Moderate innovator trap – Does convergence of innovative potential occur?

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Abstract

Based on β and σ convergence analysis, we find high persistence of technological gap for international innovation indices reported by the European Commission. Our research confirms the diverging scientific potential across the analyzed economies. On the other hand, estimation provides the evidence of convergence in case of R&D expenses and relative position on global technological frontier. We propose a simple fixed effect panel regression measuring relative innovativeness potential. Our model suggests that current ranking leaders i.e. Nordic countries (Sweden, Denmark and Finland) and Germany are likely to further outpace the United States. Central and Eastern Europe countries are achieving greatest relative gains, but are unlikely to exceed 70% of US potential. Peripheral Europe countries, South Africa, Turkey and Russia are projected to further lose innovativeness position, despite weaker initial position.

Keywords: β convergence, σ convergence, European Innovation Scoreboard, moderate innovators.

JEL classification codes: O30, O33

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1. Introduction

The perspective of global growth convergence has begun to rise a question as developed economies are more and more based on the use of knowledge. The middle-income trap concept has been several times invoked (e.g. Kharas & Kohli 2011, Eichengreen et al. 2013). The idea highlights that developing economies have problems to exceed certain threshold of GDP per capita. The problem is commonly linked with exhaustion of benefits from imitating the solutions of the developed markets and lack of capacity to provide innovative solution.

In order to measure the level of innovativeness of different countries, the European Commission introduced the European Innovation Scoreboard – a dataset consisting of 27 indicators describing e.g. scientific capabilities, Research & Development expenditure or intense of knowledge-rich activities. The studies analyzing trends in innovation potential of the European Union countries highlighted the divergence across regions. (Archibugi & Filippetti 2011, Kijek & Matras-Bolibok 2018). The aim of this Paper is to extend the geographical scope of the research and include other international economies scrutinized by the European Commission.

We propose a simple fixed effect panel regression measuring relative innovativeness potential. Our model suggests that current ranking leaders i.e. Nordic countries (Sweden, Denmark and Finland) and Germany are likely to further outpace the United States. Central and Eastern Europe countries are achieving greatest relative gains, but are unlikely to exceed 70% of the US potential. Peripheral European countries, South Africa, Turkey and Russia are projected to further lose position comparing to other developed economies.

This paper is structured as follows: the next sections presents arguments arguing for possible divergence in the innovative activities. Section 3 describes European Commission Summary Innovation Indices – probably the most comprehensive measure of various aspects of innovations. Section 4 presents methodology of our research and provides insight in different measurement techniques of convergence. Section 5 summarize results of the estimates. Finally, section 6 concludes the paper.

2. Literature review

The aim of this chapter is to summarize the debate regarding convergence of innovation. From a theoretical standpoint, technological differences across countries open the possibility for countries with low innovation profile to catch up the rest of the countries by means of imitating more productive technologies applied in leader countries, as imitation is seen as a less expensive process than innovation (Altuzarra 2010). We are going to discuss why authors report cross-country divergence of innovative potential and why similarly like in case of the macroeconomic activity stylized facts are opting for existence of "moderate innovator trap".

The innovative potential does not have a single measure. Most popular strain in macroeconomic theory associates innovation with a presence of national companies on the global technological frontier and achievement of the higher labor and multifactor productivity (e.g. Cameron et al 2005. Fu & Gong 2010, Fu et al 2011). Firm level studies suggest that convergence is not always a case even in the developed economies. While Cameron et al (2005) confirmed that the process of catching up exists based on UK industrial firms' data, numerous researchers provide evidence that technology gap between leading innovators and moderately innovative areas remains persistent in several industries (Fu et al. 2011, Iacovone & Crespi 2010). In a cross-country perspective, less productive firms tend to converge only towards the local (national) frontier rather than global one (Andrews et al 2015).

From the perspective of less developed countries, technological catch-up typically relies on Foreign Direct Investments (further FDIs) and their positive spillovers. Theoretically, technological transfer from developed economies with the labor turnover on emerging markets should improve human capital and regional potential output. Unfortunately, the FDIs are not costless and have their limitations. The most crucial barrier visible in the laggard countries is the lack of absorptive capacity (Cohen & Levinthal 1990). Firms from developed countries typically shift the production to emerging states only for a product, where technical requirements are only slightly above current technological frontier of hosting economy (Glass & Saggi 1998). There is often also a conflict of interest between needs of multinational companies providing capital and the native society needs. Authors highlight that an in-house Research and development (R&D) expenditures and motivations systems for domestic investments are required to benefit from foreign capital expenses (Griffith et al 2004, Crespo & Fontoura 2007).

Another problem is related to regional system and network connections (Doloreux & Parto 2005). Knowledge intense industries are likely to cluster within narrow geographical areas. Numerous authors confirmed that intellectual property (PCT patents) is typically used by firms remaining in the geographical proximity to the inventor (e.g. Maurseth & Verspagen, 2002, Fleming et al 2007). Finally, more interconnected countries have greater capability to introduce and exports new products (Klinger & Lederman 2009).

The European Innovation Scoreboard directly address all of the mentioned problems. Therefore we do believe the study should be most comprehensive and adequate to perform convergence analysis.

3. The European Innovation Scoreboard

During this section we introduce the European Innovation Scoreboard – a ranking proposed by the European Commission to measure innovative potential of the EU28 economies as well as other international peers (including e.g. United States, Switzerland, Japan or China).

The general summary innovation index for a European Union country is a synthetic indicator computed as an average of 27 subcomponents divided in the four pillars. Due to the data limitations indices for international economies contains only 12 subcomponents. The indices are reported annually typically in the middle of the year (June-July).

First pillar titled *Framework Conditions* contains 8 indicators for the European Union countries and only 4 for international economies. The variables available in both groups describes scientific potential of the society e.g. number of doctorate graduates, share of people with the tertiary education, as well as research capacity – i.e. international scientific publications, share of country publications amongst top 10% most cited papers. European indicators additionally account for innovation-friendly environment, including broadband penetration and opportunity driven entrepreneurship, cultural diversity (foreign doctorate students) and lifelong learning.

Second pillar – *Investments* contains two variables internationally: Research and Development (R&D) expenditure int the business sector and in the public sector. European countries report also another three variables: non-R&D innovative outlays, expansion of venture capital and availability of ICT training.

The third pillar – *Innovation activities* (9 variables within EU, 8 internationally) is focused on three aspects. First aspect describes engagement of the Small and Medium Enterprises (SME) in the innovative activities. This group consist of two variables – first one describes product or process innovation second marketing or operational improvement. The data tables will use shortcut acronyms: respectively PP innovators and MO innovators, used by the European Commission. European countries report also whether innovative activities were done in-house or outsourced.

Secondly the survey promotes cooperation between entities and creating regional networks. The three variables belonging to this aspect describes collaboration of SME enterprises, number of private-public partnerships co-publications per thousand inhabitants, and share of collaborative R&D expenses as a percent of the Gross domestic product (GDP).

The final aspect is dedicated to accumulating and using of intellectual property rights. European Commission tracks the number of patent application under PCT procedure (acronym stands for Patent Cooperation Treaty), trademarks and individuals design. Number of applications is divided per GDP in Purchasing Power Standard.

Finally, the fourth pillar *Impact* relies strongly on the concept of technological frontier. This group contains 2 common indicators for international and European Union economies: share of knowledge intense services in total services export (further KIS exports) and share of medium & high-tech products in total goods exports (further MHT exports). European indicators have additional 3 measures: first employment in knowledge intense activities, second employment fast growing innovative firms and finally the third frequency of introduction of the innovative products. (Sales of new-to-market and new-to-firm innovations).

The European Commission transforms each of mentioned variable and express it with a normalized score index, which takes values from 0 to 1 (see methodology annex for further details[3]). Higher number denotes stronger innovative potential.

The summary innovation index is calculated as an average of normalized scores from 28 indicators for European Union countries and 12 indicators for international economies. We have modified indices for the EU countries to match the indicators from international database, averaging 12 common subcomponents only. Such transformed indicators were used during all of the estimations.

The overall panel consist of EU27 countries, other European economies reporting all 28 indicators (United Kingdom, Iceland, Israel, Norway, Switzerland, Turkey) and the group of international economies (Canada, Australia, Japan, United States, China, Brazil, South Africa, Russia, India). The research covers the period from 2010 to 2017 – indicators are collected once per annum.

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[3] European Innovation Scoreboard methodology appendix is available at (2018 edition): https://ec.europa.eu/docsroom/documents/30081/attachments/1/translations/en/renditions/pdf

4. Methodology

This section presents methodology of our research. Our aim is to determine whether cross-country convergence of innovation occurs. Following Barro & Sala-i-Martin (1992) and Quah (1993), we introduce two measures of concurrences: β and σ. Secondly, we introduce simple relative models distinguishing between in-house innovative capacity and imitations (following concepts of e.g. Griffith et al 2003)

The most popular concept of convergence (β) assumes that less developed countries/areas are growing more swiftly comparing to the more affluent peers. Let's denote $innov_t$ as summary innovation index at the time *t.* We expect to see a positive relationship of average annual change during the period 2010-2017 and starting level $innov_0$ (index value at 2010).

$$\frac{(innov_t - innov_0)}{T} = \delta_0 + \delta_1 * innov_0 \tag{1}$$

Where δ_1 should take a positive value if convergence exist. On the other hand, a negative value of this parameter denotes divergence. We are going to repeat calculations for every single component creating summary innovation index.

Secondly, we also attempt to use another measure – σ-convergence. The idea of such indicator assumes that if convergence exists cross-country standard deviation should diminish over elapsed time. The downward trend should be visible, when using following formula.

$$std(innov_t) = \alpha_0 + a_1 * T \tag{2}$$

We expect $a_1$parameter in equation (2) to have negative value, otherwise divergence occurs. Similarly like in case of β-convergence the estimation will be repeated for all innovation index components.

Finally, subject literature tends to distinguish between capability of in-house innovation and imitations, we proposed a simple fixed-effects panel model:

$$d\left(\frac{innov_t}{innov_{USA_t}}\right) = \beta_0 + \mu + \beta_1 * \left(\frac{innov_{t-1}}{innov_{USA_{t-1}}} - 1\right) \tag{3}$$

Where μ is a cross-country estimated fixed effect, $innov_{t-1}/innov\_USA_{t-1} -$ is a relative distance of the country summary innovation index to United States (selected as a benchmark), $\beta_0$and β_1 are estimated parameters.

This model has relatively straightforward economic interpretation. Parameters $\beta_0 + \mu$ describes in-house innovative potential. The negative sum indicates that country is expected to remain in the middle innovation trap, as it is unlikely to catch up the United States. β_1 can be identified with improvement of innovative potential done by imitations. We expect the parameter to be negative. In such case countries lying far below technological frontier are more likely to catch-up stronger. (in line with β convergence spirit). Based on that model we are capable to calculate the steady-state where:

$$0 = \beta_0 + \mu + \beta_1 * \left(\frac{innov^*}{innov^*_{USA}} - 1 \right) \tag{4}$$

The result of such exercise should present expected relative performance in case of no policy change scenario.

5. Estimation Results

This section discusses our findings on innovative capacity convergence. We proposed three measures determining if countries described as moderate innovators are catching up towards the innovation leaders.

The results of βconvergence analysis is presented in the Table 1. Third column contains estimates of parameter δ_1 - the positive values indicates that less developed countries are catching up the distance to current leaders. The last column presents whether estimates are statistically significant.

The estimate corresponding to the Summary Innovation Index does not differ from zero, suggesting quite persistent status quo between innovative potential across the countries. The analysis of subcomponents presents three major significant trends: 1) convergence of R&D expenditures in both business and public sector and related to them position of countries' production on the global technological frontier. 2) possible divergence of scientific potential with greater internationalization of research in developed countries. 3) The relatively stable position in case of using intellectual property rights (PCT patents, designs and trademarks) and SME activities, especially when it comes to product or process innovation.

Table 1 –βconvergence.

	δ_0	δ_1	T-statistic (δ_1)	P-value (δ_1)	Significance (δ_1)
Summary Innovation Index	0.00	0.00	-0.24	0.81	
KIS Export	0.01	-0.03	-2.51	0.02	**
MHT Export	0.01	-0.01	-1.82	0.08	*
Private funded public R&D	0.02	-0.04	-2.46	0.02	**
Designs	0.01	0.00	-0.26	0.80	
Trademarks	0.01	-0.01	-1.38	0.17	
PCT patents	0.00	-0.01	-1.06	0.30	
Public-private co-publ.	0.00	0.00	0.51	0.61	
R&D exp. business sector	0.01	-0.03	-2.30	0.03	**
R&D exp. public sector	0.01	-0.03	-2.57	0.01	**
Innovation co-operation	0.01	-0.02	-1.31	0.20	
MO innovators	0.01	-0.02	-3.18	0.00	***
PP innovators	0.00	0.00	-0.26	0.80	
Most cited publications	0.01	-0.01	-1.74	0.09	*
International co-publ.	0.02	0.02	2.43	0.02	**
Tertiary education	0.01	0.00	-0.71	0.48	
Doctorate graduates	0.02	-0.01	-0.93	0.36	

*** denotes significance at $\alpha = 0.01$, ** at $\alpha = 0.05$, * at $\alpha = 0.10$

The results of σ convergence analysis are available in the table 2. The data columns 2-9 contain cross country standard deviation observed in the subsequent years. Columns 10-11 present the estimated parameters. Column 12 answers if parameter a_1 is statistically significant.

Similarly like in case of βconvergence analysis, there is no statistically significant trend for Summary Innovation Index. The indicator describing slope of time trend in a cross-country standard deviation takes value, which statistically not differs from 0.

The σ convergence analysis confirms also the divergence of scientific potential – cross country standard deviation is in an upward trend in case of indicator describing the number of doctorate graduates in population and the internationalization of scientific publications. The divergence is also statistically significant in case of selected SME activities – product and process innovations and international co-operation.

Finally, similarly to the first analysis there are a statistically significant evidence of convergence in marketing and operational innovations and knowledge intense services export.

Table 2 – σ convergence.

	Cross – country standard deviation.								Parameters		
	2010	2011	2012	2013	2014	2015	2016	2017	α_0	α_1	Test
Summary Innovation Index	0.17	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.17	-0.18	
KIS Export	0.28	0.28	0.29	0.28	0.28	0.28	0.29	0.27	0.29	-1.64	*
MHT Export	0.27	0.27	0.27	0.26	0.27	0.27	0.27	0.26	0.27	-0.57	
Private funded public R&D	0.28	0.28	0.28	0.31	0.31	0.31	0.30	0.27	0.28	1.89	
Designs	0.22	0.24	0.25	0.25	0.26	0.25	0.24	0.24	0.24	1.28	
Trademarks	0.31	0.32	0.31	0.32	0.31	0.31	0.31	0.31	0.32	-0.90	
PCT patents	0.23	0.24	0.23	0.22	0.23	0.23	0.23	0.23	0.23	0.08	
Public-private co-publ.	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.31	0.29	1.16	**
R&D expenditure business sector	0.28	0.28	0.27	0.27	0.26	0.26	0.28	0.28	0.28	-1.45	
R&D expenditure. public sector	0.27	0.27	0.26	0.26	0.24	0.24	0.26	0.26	0.27	-2.99	
Innovation co-operation	0.27	0.27	0.28	0.28	0.27	0.27	0.28	0.29	0.27	1.99	*
MO innovators	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.30	0.33	-4.10	***
PP innovators	0.26	0.26	0.26	0.26	0.27	0.26	0.27	0.28	0.26	1.95	**
Most cited publications	0.26	0.26	0.27	0.26	0.27	0.26	0.25	0.25	0.27	-1.17	
International co-publ.	0.25	0.27	0.28	0.29	0.30	0.30	0.31	0.31	0.25	8.01	***
Tertiary education	0.29	0.29	0.30	0.30	0.30	0.29	0.29	0.29	0.30	-0.18	
Doctorate graduates	0.27	0.28	0.27	0.27	0.29	0.30	0.30	0.30	0.26	4.94	***

Parameters a_1 were scaled (multiplied by 1000) to visualize whether trend has upward or downward slope.

Finally, we estimated simple model of Summary Innovation Index dynamics. Small countries i.e. those whose population does not exceed 4 million people were excluded from the sample in order to eliminate potential outliers. The data for Luxembourg, Malta, Cyprus, Croatia Slovenia, Iceland, Baltic states (Estonia, Latvia and Lithuania) were not used during the estimations.

Model parameters are presented in table 3. Table 4 presents estimated cross-country fixed effects (column 2) and steady states (column 5). Similarly, to the results of β and σ convergence analysis minor changes are expected.

Our model suggests that current ranking leaders i.e. Nordic countries (Sweden, Denmark and Finland) and Germany are likely to further outpace the United States position in the innovativeness ranking. Central and Eastern Europe countries including Poland, Hungary, Czech Republic or Romania are achieving greatest gains, but are unlikely to exceed 70% of US potential.

Another interesting example is China – our model indicates nearly stable potential (at 76% of the United States level), after rapid expansion in the years 2010-2014. The European Commission report constant depression in the export of knowledge intense serviced export. The construction of ranking is likely to underestimate the innovative potential e.g. on artificial intelligence related to strategy Made in China 2025 (as technology is utilized in the domestic market only).

On the other hand, peripheral Europe countries (Greece, Spain Portugal and Ireland) are projected to lose innovativeness position. The same problem is related to South Africa, Turkey and Russia despite their low initial position.

Table 3 –Summary Innovation Index Dynamics – Fixed effects model. .

Model parameters				
	Coefficient – estimation	Std. Error	t-statistic	Prob.
Constant	-0.41	0.06	-7.33	0.00
Summary Innovation Index – Relative distance to United States	-0.07	0.01	-7.05	0.00

Model diagnostics			
R-squared	0.55	Mean dependent var	0.00
Adjusted R-squared	0.46	S.D. dependent var	0.03
S.E. of regression	0.02	Akaike info criterion	-4.88
Sum squared resid	0.07	Schwarz criterion	-4.29
Log likelihood	567.98	Hannan-Quinn criter.	-4.65
F-statistic	6.00	Durbin-Watson stat	2.10
Prob(F-statistic)	0		

Periods included: 7, Cross-sections included: 31, Total panel (balanced) observations: 217
Period and cross-section fixed effects included.

Fixed effects and steady state computations.

	μ	$\beta_0 + \mu$	2017 scores relative to US	Steady state - relative to US	Change (pp)
Australia	0.12	0.05	111%	113%	1.6%
Austria	0.13	0.06	115%	115%	0.1%
Belgium	0.11	0.04	112%	111%	-1.4%
Brazil	-0.11	-0.18	52%	56%	3.4%
Bulgaria	-0.18	-0.25	39%	39%	0.0%
Canada	0.14	0.07	116%	118%	1.3%
China	-0.03	-0.10	75%	76%	0.8%
Czech Republic	-0.05	-0.12	69%	70%	0.9%
Denmark	0.19	0.12	127%	128%	1.7%
Finland	0.15	0.08	117%	118%	1.7%
France	0.04	-0.03	93%	94%	0.3%
Germany	0.15	0.08	117%	120%	3.0%
Greece	-0.10	-0.17	61%	59%	-1.1%
Hungary	-0.13	-0.19	50%	52%	2.3%
India	-0.17	-0.24	42%	42%	-0.1%
Ireland	0.05	-0.02	97%	95%	-1.4%
Israel	0.08	0.01	99%	102%	2.9%
Italy	-0.05	-0.12	69%	70%	1.0%
Japan	0.08	0.01	102%	103%	1.3%
Netherlands	0.14	0.07	118%	117%	-1.0%
Poland	-0.16	-0.23	43%	44%	0.6%
Portugal	-0.06	-0.13	69%	68%	-0.3%
Romania	-0.21	-0.28	29%	32%	3.1%
Russia	-0.15	-0.22	49%	47%	-1.9%
Slovakia	-0.12	-0.19	53%	55%	1.7%
South Africa	-0.14	-0.21	49%	48%	-1.5%
Spain	-0.07	-0.14	66%	65%	-0.8%
Sweden	0.19	0.12	127%	128%	1.7%
Switzerland	0.23	0.16	140%	139%	-1.3%
Turkey	-0.17	-0.24	43%	41%	-2.2%
United Kingdom	0.09	0.02	106%	104%	-1.4%

6. Conclusions

Contrary to the research outcomes for the European Union countries (Archibugi & Filippetti 2011, Kijek & Matras-Bolibok 2018), we found no statistically significant divergence trend for international Innovation Indices reported based on both $\beta$and σ convergence analysis and our fixed effects model. Still our research confirmed that technological gaps are highlight persistent and there are neither no signs of convergence.

Based on the subcomponents analysis we found divergence of scientific potential measured by number of doctorate students in population (σ convergence) and international co-publications (both measures). Our research indicates also problem with diverging process and product innovations amongst SME enterprises. On the other hand there are signs of convergence in case of position on technological frontier and R&D expenses. Both β and σ analysis confirmed spreading of marketing and operational innovations and knowledge intense services exports.

Geographical model suggest consolidation of division between core and peripheral European Union countries (Magone et al 2016), as well as North-South division in the global context (following findings of e.g. Arrighi et al 2003). The Nordic countries and Germany are expected to increase innovative potential, while peripheral economies are projected to lose position in comparison with the United States. Similarly Central and Eastern Europe are expected to develop in a fastest manner, but still its potential should remain strongly below the level of Wester economies. Finally, less developed countries like South Africa, Russia, Turkey or India show limited potential for increase of technological potential.

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