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Drivers of national innovation in transition: Evidence from an Eastern European panel

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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 study attempts to answer this question by analyzing in premiere a panel of sixteen Eastern European transition countries. It provides a detailed description of innovation by identifying regional differences in terms of historical heritage, technological specialization, commitments and main actors involved in this process, before and after the fall of communism. Secondly, it explores empirically the main drivers of their innovative output, proxied by patents, using a variety of econometric techniques. The results confirm the importance of R&D commitments from both public and private sources, the crucial role of universities and existing national knowledge base. Policy measures such as intellectual property rights protection or the business climate impact significantly the propensity to patent, while measures of transitional downturn and industrial restructuring have an important negative effect. Finally, globalization contributes to developing new innovations via inflows of foreign investment and trade.

JEL Codes: O30; O47; O57; P20;
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1. Introduction

In today's dematerialized and global economy, the ability of a country to develop, adapt and harness its innovative potential is becoming critical in terms of long term economic development and competitiveness. This fact, widely confirmed in the endogenous growth literature, is starting to generate concrete policy results 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.

This study makes a contribution to the literature by analyzing innovation and its determinants in former centralized economies from Eastern Europe and the former Soviet Union that have been excluded from previous work. Since early 1990s these countries experienced a painful transition from a closed centralized economy to a free market one that impeded not only their economic performance but also their innovational capacities. This has enhanced both the existing East-West technological divide in Europe and the important differences between transition countries in terms of efforts to innovation, technological specialization or foreign apportion from multinationals. Such significant heterogeneity along the effects of transition make this topic a very interesting but extremely challenging one both in terms of encompassing all relevant factors and data requirements. Using a newly constructed panel that national R&D inputs and policies, links between business and innovation's infrastructure, transition and globalization impacts, I provide an eclectic but consistent approach to explain the evolution of innovation output in these countries.

The objective of this study is to identify and quantify the determinants of innovation and provide some policy pointers for transitional and developing countries towards achieving a more efficient national system of innovation. 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 innovation capacities which will ensure sustained growth and competitiveness in the region.

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 providing both historical and regional comparisons. Section 4 presents the empirical approach and the dataset employed while Section 5 reports the results. Finally, Section 6 concludes, discussing the findings and policy implications.

2. Perspectives on national innovation

Since the relationship between economic growth and technological development has been postulated in the literature[1], the question of analyzing the determinants of this capacity of countries to generate flows of new knowledge has been investigated by numerous scholars. In order to gain further insights on this issue, the quest for finding good, available and rigorous proxies for innovation has given birth to a significant and increasingly sophisticated literature using patents and patent related measures for this purpose.

As a result, patents become a common measure for innovation output and a good way to track 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[2]. 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).

The relationship between R&D effort and patents has been extensively explored, especially at the micro and mezzo level. Cross-sectional studies suggest elasticities close to one (Hall et al., 2001; Griliches, 1990; Bottazi and Peri, 2003) while panel based ones confirm decreasing returns to scale using both dynamic (Blundell et al., 2002) and non-dynamic (Hausman et al., 1984; Hall et al., 1986) estimations between 0.30 and 0.50. Industry level studies come up with a similar elasticities between 0.48-0.52 (Kortum and Lerner, 2002). Nevertheless, firm level studies and to a lesser extend sector level, may miss in their estimations to true magnitude of spillovers occurring between firms, sectors and countries founded to be significant (Coe and Helpman, 1995; Jaffe, 1986; Schiff et al., 2002).

There are only few empirical investigations at the aggregate level looking across countries at innovation inputs and its determinants. However, most of this work suffers from small samples and failure to deal with unobserved heterogeneity and endogeneity problems. Keeping this in mind, patent protection, openness and cultural factors (Varsakelis, 2001) as well as government expenditure (Bebczuk, 2002) have a close relationship with R&D investment around the world. Lederman and Maloney (2003) find out that R&D intensity increases with development level while the protection of intellectual property, government investment and the quality of research institutions are the main reasons behind this surge. Moreover they examine the under-performance of Latin America and outstanding outliers like Finland, Israel, Korea or Taiwan that have radically deviated from their predicted trajectory, displaying impressive R&D takeoffs. Both their analysis and the follow-up by Bosch et al. (2005) cover industrial and developing countries

[1] Several canonical models assume constant returns to knowledge along large spillovers that lead to growth increases (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992; Jones, 1995)

[2] 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.

and controls for endogeneity issues.

Similarly, the evidence on what determines innovation output at the country level is also weak. Assuming 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 , in the case of several Latin American and Caribbean countries (Waguespack et al., 2005). Rather than focusing on few specific factors, the concept of national innovative capacity (NIC) investigates the overall sources of innovation systems at the country level (Furman et al., 2002, henceforth FPS). Thus, the NIC concept, defined as the ability of a country to produce and commercialize a flow of innovative technology over the long run, converges three main sets of ideas: a) the "knowledge production function" from endogenous growth theory (Romer, 1990; Jones, 1995); b) Porter's (1990) interaction between the private sector and the national industrial clusters and c) the national innovation systems (NIS) literature supporting the idea that innovation is significantly affected by the interaction of institutions constituting a complex system at work[3] (Freeman, 1982; Lundvall, 1992; Nelson, 1993). FPS test this conceptual framework using 17 OECD countries while the subsequent extensions (29 OECD countries - Furman and Hayes, 2004) and East Asian tigers (Hu and Matthews, 2005) validate their conclusions.

With respect to Eastern Europe, the existing literature is confined to either descriptive analyses or case studies[4]. Radosevic and Auriol (1999) depict six Central and Eastern European countries in these terms and conclude that despite their "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 stocks in sources of growth. Radosevic and Kutlaca (1999) decide that income levels are important in determining EEC patenting rates, their technological specialization is very much path dependent and there is significant country heterogeneity in how R&D is conducted. Marinova (2000)[5] emphasizes the sharp transitional decline in patents revealing regional and country specific strengths in this area while Radosevic (2004) using new data on NIC variables confirms the intermediate position of EECs at the lower innovative spectrum within the EU.

[3]Such as university systems, intellectual property, historical industrial organization, R&D labor division, private industry structure and governmental support.

[4]For a recent collection of such case studies see the volume edited by Piech K. and Radosevic S. (2006).

[5]However, this study has some severe deficiencies. First, the use of aggregated former entities (e.g. Yugoslavia, USSR) after their official secession is hard to justify. Secondly, the USPTO methodological inconsistencies (coding of countries, not corrected until 2006) yielded systematically downward biased counts for some EECs, the newly formed countries especially.

3. Stylized facts about Eastern European innovation

At the beginning of the 1990s a huge natural experiment began when Eastern Europe has suddenly embarked on its way towards a free market system. This deep transformation was also a painful one with important macro-economic disturbances[6] and institutional collapse following the regime shift. The resulted U-shaped response from the GDP, with a sharp initial decline followed by a recovery in the late 1990s, has left its mark on innovation output as well. In this section I am going to explore some stylized facts about Eastern European innovation, looking in detail both at its inputs (R&D commitments) and outputs (US patents) attempting to identify its main drivers at the country level.

a. East-West historical divide

The difference between Eastern (EECs) and Western Europe (WECs) in producing new technologies or products is quite significant. Moreover, this holds also in historical context when comparing their international patenting numbers (see Figure 1) or patent intensity, defined as the stock of patents per capita (Table 2).

4. (Figure 1 here)

This fact has multiple causes which are hard to disentangle. 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, even the most successful EECs are far away from the frontier, between the southern periphery of Western Europe (Spain, Portugal and Greece) and the EU-15 core, while the emerging ones still struggle at the bottom of this classification (see Table 2). With regards to patent assignees[7] , things have substantially changed in transition, mainly due to the recognition of private and intellectual property. Thus, 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 heterogeneity

There are also significant differences between and within 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[8]. 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 3 695 patents between 1990 and 2007. The rest of 15 countries in our sample[9] can be grouped in innovative terms into three categories. **First tier** innovators average patent stocks between 400 and 1300 during 18 years of transition. Hungary (1 208) is the most consistent but in a slight regression comparative with the prior period, Czech Republic (663) and especially

[6] Capital stock shrinkages, labor force movements, trade reorientation, significant structural changes.

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

[8] Down from about 66% in the late 1970s to 50% in the early 1980s and about 40% between 1985 and 1990.

[9] Countries that have a total of 30 or more first inventor patents in this 18 year interval; the rest are two small to be taken into account and/or with a lot of zero counts.

Poland (669) have shown remarkable improvements while Ukraine (480) just rebounded after a sharp drop in the early 1990s. The **second tier** averaged between 100 and 400 first inventor patents in this interval and is divided into two subgroups: **improvers** like Slovenia (308), Croatia (199), Romania (142) and a surprising Lithuania (105), with lower starting points and significant growth and **laggards** such as Bulgaria (152), Belarus (118) or Slovakia (127) exhibiting higher initial starting points but an overall stagnating or 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 (51), Estonia (62), Georgia (34) and Serbia and Montenegro (100), a shadow in innovation terms of the former Yugoslavia.

(Figure 2 here)

3.3 Specialization patterns

Without a doubt the decades of communist isolationism had influenced the EECs towards certain technologies. To compare their technological paths with those of Western countries, I employ the NBER US Patent dataset by Hall, Jaffe and Trajtenberg (2001) and their classification into six broad technological categories[10]. The results confirm a significant decrease in EECs' innovation output over the last 30 years and a significant change in their innovation mix in the first transitional decade (see Fig. 3).

(Figure 3 here)

When 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 a strong correlation between the level of income and the national commitments to innovation supporting the conclusions of endogenous growth theory (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

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

between EECs and WECs are tremendous and the GERD figures, even in relative terms, are significantly below the OECD median level. The 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 6a & 6b 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 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.

3.6 Summary

Historically, the EECs' innovative productivity has been declining since the late 1970s associated with growing inefficiencies of the communist regime. Moreover, the transitional shock made things worse inducing significant reductions in total R&D commitments. 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 innovation

4.1 Theoretical framework

The theoretical specification departs from an endogenous growth model and includes additional controls for a small open economy. The objective of this paper is purely empirical, thus a full model will not be provided in this context[11]. This generic economy has three sectors producing goods: output (consumption good), a human capital good (experience, education or skill) and new varieties of capital goods (ideas, innovations). Since we are interested in the latter, the production function of new ideas builds on Jones's (1995) specification augmented by additional factors that impact innovation stemming from international economics and the national innovation systems (NIS) literature:

[11] For more details please see the original papers.

$$\dot{A}_t = \delta h_t^{\beta} L_{At} A_t^{\phi} \Omega_t$$

represents the flow of new ideas at time t, h the average skill of labor while δ is the productivity of skilled adjusted unit of labor that increases with the existing stock of ideas A, consistent with a "standing on shoulders of giants" effect of inter-temporal knowledge spillovers (we expect $\phi > 0$). L_A is the share of effort (general R&D, but here we have only labor inputs) devoted to the "ideas" sector. Ω is a vector that comprises other factors that impact the idea production process both within a national (institutions, policies, resources) and international (trade, foreign direct investment) framework.

The final good (output) is produced by competitive firms employing labor (L_Y) and intermediate goods (x_i). The amount of human capital per worker determines the range of intermediate goods that firms can use. Hence the production function in this sector for a firm hiring workers with an average skill level h is:

$$Y = L_y^{1-\alpha} \int_0^h x_i^{\alpha} di$$

exhibiting constant return to scale since $\alpha \in (0,1)$. By assigning a simplifying one to one transformation between intermediate goods and units of capital the integral equals to K and the production of final output sector takes a familiar Cobb-Douglas form in the growth literature: $Y = (hL_Y)^{1-\alpha} K^{\alpha}$

In this model, human capital is interpreted as skill or experience in using intermediate goods and individuals can opt between production of consumption goods, new intermediates (ideas) or acquiring new skills via on-the-job training, education or apprenticeship programs. Thus, the labor market clearing condition is $L_A + L_h + L_Y = L$, while the skills accumulation is given by:

$$\dot{h}_t = \mu e^{\phi u(t)} h_t \left(\frac{A_t^*}{h_t} \right)^{\gamma}$$

where u(t) represents the fraction of time spent accruing new skills, A_t^* the world's technological frontier with μ and γ both positive. The last term allows for a curvature in h and is consistent with the catching-up hypothesis of Nelson and Phelps (1966), stating that, the closer one is to the frontier, the harder is to further accumulate skills.

The vector Ω comprises additional factors underlying the national innovative capacity concept postulated in FPS (2002), the rich descriptive work on NIS as well as international and transition specific variables grouped in five categories:

- *National infrastructure for innovation* (X^{INFR}) comprises resources available for innovation such as sources of finance for R&D, human capital available, investment in education and basic science as well as policies (protection of intellectual property, easiness of doing business, tax regimes)

- *Cluster specific environment for innovation* (Y^{CLUS}) emphasizes the micro-economic decisions of firms to undertake R&D aggregated at the country level in the total business expenditures on R&D, recognized as the main driver of innovation in industrialized countries
- *Linkages between the infrastructure and industrial clusters* (Z^{LINK}) are activities of various organizations like universities, research institutes and public think tanks that provide a link between elements of the first two groups.
- *Transition specific factors* (T^{TRAN}) are extremely important for Eastern Europe and their disruptive influence has impacted innovation via economic mechanisms
- *Globalization related factors* (W^{GLOB}) such as openness to trade, foreign investment flows or migration (brain drain) play and increasingly significant role in today's global economy giving opportunities for learning, imitating and building on new technologies and reducing the duplication of R&D efforts among countries.

Thus, $\Omega = \{X^{INFR}, Y^{CLUS}, Z^{LINK}, T^{TRAN}, W^{GLOB}\}$ incorporating a wide set of resources, policies and economic variables that influence the intensity of innovation between countries according to the previous literature. Moreover, this set-up implies complementarity among its components, which may raise problems in the econometric part due to the high number of regressors, low variance and possible collinearity of aggregated country variables. For the estimations, I opt for log linear specification of (eq1), except for the qualitative and percentage variables, which makes it less sensitive to outliers and easier to interpret as elasticities. Hence the flow of new ideas is specified as an eclectic production function where all the factors described above enter on the right hand side:

$$\log \dot{A} = \beta \log h + \phi \log A + \delta \log L_A + \delta_I \log X^{INFR} + \delta_C \log Y^{CLUS} + \delta_L \log Z^{LINK} +$$

$$[illegible]_T \log T^{TRANS} \; [illegible]_I \log W^{GLOB} \; [illegible] \; \#$$

4.2 Variables

In this section I will briefly describe the variables used to test (eq4). Further details on data sources and construction are provided in Appendix A. The data covers 16 EECs during the period 1990 to 2007. Means and standard deviations of the employed variables are reported in Table 6, while pair-wise correlations appear in Table 7. As expected, the main challenge was the availability and quality of data, since 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[12].

Keeping in mind the pitfalls of patents as proxies for innovation widely discussed in the literature, I employ in my analysis the number of *patents at the USPTO*. This variable constitutes a good measure of technologically and commercially significant innovations at the world's frontier, especially useful for cross-country studies since it avoids comparability issues for national granted patents such as differences in standards, costs or protection offered as well as commercial benefits that are proportional to the size of the market where the patent is granted[13].

[12]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.

[13]In 2005 USA attracted the largest patent applications (417 508) and grants (157 717) worldwide demonstrating

Consistent with the microeconomic evidence, I include the *gross domestic expenditure on R&D* as a raw measure of national innovation effort. However, the contribution of private businesses to R&D finance may be particularly important (Bassanini et al, 2001) while for emerging innovators the government's support significantly affect their patenting rates (Hu and Matthews, 2005). Hence I include a couple of indicators drawn from the literature (*Business R&D; Government R&D*) as the two main components of gross R&D efforts.
Skilled *human capital* is required to complement the financial R&D efforts (Griffith et al., 2004). Universities represent a vital link in this process by providing both the skilled human resources and basis for research that yields spillovers back to the industry (Jaffe et al., 1993; Adams et al., 2000). In a systemic view, *the R&D performed by university* successfully links the available national infrastructure for innovation with the specific business efforts.
From the policy perspective, a key variable is the *intellectual property rights regime*. These issues have become increasingly important in the last years with their embedment in international agreements such as TRIPS. The IPR index employed in this paper takes into account both dimensions of this issue: the *formal* one, represented by legal commitments to IP treaties (Park and Wagh, 2002) and the *informal* one counting the actual enforcement of these laws (Smarzynska - Javorcik, 2002).
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 inventiveness. A bureaucratic country will be less successful in both attracting foreign innovative firms and encouraging domestic entrepreneurs. Both the number of procedures required to start a firm and the costs associated with it, vary significantly worldwide[14]. 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 have a negative impact on innovation output.
Prior to 1990s, Eastern Europe was virtually closed to foreign flows of capital and goods. Since then, EECs have made impressive changes and today they represent an attractive destination for *foreign direct investment*. An increasing number of multinationals are entering the region and their interest includes also R&D activities, seeking to take advantage of the cheap yet skilful local labor force. This suggests new opportunities for innovation production (Athreye and Cantwell, 2007). This complements the positive impacts from *trade intensity* through which technological transfers occur (Coe and Helpman, 1995) and competition increases in these markets.
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[15]. These distortions have disruptive effects both on economic and innovation mechanisms (Srholec, 2007) and 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 in terms of reducing these distortions towards an international benchmark of market economies (see Appendix A).

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the biggest commercial appeal for innovations (USPTO Patent Statistics Chart, 2006).

[14]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.

[15]Two distinctive features were a very small service sector and an oversized industrial one as a result of the economic development strategy during the early communist years. Most of the countries dealt with this latter legacy throughout the 1990s via privatizations, restructurings or liquidation of industrial mammoths.

The *cumulative output decline* shows the percent difference between the end of transitional downturn in the region (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 even after this time.

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.

Hypothesis 1. *A stronger and effective the IPR regime increases the number of new-to-the-world innovations produced in a country*. There is an ongoing debate whether developing countries should 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 (Aghion et al., 2001) 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 segment abroad while its upstream activities (R&D) 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. *EEC's ability to produce innovations relies more in present R&D commitments than on the stock of prior 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 rather than business R&D expenditure*, identified usually as 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).

Hypothesis 4. *Globalization related factors have a positive effect on innovation.* This view is consistent with the belief that trade and foreign direct investment are accompanied by significant positive spillovers on productivity and innovation of the host country (Coe and Helpman, 1995; Saggi, 2002). The recent rise in trade, FDI and outsourcing activities may give rise to new niches of innovation production for developing countries that are above a threshold level of absorptive capacity such as the EECs.

5. Empirical analysis and results

5.1 Methodology

The estimation of the relationship between innovation's output and inputs is not a straightforward one for several reasons. First, the nature of the chosen output (patent) data is a discrete, non-negative but potentially with large amount of zeros, has determined in the firm level literature the use of count models with an exponential specification, assuming a Poisson or a negative binomial distribution (Hausman et al., 1984; Blundell et al., 2002). However, in this case, the study sample comprises only countries with relatively constant, even if not significantly large, activity at the USPTO. This has resulted in a low number of zero observations (5.83% of the total) reducing somewhat the concerns that require the use of a count model[16]. Secondly, the issues of dynamics of innovation imply the existence of some lag structure between inputs and output, while its existence and value are still subject of research (Blundell et al., 2002). This paper will attempt to address these issues by exploring the data using several approaches and perform some robustness checks to validate the obtained results.

With respect to the empirical implementation of (eq4), the flow of new innovations, (j,t), is proxied by the number of patents granted in year t to country j. However, in practice, we observe a lag between a patent application and a grant at the USPTO which is on average of two years for processing this information (Furman and Hayes, 2004). Hence, (eq4) becomes:

$$\log PAT_{j,t+2} = \beta \log h_{j,t} + \phi \log PATS_{j,t} + \delta \log L_{Aj,t} + \delta_I \log X_{j,t}^{INFR} + \delta_C \log Y_{j,t}^{CLUS} +$$

$$+ \delta_L \log Z_{j,t}^{LINK} + \delta_T \log T_{j,t}^{TRANS} + \delta_I \log W_{j,t}^{GLOB} + \varepsilon_{j,t}$$

where PAT is the flow of USPTO patents at time $t+2$ while $PATS$ represents the computed stock of knowledge at t. All regressors are lagged by two years and this structure also addresses some endogeneity issues associated with this specification since two year lagged regressors are predetermined with respect to the dependent variable.

5.2 Estimation

Most of the variables enter in log form, yielding useful results in terms of subsequent interpretation (elasticities) and minimizing the influence of possible outliers. In order to take advantage of three key variables that lack the time dimension [17], I opt for a GLS estimator and include various controls (year and regional dummies) to capture possible as much as possible from the unobserved heterogeneity (Wooldridge, 2002). To make sure that my regressions are not spurious from a time series perspective, I perform the most common two panel unit root tests involving regressions on lagged difference: Levin Lin and Chu (2002) which assumes a cross-

[16]Also, several recent aggregated studies treat patents as continuos (Botazzi and Peri, 2003; FPS and subsequent work on NIC; Bosch et al., 2005). However, count models could provide additional robustness estimates for our results.

[17]Effectiveness and enforcement of IPR, cost of doing business and cumulative transitional output drop have only one value for each cross-section. Human capital, educational expenditure (% of GDP) and the R&D statistics present low variance over time. A fixed effects estimation will discard the latter while making the former insignificant in the regressions.

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 6 confirming that the variables employed are stationary.
In addition, I run a couple of diagnostic tests to make sure that the proposed estimates are efficient. 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 is strongly rejected in all models except *Robust2*, proving that this is an issue to take into account. As a result of these concerns, I use a FGLS (feasible generalized least squares) estimator that is robust to first-order panel-specific autocorrelation and panel heteroscedasticity. Table 8 presents the panel estimations including additional time fixed effects and dummies for the CIS and Baltic countries.
Model 1 estimates a simple knowledge production function for national innovation like (eq1) including the resources devoted to the R&D sector and the stock of previous knowledge in terms of patents. Both terms are highly statistically significant and explain a good proportion of the variance in innovative output. An alternative estimation not reported here to preserve comparability with the other models yields similar results using a more accurate measure of L_A (number of researchers) and controlling for R&D intensity of a country[18]. *Model 2* explores in detail the factors underlying a country's national infrastructure for innovation both in terms of commitments (R&D GOVERNMENT) and policies (IPR regime, COST OF DOING BUSINESS) that complement existing knowledge (US PATENT STOCK). *Model 3* incorporates the contribution of business sector (R&D BUSINESS) and the importance of linkages between them and the national capacities emphasizing the role of universities (UNIVERSITY R&D PERFORMANCE) in facilitating this technological communication, sharing and development. *Model 4* incorporates additional controls for the negative effects of transition via restructuration costs within the sectoral configuration (INDUSTRIAL DISTORTIONS) and overall collapse of the economy (OUTPUT DECLINE) which prove to be very important for Eastern European innovation as well. Finally, *Model 5* or the "Full Model" goes beyond to the national dimensions of innovative performance by including significant external forces such as FDI INFLOWS and TRADE INTENSITY that cannot be ignored in today's global and interlinked economy.
The first point to highlight is that regardless of the number of regressors, variety of variables and specifications in these estimations, the results are very robust. Keeping in mind that the focus of this study is on transition countries with large disparities both within and between them and the industrialized world (Western Europe, OECD), this becomes even more remarkable. Secondly, the estimations reveal a consistent picture with the postulated production function (eq5) for new-to-the-world innovations, proxied here by US patents, despite its eclectic nature that builds on multiple strains of literature.
In the following I am going to briefly review and summarize the results. For model selection I employed the two most common information criteria (Akaike and Schwarz Bayesian) which are reported in the lower part of Table 8. Both rank *Model 5* or the "full" one as the preferred one from an econometric perspective so these findings will be emphasized. The previous stock of knowledge appears to be the most important national source for the stream of new innovations

[18] The elasticities are 0.23 for log (researchers), 0.25 for log (R&D per researcher) and 0.66 for log (US patent stock), all significant at p<0.000.

with an estimated elasticity of 0.37 in contradiction with our second hypothesis. Government investment in research and development (0.13) outplays the correspondent business expenditure (0.11), consistent with Hypothesis 3. Both exercise a positive and highly significant impact on the stream of new patents for the EECs. The links between industry and government via universities and laboratories is a crucial one (1.53) while the policy choices represented by the regulatory burden on businesses (-0.01) and effective IPR regime (0.13) are also very important. In the case of EECs, one cannot ignore the adversity of transition process comprised in a cumulative output decline (-0.01) measure and the disruptive reallocation and structural restructuring given by an industrial distortion index (-0.68). All variables enter significantly and additively in these regressions suggesting the importance of these diverse factors to the innovative capacity of a country.

5.3 Robustness

Additional controls: human capital (HK), HK enhancing policies and population

Human capital plays both a direct role in impacting the productivity and innovative capacity of a country (Engelbrecht, 2002) as well as an indirect one by determining the efficiency of its absorptive capacity (Nelson and Phelps, 1966). Thus, I would like to control for these cross-country differences and see their impact on innovation output (*Robust 1*). The skilled amount of human capital available in these countries is proxied by the widely employed variable from Barro and Lee (1996) and its updated 2000 version. This index reports the average years of secondary schooling in male population over 25 years old over five-year periods.

Moreover, in line with the literature (Acs et al., 2002; Varsakelis, 2006; FPS) that emphasizes the role of *education* in stimulating national innovation, I include also a control for the effect of this policy (*Robust 2*). Specifically, 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.

Finally, theoretical considerations and historical analysis suggest that market size (expressed here by *population*) matter by providing bigger incentives for innovations. Furthermore, using patent counts as dependent variable may raise some concerns regarding a scale effect. One option would be to "deflate" all relevant variables by population and obtain per capita values, while the other is to include it in the regressions and test whether scale effects have an independent influence on patenting activity. For convenience, I opt for the latter in *Robust 3*.

When included in the preferred model, all three variables appear with the expected signs and high magnitude coefficients but no statistical significance, suggesting that the preferred model is well specified while keeping in mind also the low variance of this controls[19]. Also, the results of the three robustness checks point out to the importance of aggregated human capital available (1.201) and investing in education a higher share of GDP (4.158) while some scale effects are indeed present (0.263). However, *Model 5* remains robust to the inclusion of these variables.

Different proxies for innovation at the technological frontier

[19]The Barro and Lee data is available only at 5 year intervals while for the investment in education (% GDP) the coverage is very poor for the EECs prior to 1998.

The choice of USPTO patents as a proxy for new-to-the-world innovations with commercial potential has been used extensively in the literature. However, one might argue that factors such as trade intensity with the USA, geographical distance and integration (political, economic) may bias downward the amount of innovations patented in the USA, especially for Eastern European countries who are rather focused on re-integrating back into a wider Europe. To account for such possibilities, I perform a similar analysis using *EPO (European Patent Office) patent data*. Hence I use the same specification (eq5) with EPO patents and stocks to test the robustness of my preferred model[20]. The last column in Table 8 reports this model (*Robust 4*). Despite the lower quality of the data, the model performs very well and except the GOVERNMENT R&D and OUTPUT DECLINE, all other estimates remain in the previous range and highly significant.

Estimation technique

As mentioned in the beginning of this section, the choice of estimation techniques is an important issue in this literature. While the low number of zero patents in our sample justifies treating this variable as continuos in these estimations, I would like to check these findings by employing also count models.

Table 9 presents the results of these additional estimations. The first column reports the *FGLS* results with the full model. In the second column, I perform also a simple *OLS* regression with *Newey-West* standard errors which are both heteroskedasticity and autocorrelation consistent[21]. The majority of the coefficients remain robust to this estimator compared with the benchmark (FGLS). Next, I estimate a PRM (*Poisson regression* model) which assumes equidispersion or $Var(PAT) = E(PAT)$ and conditional zero mean of errors but allows for heteroskedasticity. The coefficients remain highly significant and with expected signs while R squared is extremely high (0.98). However, in practice, PRM rarely fits the data due to overdispersion. Estimates of a PRM for overdispersed data although unbiased are inefficient since usually the standard errors are biased downward. To test this restriction I use two methods: the one described by Cameron and Trivedi (1990) and the Woolridge (1997) approach. The former uses fitted values of the dependent variable to regress $(PAT - PAT\_f)^2 - PAT$ on ($PAT\_f)^2$, while the latter regresses the standardized residuals on predicted values of patents. In our case, both t-statistics are highly significant leading us to reject the Poisson restriction. Moreover, the significance of the estimated coefficients indicates overdispersion in the residuals. As expected, these results suggest that the *negative binomial* distribution is preferred over the Poisson one. Column 3 reports the NegBin (ML) estimation with estimated coefficient in the line with previous results, except the COST OF DOING BUSINESS and UNIVERSITY R&D that lose their statistical significance just like in the OLS NW estimation. Given the evidence of overdispersion, I re-estimate the model using a two-step *negative binomial quasi-generalized pseudo maximum likelihood* estimator (QML) with GLM robust standard errors and covariance and using the determined variance from the above Woolridge test. The results are robust to inclusion of GLM covariances and standard errors proving that our initial conjectures about this preferred model are confirmed regardless of the estimation technique.

[20]Due to data availability, I use patent applications rather than grants, which makes this variable a weaker proxy.

[21]It uses autocorrelations up to m = 4 to compute the standard errors. For the truncation parameter m, I employ the usual rule of thumb and compute it as (0.75*(N^1/3)) which equals 3.92, rounded up to 4.

6. Discussion and conclusions

This study contributes to the cross-country empirical literature investigating the determinants of innovation at a national level in transitional Eastern Europe while this analysis could be extended for further developing countries. The approach undertaken builds on the theoretical grounds of endogenous growth complemented with elements from the national innovation systems in an eclectic approach similar to FPS. The results are broadly robust to estimation technique and imply, despite the high numbers of factors considered along endogeneity concerns, that they contribute additively to a country's innovative performance, as proxied by international patenting.
From the results a number of interesting observations and policy recommendations emerge. The estimated returns to R&D in the EECs show strong decreasing to scale, consistent with previous results looking at developed and developing countries (Bosch et al., 2005). Overall, the EECs' variation in patenting rates depends significantly on R&D commitments (manpower and finance) similar to OECD (FPS; Furman and Hayes, 2004) but also on governmental efforts just like in the case of Asian Tigers latecomers (Hu and Matthews, 2005). Moreover, the government's contribution outperforms business R&D investments, usually identified as the main driver of innovation in developed countries. Associated with the latter's continuos downward trend, this calls for significant measures to provide incentives and support (in form of tax breaks or subsidies) to private firms performing R&D[22]. Complementary, reducing the bureaucratic burden in these countries has positive impacts over the medium/long term evolution of patenting, stimulating both domestic and foreign firms. Furthermore, increasing intellectual property protection sends a signal to both domestic inventors and multinationals, impacting positively the total amount of patents. The highly postulated role of human capital and policies meant to enhance it, such as investment in tertiary and secondary education, appear to have a positive effect. As expected, the macroeconomic transitional forces played an important negative role, especially in the 1990s when the hard adjustments were taking place. Opposite to their disruptive effect, globalization has opened the channels for new sources of knowledge via trade, FDI, communication or migration. However, the bulk of inward FDI, despite increasing over time and especially the high-tech one, remains confined to a handful of countries that provide the right mix of policies and infrastructure. The rest need to catch-up also in this perspective.
Overall, the analysis finds that both innovation-oriented and business friendly policies along a balanced innovation investment mix are prerequisites to develop the EEC's national innovation capacities and ensure their competitiveness on international markets. Even though these countries are a living proof that innovation takes place despite inefficiencies and austere conditions, the need for a sustained growth in the region through knowledge accumulation is obvious. This fact becomes even more important now, when the initial drivers of growth (reallocation of resources, benefits from restructuring, comparative advantage in labor intensive industries) are slowly petering out through economic integration within the structures of European Union.

[22]With the exception of Slovakia and Czech Republic, all the listed EECs perform poorly in terms of business R&D averaging under 0.5 percent of GDP while the leaders (Sweden, Japan, USA) invest between 2.4 and 1.91 percent (European Innovation Scoreboard 2006)

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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
TRIPS Trade Related Aspects of Intellectual Property Rights
WECs Western European Countries
UIS UNESCO Institute for Statistics
USPTO United States Patent and Trademark Office

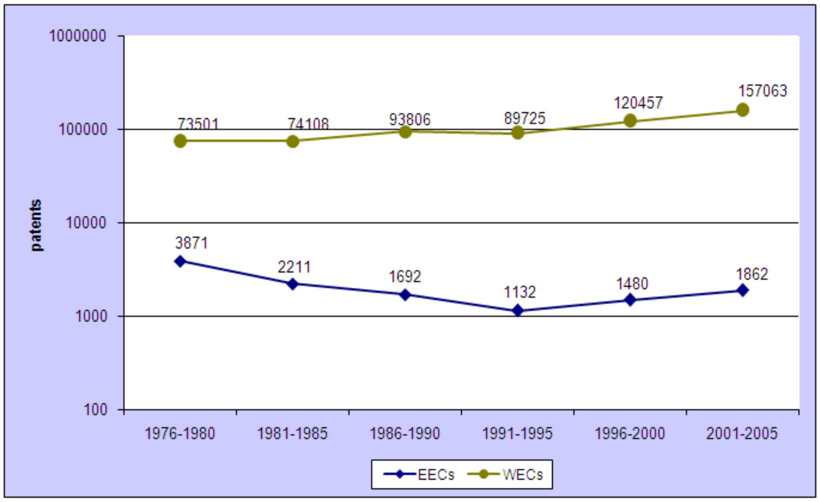

Figure 1 Trends in patenting in the USA. Eastern-Western European comparison

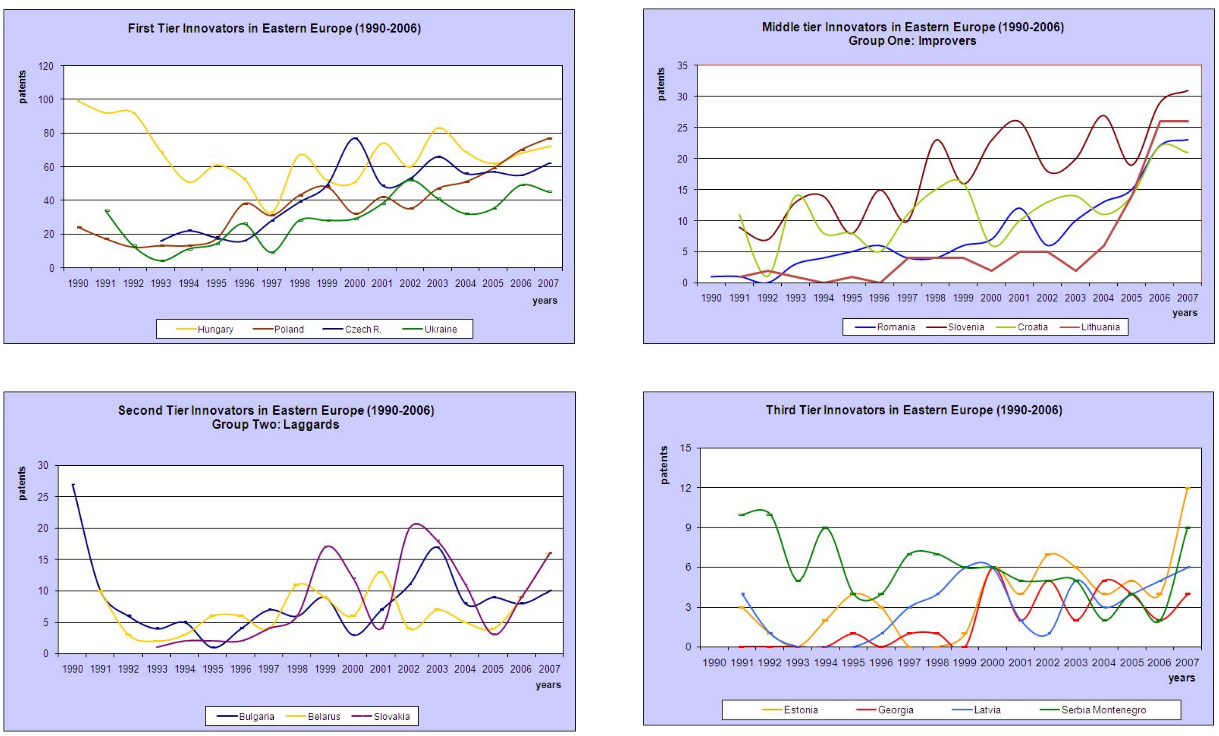

Figure 2 Regional heterogeneity in Eastern European innovation (1990-2007)

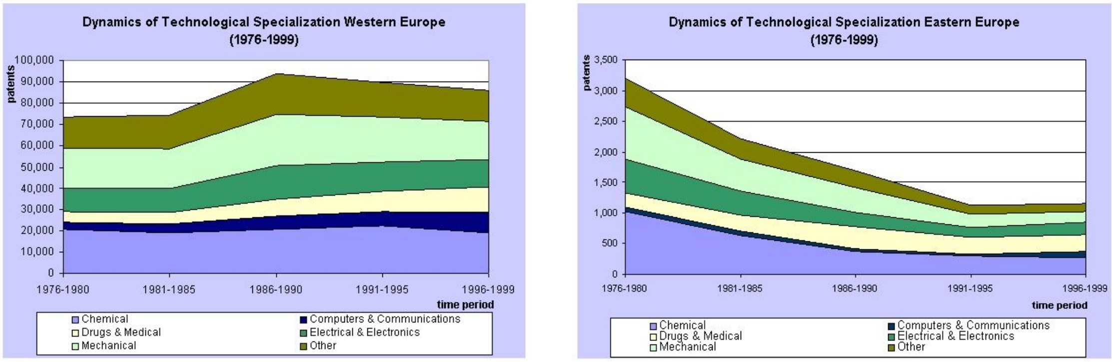

Figure 3 Technological specialization: East vs. West. Historical comparison

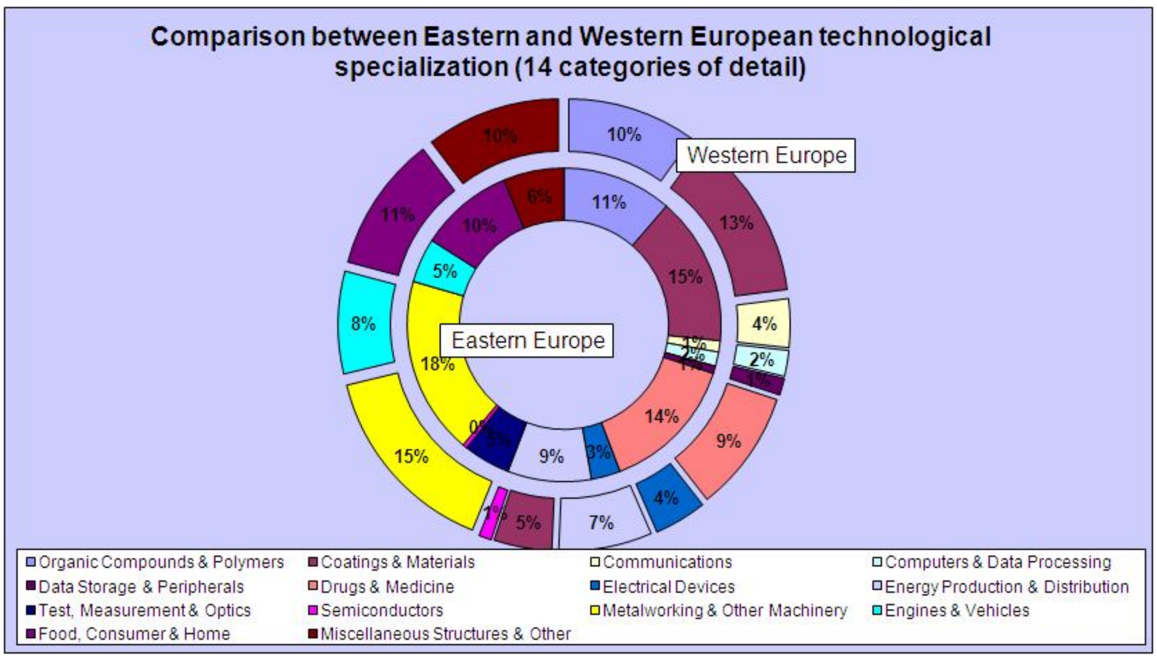

Figure 4 Detailed technological specialization comparison using USPTO patent stocks (1999)

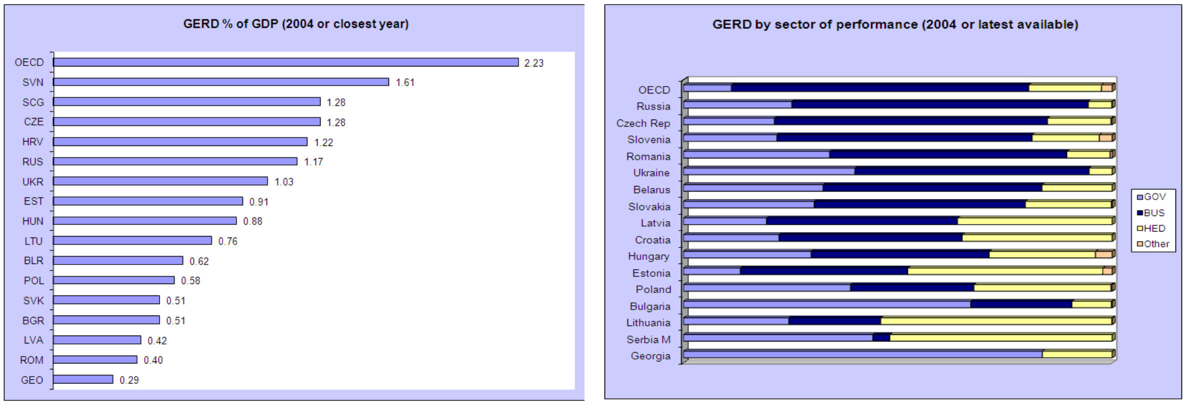

Figure 5a and 5b Gross Expenditure on R&D in the EECs as a percentage of GDP broken down by sources of funds (GOV- Governmental, BUS- Business, HED- Higher Education)

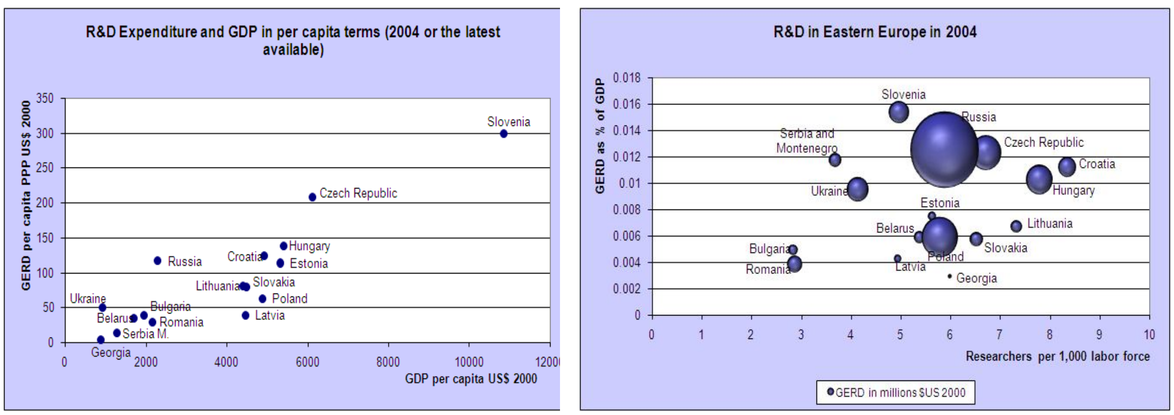

Figure 6a and 6b. Correlations between R&D intensity, income levels and researchers in Eastern Europe

Table 1 Macroeconomic factsheet 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%	42.6[illegible]%	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 Descriptive statistics of the variables employed and panel unit root tests

Variable	*N*	*Mean*	*Std. Dev.*	*Min*	*Max*	*LL*	*IPS*
log(US patents)$_{t+2}$	257	2.48	1.36	0.00	5.84	-6.23***	-4.17***
log (R&D Total)	229	12.15	1.38	8.77	15.82	-9.33***	-5.73***
log(US patent stock)	288	3.81	1.50	0.29	7.41	-5.84***	-3.90***
IPR index	288	6.05	3.04	2.20	11.25	-	-
Cost of doing business	288	38.45	15.27	16.00	76.50	-	-
log (R&D Government)	162	11.61	1.16	9.52	15.76	-26.27***	-5.02***
log (R&D Business)	164	11.41	1.46	7.70	14.66	-10.73***	-1.55*
R&D performed university	178	0.20	0.14	0.02	0.56	-8.19***	-0.89

log (industrial distortions)	236	-1.20	0.42	-2.25	0.20	-4.08***	-2.55***
cumulative output drop	288	-11.02	25.28	-56.60	41.14	-	-
log (FDI inflows)	252	6.37	1.73	1.39	10.27	-7.86***	-4.63***
log (Trade intensity)	232	-7.19	0.58	-9.42	-5.96	-4.37***	-2.93***
log (Human capital)	255	2.19	0.15	1.79	2.35	0.06	1.12
Education share (% GDP)	196	0.03	0.01	0.01	0.05	-4.53***	-1.40*
log (Population)	256	9.10	1.20	7.18	11.90	-3.52***	1.35
log (EPO patents)$_{t+2}$	202	2.47	1.55	0.00	5.47	-11.88***	-8.93***
log (EPO patent stock)	192	3.55	1.77	-0.67	7.07	1.69	-1.26*

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 7 Pair-wise correlations

	Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*
1	log(US patents)$_{t+2}$	1.00																
2	log (R&D Total)	0.78	1.00															
3	log(US patent stock)	0.89	0.81	1.00														
4	IPR index	0.50	0.47	0.48	1.00													
5	Cost of doing business	0.08	0.09	0.20	0.26	1.00												
6	log (R&D Government)	0.81	0.93	0.77	0.38	-0.02	1.00											
7	log (R&D Business)	0.76	0.97	0.75	0.43	-0.02	0.88	1.00										
8	R&D performed university	-0.28	-0.41	-0.32	-0.16	-0.10	-0.29	-0.49	1.00									
9	log (industrial distortions)	-0.02	0.05	0.05	-0.23	0.12	-0.06	-0.02	-0.28	1.00								
10	cumulative output drop	0.19	0.28	0.23	0.67	0.36	0.19	0.12	0.13	-0.55	1.00							
11	log (FDI inflows)	0.66	0.49	0.66	0.40	-0.13	0.56	0.46	-0.04	-0.22	0.26	1.00						
12	log (Trade intensity)	0.18	-0.04	0.31	0.27	0.44	-0.25	-0.28	0.11	-0.09	0.23	0.39	1.00					
13	log (Human capital)	0.18	0.14	0.17	0.05	-0.18	0.07	0.02	-0.29	0.40	-0.14	0.21	-0.04	1.00				
14	Education share (% GDP)	-0.44	-0.47	-0.43	0.02	0.20	-0.41	-0.43	0.47	-0.01	0.08	-0.35	0.08	-0.01	1.00			
15	log (Population)	0.61	0.72	0.65	0.03	-0.17	0.71	0.68	-0.51	0.33	-0.20	0.39	-0.23	0.45	-0.45	1.00		
16	log (EPO patents)$_{t+2}$	0.88	0.76	0.90	0.46	0.27	0.73	0.70	-0.24	-0.01	0.23	0.70	0.23	-0.01	-0.40	0.58	1.00	
17	log (EPO patent stock)	0.80	0.55	0.86	0.39	0.20	0.57	0.53	-0.13	0.00	0.19	0.69	0.28	0.06	-0.38	0.46	0.81	1.00

Table 8 Determinants of new Eastern European innovations (FGLS estimation‡)

MODELS		Model 1	Model 2	Model 3	Model 4	Model 5	Robust 1	Robust 2	Robust 3	Robust 4
Variables		Jones simple prod. function	National commitments	+ Ind. clusters & linkages	+ Transition factors	+ Globalization factors	Full + Human capital	Full + Educ Policy	Full + Population	Full with EPO PATENTS
L_A	LOG R&D TOTAL	0.242***								
		(0.063)								
A	LOG US PATENT STOCK	0.664***	0.595***	0.446***	0.441***	0.372***	0.368***	0.376***	0.350***	
		(0.070)	(0.061)	(0.077)	(0.086)	(0.079)	(0.079)	(0.080)	(0.082)	
X^{INF}	IPR INDEX (LEGIS+ENFORCE		0.051**	0.091***	0.144***	0.135***	0.146***	0.136***	0.144***	0.159***
			(0.023)	(0.020)	(0.033)	(0.037)	(0.038)	(0.040)	(0.038)	(0.027)
X^{INF}	COST DOING BUSINESS		-0.006*	-0.012***	-0.014**	-0.016***	-0.005	-0.016***	-0.000	-0.013*
			(0.003)	(0.003)	(0.005)	(0.005)	(0.010)	(0.006)	(0.011)	(0.007)
X^{INF}	LOG R&D GOVERNMENT		0.274***	0.153**	0.164**	0.131*	0.153**	0.149**	0.130**	-0.050
			(0.056)	(0.072)	(0.074)	(0.067)	(0.069)	(0.075)	(0.065)	(0.058)
Y^{CLUS}	LOG R&D BUSINESS			0.247***	0.107	0.118*	0.133*	0.117	0.095	0.238***
				(0.080)	(0.083)	(0.069)	(0.070)	(0.074)	(0.071)	(0.064)
Z^{LINK}	UNIVERSITY R&D PERFORM			1.389**	1.573***	1.535***	2.308***	1.648***	1.407**	0.228
				(0.579)	(0.609)	(0.569)	(0.791)	(0.613)	(0.560)	(0.652)
T^{TRANS}	LOG INDUSTR DISTORTIONS				-0.335**	-0.681***	-0.886***	-0.680***	-0.829***	-0.418**
					(0.137)	(0.174)	(0.229)	(0.184)	(0.191)	(0.183)
T^{TRANS}	OUTPUT DECLINE				-0.012***	-0.013***	-0.023***	-0.014***	-0.019***	0.001
					(0.004)	(0.004)	(0.008)	(0.004)	(0.005)	(0.007)
W^{GLOB}	LOG FDI INFLOWS					0.137***	0.119***	0.134***	0.109**	0.110***
						(0.041)	(0.042)	(0.042)	(0.043)	(0.033)
W^{GLOB}	LOG TRADE INTENSITY					0.368*	0.240	0.384*	0.422**	0.488***
						(0.205)	(0.230)	(0.213)	(0.208)	(0.246)
Controls										
X^{INF}	LOG HUMAN CAPITAL						1.201			
							(0.939)			
X^{INF}	EDUCATION SHARE							4.158		
								(6.999)		
X^{INF}	LOG POPULATION								0.263	
									(0.168)	
A	LOG EPO PATENT STOCK									0.231****
										(0.052)
	CONSTANT	-3.439***	-2.546***	-3.972***	-3.604***	-0.668	-5.482	-0.897	-2.997	0.977
		(0.739)	(0.764)	(0.844)	(0.919)	(1.814)	(4.241)	(1.940)	(2.417)	(2.317)
	CIS DUMMY	-0.128	0.060	0.597***	1.005***	1.345***	0.931**	1.351***	0.708	1.731***
		(0.127)	(0.153)	(0.159)	(0.299)	(0.283)	(0.442)	(0.293)	(0.501)	(0.530)
	BALTICS DUMMY	0.178	0.092	-0.019	-0.250	-0.343	-0.591*	-0.360	0.018	-0.504*
		(0.289)	(0.209)	(0.267)	(0.324)	(0.312)	(0.353)	(0.331)	(0.371)	(0.293)
	YEAR FIXED EFFECTS	yes	yes	yes	yes	yes	yes	yes	yes	yes
Wald Chi square		634.60	678.53	903.74	949.83	1436.70	1568.33	1432.67	1480.57	1602.71
AIC		249.96	150.18	109.87	103.83	96.74	96.24	100.23	95.97	64.97
BIC		317.93	217.83	181.32	180.86	179.70	182.17	181.37	181.89	144.39
N		221	160	145	143	143	143	143	143	126
LR test: H0 no heteroskedasticity		147.51***	71.02***	123.86***	120.35***	114.05***	116.55***	105.88***	90.21***	87.42***
W test: H0 no serial correlation		4.251*	6.724**	4.226*	7.360**	12.88***	15.67***	11.84***	11.90***	2.90

‡GLS estimation robust to heteroskedasticity and group specific autocorrelation of order one.
* P<0.1; ** P< 0.05; *** P<0.01 (standard errors in parenthesis)

Table 9 Determinants of new Eastern European innovations (additional estimations‡)

		Model 5 (Full model with LOG USPAT $_{t+2}$)				
	Estimation	**FGLS**	**OLS (N-W)†**	**Poisson**	**NegBin (ML)**	**NegBin (QML)**
A	LOG US PATENT STOCK	**0.372*** **	**0.421*** **	**0.536*** **	**0.438*** **	**0.501*** **
		(0.079)	(0.080)	(0.040)	(0.059)	(0.067)
X^{INF}	IPR INDEX (LEGIS+ENFOR)	**0.135*** **	**0.082** **	**0.046*** **	**0.066*** **	**0.051* **
		(0.037)	(0.036)	(0.018)	(0.022)	(0.029)
X^{INF}	COST DOING BUSINESS	**-0.016*** **	**-0.007**	**-0.012*** **	**-0.007**	**-0.010* **
		(0.005)	(0.008)	(0.003)	(0.006)	(0.005)
X^{INF}	LOG R&D GOVERNMENT	**0.131* **	**0.269** **	**0.213*** **	**0.227*** **	**0.211** **
		(0.067)	(0.124)	(0.054)	(0.085)	(0.087)
Y^{CLUS}	LOG R&D BUSINESS	**0.118* **	**0.069**	**0.125** **	**0.130* **	**0.137* **
		(0.069)	(0.100)	(0.050)	(0.078)	(0.081)
Z^{LINK}	UNIVERSITY R&D PERFORM	**1.535*** **	**1.074**	**0.775* **	**0.883**	**0.805**
		(0.569)	(0.869)	(0.418)	(0.661)	(0.679)
T^{TRANS}	LOG INDUSTR DISTORTIONS	**-0.681*** **	**-0.733*** **	**-0.736*** **	**-0.654*** **	**-0.710*** **
		(0.174)	(0.226)	(0.107)	(0.163)	(0.176)
T^{TRANS}	OUTPUT DECLINE	**-0.013*** **	**-0.012** **	**-0.008*** **	**-0.010*** **	**-0.009** **
		(0.004)	(0.005)	(0.002)	(0.003)	(0.004)
W^{GLOB}	LOG FDI INFLOWS	**0.137*** **	**0.191*** **	**0.082*** **	**0.149*** **	**0.111** **
		(0.041)	(0.055)	(0.027)	(0.044)	(0.046)
W^{GLOB}	LOG TRADE INTENSITY	**0.368* **	**0.520** **	**0.650*** **	**0.548** **	**0.613*** **
		(0.205)	(0.211)	(0.104)	(0.221)	(0.186)
	CIS DUMMY	**1.345*** **	**1.030*** **	**0.942*** **	**0.905*** **	**0.919*** **
		(0.283)	(0.338)	(0.154)	(0.298)	(0.267)
	BALTICS DUMMY	**-0.343**	**0.025**	**0.279**	**0.177**	**0.268**
		(0.312)	(0.374)	(0.178)	(0.263)	(0.291)
	CONSTANT	**-0.668**	**-0.930**	**-0.967**	**-2.008**	**-1.402**
		(1.814)	(2.031)	(0.862)	(1.639)	(1.489)
	YEAR FIXED EFFECTS	yes	yes	yes	yes	yes
CT test overdispersion		-	-	0.005****	-	
Woolridge test overdispersion		-	-	0.007**	-	
AIC		96.74	1.47	7.29	6.98	7.11
BIC		179.70	2.05	7.87	7.58	7.69
R^2		-	0.90	0.98	0.95	0.97
N		143	143	143	143	143

* P<0.1; ** P< 0.05; *** P<0.01 (standard errors in parenthesis)
† Regression with Newey-West standard errors (maximum lags = 4)