1). The IPR index employed is a combination of the above two dimensions: legislative protection (Ginarte-Park index) and the degree of enforcement (US Special 301). I have extended it also for the former Yugoslav republics which were not covered (e.g. Serbia and Montenegro, Slovenia and Croatia) based on the same ranking guidelines which are in Table 6.

Cost of doing business

The variable used in this study was computed using the 2003-2006 average duration for starting up a new business, indicating the regulatory cost of business. World Bank's Doing Business database provides objective measures of business regulations and their enforcement in comparable terms across 175 economies. The limitation of this dataset is given by its rather short time span (2003-2006) which covers only a relatively recent period.

Industrial distortion index

The distortion index is based on the benchmark employment percentages in four broad sectors (agriculture, industry, market-oriented services and non-market-oriented services) in 50 other market based economies and after controlling for levels of GDP following the estimation in Raiser et al. (2004)[3]. The index is computed using the Euclidian distance formula as follows:

$DIST_{j,t} = SQRT\{(S_a - S_a^b)^2 + (S_i - S_i^b)^2 + (S_{ms} - S_{ms}^b)^2 + (S_{nms} - S_{nms}^b)^2\}$,

where S_i represents the actual share of employment in sector i and S_i^b represents the benchmark share in the same sector. The index is a measure of the overall distance of an economy from a market economy with the same per capita income. The values come from my own computations using employment data available through LABORSTA (the International Labor Office statistics database) and GDP per capita levels from the World Bank's Development Indicators 2007.

Expenditure on tertiary and secondary education

The public national expenditure on education is collected mainly from the World Bank's EdStats database and completed with data from national statistics offices. The

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[1] This index is constructed by taking into account five dimensions of patent protection: the extent of coverage, membership in international patent agreements, protection from restrictions on patent rights, duration and mechanisms of enforcement, all broken down into sub-categories with assigned weights yielding final index values between 0 and 5, with 5 being the highest degree of IPR protection.

[2] This simple index is capturing both the legislative and actual enforcement of the IPR regime and it is based on the description of IPR regimes by the International Intellectual Property Alliance in their recommendations for countries to be placed on the US Special 301 Watch list paying close attention to trademark and copyright laws.

[3] However, their index is defined differently as the sum of absolute values of (s-s*) divided by 2, where s is the actual share of employment in sector j, and s* is the benchmark in the same sector.

percentages of tertiary and secondary expenditures vary between 0.42 and 0.73 among countries but very little over time within the same national entity.