National Technological Capabilities and Innovation Performance

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Paper prepared for the EACES workshop "Comparative empirical studies: what can we learn for transition and developing countries?", 08. April 2010, Higher School of Economics, Moscow

Abstract

We analyze the relationship between national technological capabilities and the innovation performance for a set of Western and Eastern European countries. Based on the theory and previous empirical studies we presume that there might be some sort of "diminishing returns" here, i.e. that the improvements in technological capabilities alone have a positive, but declining impact on the innovation activity of the economy. We find some support for this hypothesis. Moreover we examine if the East-West gap in terms of innovation performance of the firms can be explained by the lower technological capabilities in Eastern Europe. We conclude that, while this is a significant factor, it cannot justify the size of the gap.

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Introduction

Ever since the empirical literature following the Solow growth model made it clear that a major role in economic growth is played by the Solow's "residual" i.e. the progress in total factor productivity (TFP), an increasing attention has been given to the link between changes in technology and economic growth (Verspagen 2005). In the theoretical literature the concept of innovation has become key: this applies mostly to the evolutionary theories but also to mainstream economics endogenous growth models (Castellacci 2007, 2008).

The problem with testing these theories is that direct measures of innovations, comparable across countries, are largely unavailable (Smith 2005). Consequently, empirical studies usually resort to various indicators of national technological capabilities, such as education, knowledge production or information infrastructure. This is consistent with the theories tested, which assume that technological capabilities determine economy's ability to introduce product or process innovations. Nevertheless in the causality chain "technological capabilities – innovation performance – economic growth" direct links remained unexplored in cross-country empirical studies.

We analyze the former link i.e. that between technological capabilities and innovation performance to answer two principal questions. Firstly, both theory and empirical studies indicate that there might be some sort of "diminishing returns" here, i.e. that *the improvements in technological capabilities alone have a positive, but declining impact on the innovation activity of the economy*. We attempt to verify that hypothesis. Secondly, we take a closer look at the differences between Western and Eastern European countries, and we ask to what extent can the lower innovation performance of the latter be explained by their poor level of technological capabilities.

We mainly study the countries of the European Economic Area, however we include Russia and Ukraine in some of the analyses. The focus on EEA is motivated, firstly, by the availability of data, in particular from the Eurostat-coordinated Community Innovation Survey. Secondly, since the last EU enlargement the EEA has become a group of countries that differ quite significantly in their level of development but share several institutional (and cultural) characteristics, usually not controlled for in empirical studies.

The article is organized as follows. In the next section we introduce basic concepts and review recent literature. Section three presents our empirical study. Section four concludes and formulates policy implications.

1. National Technological Capabilities, Innovations and Growth

a) Background

As Archiburgi and Coco (2004) put it "the technological capabilities of a country are composed of a variety of sources of knowledge and of innovation". They argue that a comprehensive measure should account for various characteristics of knowledge, such as different levels of its codification or embodiment. In introducing their own indicator of technological capabilities Archiburgi and Coco use eight different measures[2] fitting into three dimensions: the creation of technology, the technological infrastructure, the development of human skills.

According to the technology club theory reviewed by Castellacci (2008) countries with different constellations of technological capabilities will exhibit different patterns of growth, depending on their role in the creation and diffusion of innovations. Therefore one should expect clusters of countries sharing similar technological capabilities and growth histories. Is this presumption supported by data?

First of all, empirical studies proved the existence of clusters differing in technological capabilities. Ranking 162 countries according to the ArCo (Archiburgi-Coco) indicator results in distinguishing four groups: leaders, potential leaders, latecomers, marginalized[3]. This arbitrary classification is statistically verified by Castellacci and Archiburgi (2008) who apply cluster analysis to the same dataset. Factor analysis of the eight measures by Archiburgi and Coco resulted in distinguishing two factors: "technological infrastructures and human skills" and "creation and diffusion of codified knowledge". The following cluster analysis yielded three groups (instead of three): "advanced", "followers" and "marginalized". Castellacci (2008) applied cluster analysis to two predefined kinds of technological capabilities – that he calls "innovation capacity" and "imitation capacity" – obtaining again three clusters, to which he gives the same three names.

Technological capabilities clusters clearly differ in their levels of economic development, as proven by practically all the studies listed above. Also Fagerberg and Srholec (2008) in their analysis of different kinds of national capabilities (technological, social, political) confirmed that technological capabilities turn out to be significant in different specifications of cross-country regressions.

Moreover it seems that technological capabilities at least co-determine the patterns of growth. Fagerberg and Srholec perform various kinds of the so-called Barro-regression i.e. a regressions of the growth in GDP on the initial level of GDP per capita and a set of country characteristics, that in this particular case result from a factor analysis on a wide group of indicators[4]. The growth of 125 countries between the 1992-1994 and 2002-2004 periods is analyzed. Apparently the increase in the factor "innovation system" is significant in all the models specified, while the *level* of the innovation system in the initial period is significant in all but one model[5].

Progress in technological capabilities proves significant also in the empirical growth model by Castellacci (2008). In his work a longer time span is considered (1970-2000) but this comes at a price of a smaller set of countries (69). In addition, the technology club hypothesis gains some support,

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[2]These are: patents, scientific articles, Internet penetration, telephone penetration, electricity consumption, tertiary science and engineering enrolment, mean years of schooling and literacy rate. The authors restrict themselves to this undoubtedly incomplete list in order to circumvent problems with data availability and obtain a possibly wide country coverage (162 countries).

[3] Several other technology indicators are available in the literature: the Technology Index for Core Countries and Technology Index for Non-Core Countries by WEF, Technology Achievement Index by UNDP, the UNIDO measures, the RAND corporation Science and Technology Capacity Index (STCI). See Archiburgi and Coco (2005) for a review and comparative analysis.

[4] By "various kinds" we mean different estimation methods (OLS, iteratively re-weighted least squares, stepwise regression), different sets of explanatory variables and different sets of observations.

[5] Three other factors used as explanatory variables are "governance", "political system" and "openness". Moreover several geographic and history-related dummies are considered.

since in the piecewise linear model, in which regression slopes are allowed to differ across the country clubs, the three clusters indeed look quite differently, with different variables being significant and positive or negative.

b) Diminishing returns?

One interesting outcome of Castellacci's work is that several of the technological capability measures (patents, scientific articles, telephone and internet penetration) seem to be subject to a kind of law of diminishing returns: the increase in these variables has a smaller impact on growth in a "higher" cluster than it has in a "lower" one. This is consistent with one influential part of the innovation literature i.e. the National Innovation System paradigm. According to this stream how much countries innovate is determined by the functioning of the "national innovation systems", extremely complex entities, which performance depends not only on the condition of their elements, but, more importantly, on the linkages between actors and the institutional features of the system (Edquist 1997). From a NIS point of view a merely quantitative increase in any specific technological capacity can only have a limited impact on the innovation performance of the economy. On the other hand, concavity of the innovation performance function would be also quite important from the new growth theory point of view (the idea behind these models is that there is no diminishing returns to knowledge)

The question of diminishing innovation returns is also important from the policy point of view. Technological capabilities can be relatively easily addressed by economic policy measures. In fact history has seen several attempts to strengthen the innovation performance of economies this way, from the "linear model of innovation" by V. Bush (1945) through the Lisbon Strategy of the European Union. However if the hypothesis of diminishing returns to technological capabilities is correct, then such policies firstly, have their limits, and secondly might work differently in more and less developed countries. If so, then quite different science and technology policies might be recommendable for different sets of countries.

In the European Union context it is not unlikely that the new member states have more to gain from investments in technological capabilities than the countries of EU-15. To verify this we will look at the relationship between technological capabilities and innovation performance of the EU economies. In fact the EU offers a unique opportunity to test the diminishing returns hypothesis, because innovations are measured directly by Community Innovation Survey (see section 3).

c) The East-West perspective

It is worth stressing that in both papers employing cluster analyses discussed earlier (i.e. Castellacci, Archiburgi 2008 and Castellacci 2008) most (though not all) of the "old" EU member states belong in the "advanced group" while *all* the new EU member states and *all* the countries of the Community of Independent States fit into the "followers" group (Table A1).

[Table A1 about here]

A casual analysis of two variables often used as measures of technological capabilities: gross expenditure on research and development (GERD) as a percentage of GDP and the number of patents per million of inhabitants suggests that there is a significant gap between the advanced Western European EU member states on one hand, and the East of the EU and the CIS countries on the other. In terms of GERD – which is often treated as a general measure of country's technological competence - with the exception of Cyprus, Malta and Greece, all the Western EU countries spend more on R&D than almost all new EU member states, Russia and Ukraine. Only three countries: Estonia, Slovenia and the Czech Republic exhibit relative GERD levels comparable with those of less advanced EU-15 economies.

[Figure 1 about here]

The gap is even more evident with respect to the patent applications, often considered as a measure of codified knowledge on the country level. Here only Slovenia can compare with the least advanced Western countries. Russia and Ukraine show extremely low levels of patent claims. Interestingly the same applies to China.

[Figure 2 about here]

2. Empirical analysis

Generally speaking our methodology consists in regressing, on industry level, the share of innovating firms on various measures of national and sectoral technological capabilities. A more detailed description of our dataset and estimation strategy follows in sections (a) and (b). Results are discussed in section (c).

a) Data

Our principal source of data is the Eurostat. The dependent variable, as well as several independent variables are based on the 2006 edition of the Community Innovation Survey (CIS) that inquired enterprises about their innovation strategies and performance in 2006 (with some questions going back to 2004). The results of the CIS survey are publicly available only after they are aggregated to the 2-digit level of the NACE classification, implying that we have at most 23 observations for each country. The number of countries participating in the CIS is 30 (all EU member states plus Norway, Croatia and Turkey) but we will limit ourselves to 28, due to the lack of data for Croatia and Turkey. This leaves us with potentially 28x23=644 observations, however for several industries and countries data are missing so that an average dataset will consist of about 450-550 observations.

Our dependent variable is percentage of manufacturing enterprises that did introduce any product or process innovation in 2006. The independent variables can be divided into groups according to the three components technological capabilities they represent: skills, codified knowledge and technical infrastructure. Ideally in each group we would like to have indicators referring both to the industry-level and to the country-level. We managed to achieve this for the skills component, which are measured at the branch level by "pseudo-skill intensity" of the branch[6], and at the country level by

[6] Pseudo-skill-intensity in country c and branch k is calculated as the product:
[Wage in (k,c)/Wage in manufacturing in c] * technical skill intensity of the country c
Where technical skill intensity of c can be defined as the number of "Technicians and associate professionals, Professionals, Legislators, senior officials and managers in economy (excluding family workers, to cut off at least some of the farmers)" over employment in industry (this is base on the LFS data and represents, in fact,

the number of engineers and scientists per 1000 persons employed. Also the codified knowledge component is measured at both levels. At the branch level we look at the R&D expenditures of the companies, both intra- and extramural, as a share of their turnover. At the national level we use three alternative indicators: total expenditure on R&D as a percentage of GDP (2004-2006 average), patent applications to the European Patent Office per millions of labour force at the national level (again, 2004-2006 average) and the number of citations of articles published in peer-reviewed international journals (excluding self-citations) per thousands of inhabitants. The latter indicator was taken from the freely available Scopus database and it refers to the journals published by Elsevier. Finally, for the technical infrastructure component of the technological capabilities, we were able to collect data only on the country level. This is because data on the machine stock are not available from the Eurostat website, while data on investments were either incomplete, when taken from CIS or seemed incompatible with the CIS data, when taken from business statistics SBS[7]. Consequently we used only two country-level indicators: broadband penetration rate, and the price of telecommunication services.

Since technological capabilities are correlated with GDP per capita, which in turn might depend on the innovation performance of the economy, we run into possible endogeneity problem. To solve this we use life expectancy as an instrument for GDP per capita (the CIA factbook was our source for this data).

b) Estimation strategy

Our baseline model is the following:

$$v_{ij} = \alpha' X_{ij} + \beta' Y_i + \gamma_j z_j + \varepsilon_{ij} \qquad (*)$$

where v_{ij} is the is percentage of companies in the country i in industry j that introduced product or process innovations, $X_{ij} = \left(x_{ij}^1, \ldots, x_{ij}^L\right)$ is the vector of industry-level technological capabilities, $Y_i = \left(y_i^1, \ldots, y_i^K\right)$ stands for the vector of national technological capabilities and z_j is the industry fixed-effect.

Two variations of the model above will be estimated. To verify the existence of diminishing returns to technological capabilities we take a model with a square term:

$$v_{ij} = \alpha' X_{ij} + \beta' Y_i + \eta (y_i^k)^2 + \gamma_j z_j + \varepsilon_{ij} \qquad (**)$$

where y_i^k is the technological capability in question. Each of the capabilities is tested separately implying that we run several regressions.

The innovation gap between East and West is analyzed by a model with country fixed-effects:

$$v_{ij} = \beta' Y_i + \gamma_j z_j + \lambda_i c_i + \varepsilon_{ij} \ (***)$$

more the technical skill-intensity of industry than that of manufacturing; one can argue however that these indicators should be correlated in an international comparison)

[7] SBS has a different coverage than CIS, which might be the reason why the correlation of innovativeness according to CIS and investment-intensity according to SBS is actually negative (!), while the same correlation for CIS-based investment-intensity is positive.

Where c_i is the country fixed effect. A limited vector of national capabilities will be considered and no industry-level capabilities so as to avoid collinearity problems ("dummy trap").

Since our dependent variable is limited to the interval [0,100] we apply a double-truncated Tobit model with robust standard error to correct for possible heteroskedacticity due to industry-level data.

c) Results

We start by looking at the correlation between principal country-level variables (Table A2). Apparently, four measures of technological capabilities: GERD, patents, scientific articles and broadband penetration rate, are highly correlated with one another. Consequently we will avoid using them in the same regression, so as to evade the multicollinearity problem.

[Table A2 about here]

We first run a series of regressions based on model (*). Results are presented in Tables A3. Among the industry-level technological capabilities only the expenditure intensity on external R&D turns out to be significant (somehow surprisingly the coefficient for pseudo-skill-intensity is negative but insignificant in all but one estimations). Technological capabilities are positive and significant independent from their kind and measurement with the exception of the number of citations of scientific articles. The fit of the model as measured by pseudo-R-square is rather poor but this is not uncommon for this kind of econometric models, and, what is more, it is the significance of parameters that matters for us here[8].

[Table A3 about here]

Table A4 included the estimation results of model (**), testing the existence of diminishing returns. The test is positive for three correlated measures of technological capabilities: GERD, scientific publications and broadband penetration. On the other hand, apparently there are no diminishing innovation returns to patents, human resources and telecommunication prices.

[Table A4 about here]

Diminishing returns are due to the more developed countries of the EU. This is evident when model (**) is estimated separately for the upper and lower (in terms of GDP per capita) halves of the country set. Table A5 presents the results for the three measures of technological capabilities that do show diminishing returns in the whole sample. Only GERD works for both sets of countries, but the coefficient for the square terms is bigger in the upper half of the countries' pool. Coefficients for scientific publications have expected signs for the richer countries but "wrong" signs for the poorer half. Finally, while there are diminishing returns to the broadband penetration rate in the upper half of the countries, there are none in the lower half: indeed the opposite seems to be the case.

[8] We might add at this point that the overall R-square is about 0.3 when models (*) and (**) are estimated by OLS with industry fixed-effects (results not reported in the paper)

[Table A5 about here]

These observations are confirmed by the results of the estimation of equation (***), reported in Table A6. Here the significance of country dummies indicates a level of innovation performance that is higher/lower than it would be if the relation between technological capability in question and innovation performance was linear. The variables are significant and negative for most measures of national capabilities for Hungary, Netherlands, Sweden and the United Kingdom. Note that with the exception of Hungary these are countries with rather high level of technological capabilities. On the other hand countries that perform significantly “above expectations” are Estonia and Portugal.

[Table A6 about here]

Regarding the East-West gap, note that with the exception of Estonia, none of the dummies for the new member states (NMS) turned out to be positive and significant in any of the regressions. What is more, all NMS but Slovenia at least once showed negative and significant coefficients for country dummies.

3. Conclusions

The paper analyzed the relationship between national and sectoral technological capabilities and innovation performance of industries for a set of 28 countries that realize the Community Innovation Survey (CIS). Firstly, we sought to confirm the existence of a kind of diminishing innovation returns to national technological capabilities. The hypothesis is supported for three measures of technological capabilities gross expenditure on research & development, broadband penetration and scientific publications, and, it seems to work particularly well for more developed countries. On the other hand, the relationship between such measures of technological capabilities as patents, the availability of human resources in science and technology and the price of telecommunication services on one hand, and the innovation performance of firms on the other hand, seems to be close to linear. Why the hypothesis on diminishing innovation returns works well for some measures and poorly in others is a question for further research.

We also attempted to contribute to the literature on the inferior innovation performance of Eastern European countries. These countries have low national technological capabilities, and, in the light of our results investing in these capabilities seems to be the right policy to choose. This is because diminishing innovation returns occur if anything in more developed economies. Yet, as demonstrated by our study, the innovation performance of these countries is probably below their technological capacities already now. Consequently, the low level of technological capabilities alone cannot explain the smaller share of innovating firms. Weak linkages in the Eastern European National Innovation Systems are certainly a possible explanation (see e.g. Radosevic and Reid 2006). One clear exception to this pattern is Estonia that has both relatively high level of technological capabilities and excellent innovation performance.

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Tables

Table A1.

Country	*Classification according to Castellacci (2008)*	*Classication according to Castellacci, Archiburgi (2008)*
Old EEA		
Austria	followers in 1990 but advanced in 2000	followers in 1990 but advanced in 2000
Belgium	advanced	followers in 1990 but advanced in 2000
Denmark	advanced	advanced
Finland	advanced	advanced
France	advanced	followers in 1990 but advanced in 2000
Germany	advanced	advanced
Greece	followers	followers
Ireland	followers	followers
Italy	followers	followers
Luxembourg	followers	followers
Malta	followers	followers
Netherlands	advanced	advanced
Norway	advanced	advanced
Portugal	followers	followers
Spain	followers	followers
Sweden	advanced	advanced
Turkey	followers	followers
United Kingdom	advanced	advanced
New EU member states		
All countries	followers	followers
CIS countries		
All countries	followers	followers

Table A2. Correlation between main variables on the country-level

	GERD	Scientists and engineers	Patents	Articles	Broadband penetration	Telecom services price
Scientists and engineers	0.6385					
Patents	0.8561	0.6070				
Articles	0.8386	0.6309	0.6973			
Broadband penetration	0.7461	0.4944	0.7277	0.8485		
Telecommunication services price	-0.1006	0.1146	-0.1347	-0.0490	-0.2241	
Life expectancy	0.4821	0.3190	0.5627	0.4923	0.4745	-0.2430

Table A3. Results of the estimation of the baseline model (*)

Dependent var: inno_rate

	1		2		3		4		5	
Firm R&D expenditure (intramural)	**.64**	*.65*	**.71**	*.64*	**.42**	*.62*	**.04**	*.63*	**.65**	*.67*
Firm R&D expenditure (extramural)	**6.62**	*3.47*	**7.24***	*3.39*	**5.90**	*3.29*	**7.14**	*3.80*	**7.88***	*3.71*
GERD	**6.30****	*1.12*							**4.48****	*1.17*
Patents			**.038****	*.005*						
Articles					**.008**	*.015*				
Broadband penetration							**.57****	*.19*		
Telecommunication services price									**-15.71****	*5.94*
Pseudo-skill-intensity	**-2.18**	*2.10*	**-5.65***	*2.08*	**-.52**	*2.77*	**-5.43**	*3.03*	**-2.86**	*2.23*
Scientists and engineers	**1.67****	*.46*	**1.65****	*.46*	**2.80****	*.49*	**2.64****	*.46*	**3.15****	*.52*
Life expectancy	**1.73****	*.36*	**1.60****	*.35*	**2.40****	*.35*	**2.16****	*.37*	**1.28****	*.44*
Constant	**-113.14****	*27.30*	**-96.68****	*26.88*	**-163.57****	*26.67*	**-147.05****	*27.56*	**76.65***	*4.28*
Observations	**541**		**541**		**541**		**519**		**453**	
Log pseudolikelihood	**-2165.49**		**-2158.14**		**-2183.86**		**-2086.90**		**-1820.40**	
Pseudo R2	**.08**		**.09**		**.08**		**.08**		**.08**	

Robust standard errors in italics .** and * denote significance at 1% and 5% level respectively

Table A4. Results of the estimation of the model with square terms (**)

	1		2		3		4		5		6	
Firm R&D expenditure (intramural)	**.44**	*.64*	**.75**	*.64*	**.27**	*.61*	**.37**	*.64*	**.61**	*.67*	**.67**	*.65*
Firm R&D expenditure (extramural)	**6.18**	*3.66*	**7.19***	*3.38*	**5.88**	*3.36*	**6.41**	*3.91*	**8.04***	*3.71*	**6.64**	*3.48*
GERD	**16.75****	*3.78*							**4.41****	*1.18*	**6.20****	*1.11*
GERD - square	**-2.67****	*.79*										
Patents			**.025**	*.020*								
Patents - square			**.00002**	*.00003*								
Articles					**.18****	*.04*						
Articles - square					**-.0006****	*.0001*						
Broadband penetration							**3.10****	*.49*				
Broadband penetration - sq							**-.088****	*.014*				
Telecommunication services price									**8.01**	*40.3*		
Telecommunication services price -sq									**-30.48**	*48.90*		
Pseudo-skill-intensity	**-2.79**	*2.12*	**5.19***	*2.25*	**.20**	*2.90*	**1.34**	*2.86*	**-3.28**	*2.42*	**-1.57**	*2.14*
Scientists and engineers	**1.66****	*.43*	**1.68****	*.47*	**2.32****	*.47*	**2.55****	*.42*	**3.19****	*.52*	**-2.03**	*2.37*
Scientists and engineers - square											**.35***	*.20*
Life expectancy	**1.46****	*.40*	**1.72****	*.42*	**1.59****	*.40*	**1.36****	*.40*	**1.32****	*.47*	**1.70****	*.36*
Constant	**-99.02****	*29.03*	**-106.05****	*31.86*	**-107.06****	*30.17*	**-104.80****	*28.69*	**-84.00***	*40.02*	**-102.18****	*27.91*
Observations	**541**		**541**		**541**		**519**		**453**		**541**	
Log pseudolikelihood	**-2158.93**		**-2157.81**		**-2170.31**		**-2058.97**		**-1820.22**		**-2164.60**	
Pseudo R2	**0.09**		**0.09**		**0.08**		**0.09**		**0.08**		**0.08**	

Table A5. Results of the model with square terms (**) for the upper and lower halves of the country set (in terms of GDP per capita)

Dependent var: inno_rate	Lower half						Upper half					
	1		**3**		**4**		**1**		**3**		**4**	
Firm R&D expenditure (intramural)	**1.59**	*2.35*	**1.23**	*2.50*	**1.64**	*2.07*	**.51**	*.60*	**0.26**	*0.56*	**.67**	*.68*
Firm R&D expenditure (extramural)	**9.14**	*5.11*	**8.64**	*4.95*	**9.60***	*4.61*	**1.42**	*3.26*	**5.31****	*2.73*	**2.46**	*4.26*
GERD	**41.43****	*15.97*					**41.42****	*4.63*				
GERD - square	**-17.85****	*8.33*					**-7.48****	*.94*				
Patents												
Patents - square												
Articles			**.17**	*.28*					**.09**	*.049*		
Articles - square			**.002**	*.004*					**-.0003****	*.0001*		
Broadband penetration					**-3.05****	*1.16*					**4.98****	*.94*
Broadband penetration - sq					**.27****	*.06*					**-.13****	*.025*
Pseudo-skill-intensity	**8.30**	*5.76*	**6.08**	*5.63*	**3.20**	*5.46*	**-7.95****	*2.23*	**-1.78**	*3.22*	**-1.40**	*3.22*
Scientists and engineers	**.60**	*1.05*	**-.02**	*1.05*	**.57**	*.90*	**1.72****	*.46*	**3.25****	*.57*	**2.44****	*.51*
Scientists and engineers - square												
Life expectancy	**1.71****	*.54*	**1.19**	*.61*	**1.83****	*.46*	**-.42**	*.55*	**1.10***	*.55*	**-3.60****	*1.11*
Constant	**-132.69****	*40.33*	**-77.06**	*43.40*	**-93.87****	*-4.44*	**31.38**	*42.44*	**-77.06**	*43.40*	**278.03****	*84.57*
Observations	**263**		**263**		**263**		**278**		**278**		**256**	
R-sq: within	-1063.63		-1060.02		-1020.02		-1044.40		-1080.32		-1020.02	
R-sq: between	.06		.07		.10		.11		.08		.10	

Robust standard errors in italics .** and * denote significance at 1% and 5% level respectively

Table A6. Significance and sign of the country fixed effects in model (***)

	GERD and scientists/engineers	Publications and scientists/engineers	Broadband and scientists/engineers	Patents and scientists/engineers
Bulgaria		negative		negative
Czech Republic	negative			
Denmark				
Germany		positive	positive	
Estonia	positive	positive	positive	positive
Ireland			positive	
Greece			positive	
Spain				
France		positive	positive	
Italy			positive	
Cyprus			positive	
Latvia		negative		negative
Lithuania		negative		
Luxembourg		positive	positive	
Hungary	negative	negative		negative
Malta				
Netherlands	negative	negative	negative	negative
Austria		positive	positive	
Poland		negative		
Portugal	positive	positive	positive	positive
Romania		negative		negative
Slovenia				
Slovakia		negative		negative
Finland				
Sweden	negative	negative		negative
United Kingdom	negative	negative	(omitted)	negative

Note: There was no dummy for Belgium and dummy for Norway had to be excluded due to collinearity

Figures

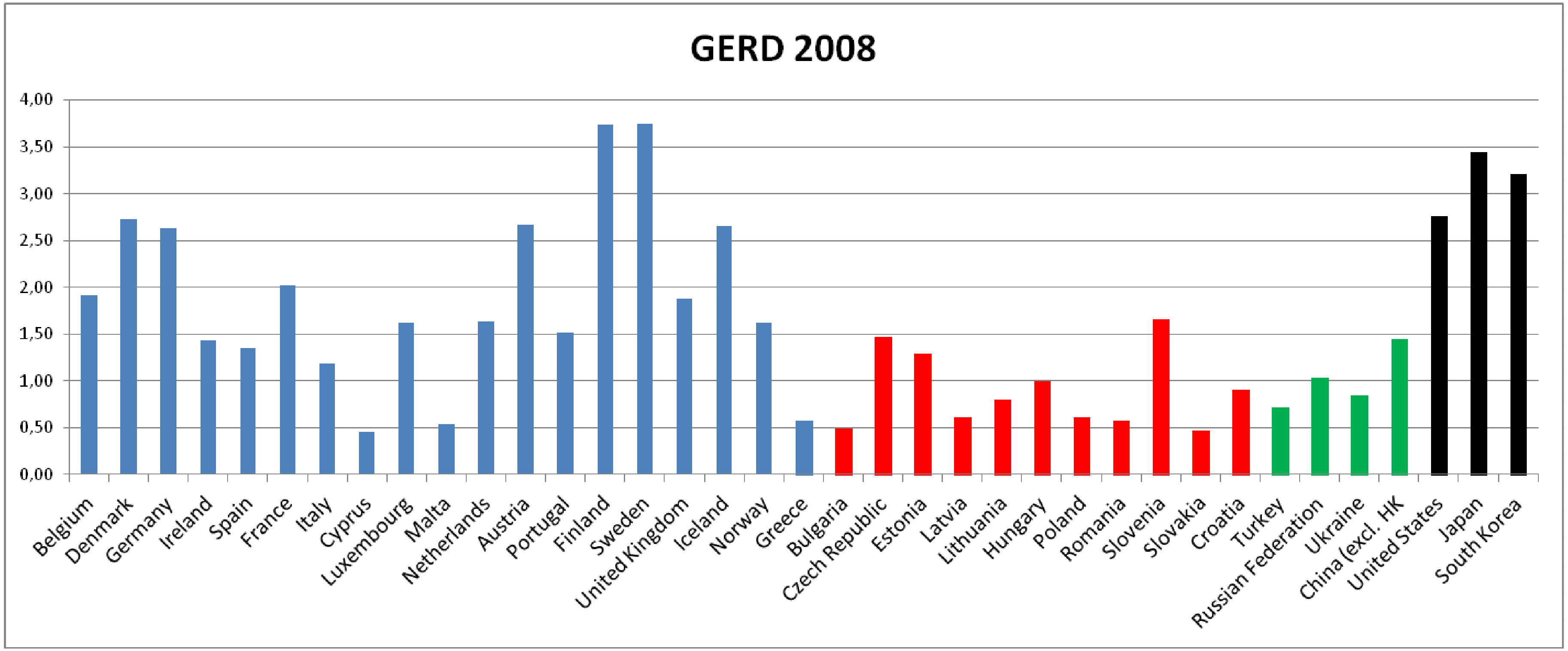

Figure 1: Gross Expenditure on Research and Development as a percentage of GDP
Source: Eurostat, Russian and Ukrainian Statistical Offices

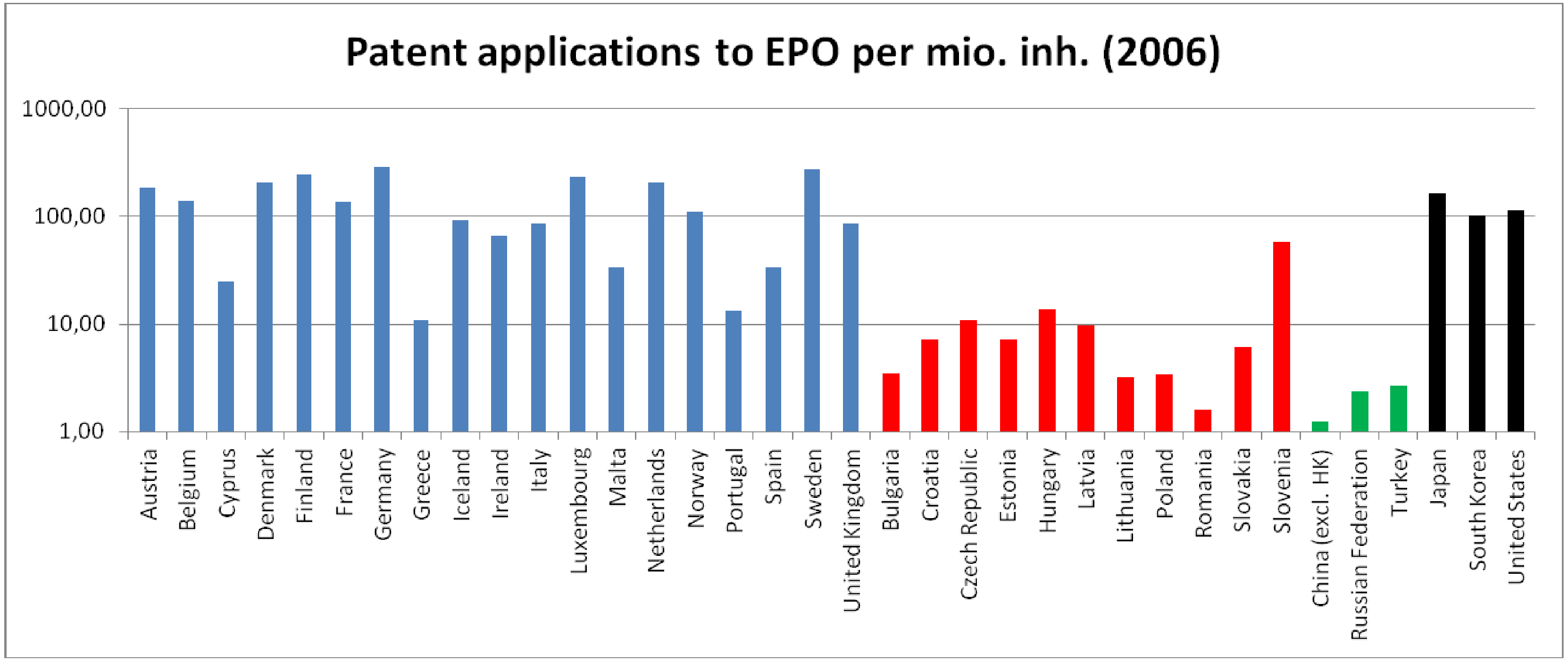

Figure 2: Patent applications to the European Patent Office per million of inhabitants
Source: Eurostat