Estimation of Innovation Value Adding Effect on the National Economy Development

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ABSTRACT

Neoclassical economic theory states that the growth of the nation primarily is dependent on the innovation potential of the country. However, this theory is often being refuted by the recent empirical research, proving that the innovations are becoming more cost-extensive, late in generating return on invested capital and not as useful as they used to be.

The present study researches the effect of innovation on the EU member-countries economic development, having selected R&D expenses, number of patents and number of researchers as innovation proxies.

The results prove that there is a strong relationship between the R&D expenses and GDP growth as well as the labour productivity, but no evidence was found that the number of scientists or the number of patents significantly influence economic development of the country.

Keywords: R&D expenses, number of patents, innovations value added, economic development

1. INTRODUCTION

The postulates of the neoclassical growth theory that the innovations are one of the major economic growth drivers is well-known in the modern environment, but lately this theory was questioned by a number of researchers (Wang, Gordon, Yang).

Cobb-Douglas function clearly shows that the total output growth is directly influenced by the labour and capital inputs as well as the total factor productivity (TFP), which can be increased by the changes in technology spurred by innovations, changes in laws, in trade restrictions, and in restrictions on capital flows, etc. Coe et al. (2008) empirically prove that R&D capital stocks have clear impact on the TFP.

The inventions of the previous two centuries undoubtedly were the main reason for the increased standards of living, for economic development at the breath-taking speed. Currently the innovations are the major determinants of the country's competitiveness on the global markets.

However, the law of diminishing productivity curve hints that the slowing global growth might indicate that the innovations though still large in their number cannot substantially influence economic development; they often do not add real value and may generate negative return on invested capital. The diminishing effect on the output of R&D departments is well-seen in pharmaceuticals industry – the companies tend to spend more time and money resources relative to the output than they used to.

Therefore, the ultimate goal of this study is to prove or refute the following hypothesis:

Innovations, as proxied by the R&D expenses in % of GDP, number of patents and number of researchers, have a value enhancing effect on the total countries' output.

The authors conducted the cross-country study to determine the differences of the population welfare and the innovation potential between the countries to understand whether R&D investments, number of patents and scientists can be considered to be a 'secret sauce' for the economic development of the nation.

As mentioned before, the authors selected independent variables – R&D expenses (RD) in % of GDP, number of patents and number of researchers. RD is the innovations input – the potential cost of the inventions but its main shortcoming is the unknown time lag, when the investments innovations will be reflected in GDP growth. Similar to RD measure is the number of scientists, which is also an 'investment' in future innovations. The patents, however, are the innovations output, representing the successful outcome of the investment, which are supposed to be monetized. Though all these measures are primarily attributed to the industries, these are readily-available data, providing plausible results.

2. LITERATURE REVIEW

Famous economists, authors of the neoclassical economic growth theory, such as Solow, Romer (1986), Lucas (1988) etc. state in their works that the innovations is the main power engine of the economic development. Modern scientists conducting empirical research have splitted into two opposing groups – the ones, who provide the evidence to support economic theory, while another group of researchers, which refutes the theory, saying that innovations are not efficient anymore and hardly add value but rather require large investments. For example Economist (2013) mentions the growing number of researchers and the increasing R&D expenses in % of GDP, but also quotes Pierre Azoulay of MIT and Benjamin Jones, who say that the researchers are less efficient – "in 1950 an average R&D worker in America contributed almost seven times more to "total factor productivity"—essentially, the contribution of technology and innovation to growth—that an R&D worker in 2000 did".

Gordon in his recent NBER publication (2012a) expresses concern about the innovations development, their usefulness and influence on the economic growth, saying that there are six headwinds that will drag their growth effect down: demography, education, inequality, globalization, energy/environment, and the overhang of consumer and government debt. He is also sceptical about the innovation power to drive the future economic growth in his Wall Street Journal article (2012b).

Changtao Wang (2013) taking patents and trademarks registrations as innovation proxies claims than innovations might not have a significant influence on the economic growth. He states that the role of innovation varies across the time periods, being very high before World War II and diminishing after it, especially in the major world's innovating nations such as Germany, US and UK.

Leo Sveikauskas (2007) focusing on the R&D efforts in US clearly distinguishes between the private and public R&D, providing the evidence that privately financed R&D returns are 25%, while state financed R&D returns are near zero.

Patent rights achieve their main aim to increase standard of living and therefore, support economic growth – evidence proof is provided by Hu and Png (2013), who researched 54 manufacturing industries in 72 countries. They have concluded that growth in the patents-intensive industries is to a large extent dependent on the patent rights. Patents have also greater effect in higher-income countries.

Macro-level analysis of Japanese and S. Korean cases was made by the Sinha (2008), when he concluded that GDP exerts influence on the number of patents, while he was not able to determine the reverse causality.

Another Asian economy, Taiwanese, was researched by Chih-Hai Yang (2006), who proved in his publication that the increase in patenting positively influences economic growth, while the long-term growth is largely driven by the worldwide discoveries.

3. RESEARCH DESIGN

The first step in the project is dedicated to the discovery of the innovation value-added effect to the economy development on macro- and micro-level, therefore the present paper provides an overview of the European Union member-countries' innovation potential determinants' current status and their historical perspective. The key data the authors consider are RD investments in % of GDP, number of patents and number of researchers.

Two periods were analyzed: 1. 1996 – 2013 to have a complete historical overview; 2. 2003-2013 to have a more recent overview, which might be more relevant to the current situation.

A number of regression equations were used to achieve the study goal of discovering how the innovation potential determinants influence GDP growth, stock market performance and the productivity of the economy, which is described hereas labour productivity and total factor productivity:

$$GDP\,\% = \alpha_0 + \alpha_1 * RD\% + \alpha_2 * Patents\% + \alpha_3 * Researchers\%, \quad (1)$$

$GDP\,\%$ - GDP Compound annual growth rate (CAGR);

$RD\,\%$ - R&D expenses CAGR;

$Patents\,\%$ - Number of patents CAGR;

$Researchers\,\%$ - Number of researchers CAGR (only considered for a shorter period of 2003-2013 as earlier data was unavailable).

The authors account for one year lag for the dependent variable versus the independent variables to allow a certain time as the effect of the investments turning into the monetary benefit is not immediate.

The following list presents other indicators, which were used as ‘y’ in the regressions for the same ‘x’ mentioned above:

- Labour productivity % - Labour productivity (Euro per H worked) compound annual growth rate;
- TFP % - Total factor productivity estimated as Tornqvist index CAGR;
- Stock Index % - Country stock index performance CAGR (only considered for shorter period of 2003-2013 as earlier data was unavailable for all countries).

TFP was selected for the testing as according to the economic theory, this indicator should be directly influenced by the innovations. The stock market value was added to the selection of the dependent variables as it tends to be the leading indicator of the nation’s development and economic growth.

Additionally, the authors considered the regression, where per capita data were used for the most recent year under review:

$$GDP\ per\ cap. = \propto_0 + \propto_1 * \frac{Population}{Number\ of scientists} + \propto_2 * \frac{Population}{Number\ of\ patents} \quad (2)$$

This equation was used to understand whether the welfare of a person, as described by GDP per capita, is to a certain extent dependent on the number of scientists or the registered patents relative the population of the country.

Three primary sources of information were used in the process of research: World Bank, Eurostat and the Conference Board Total Economy Database.

4. RESEARCH RESULTS

A. Current and Historical View on State Innovation Potential

R&D investments as defined by UNESCO Institute of Statistics are directed to “creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications”, which means the investment in the development of the nation. It also means that these investments are expected to provide monetary benefits in the future.

Figure 1 chart provides a cross-country comparison of the R&D expenses relative to the country’s GDP. Top 3 positions are taken by the Northern European countries – Finland, Denmark and Sweden (if Norway is included with 1.65%, it would be in the middle of the sample).

The lowest amount dedicated to R&D is seen in the developing economies (which still have lowest GDP per capita among EU members) such as Romania, Bulgaria, and Latvia. Greece, obviously struggling with the very poor economic conditions, is investing in R&D similarly low amount of GDP.

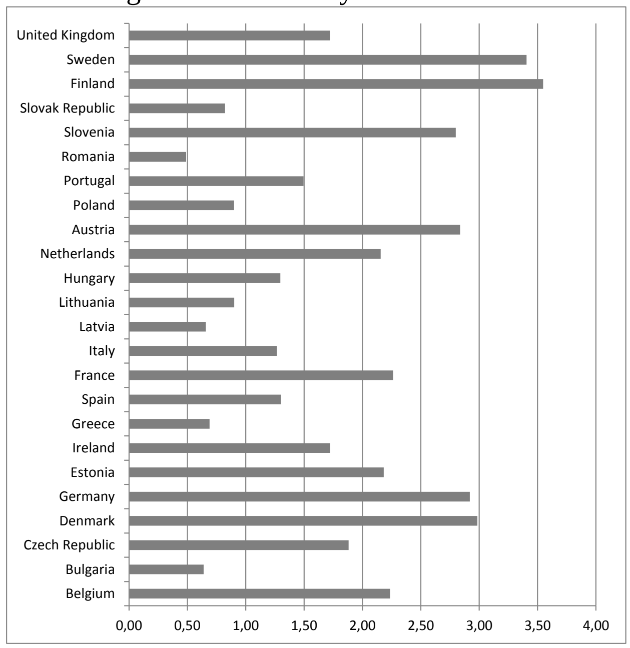

Figure 1. R&D Expenses in % of GDP (2012)

Estonia being a developing country is certainly worth mentioning as it obviously pursues a long-term strategy make as significant investments in R&D as France, Belgium and Netherlands. Substantial increase in R&D investments in 2011 and 2012 were made in developing Slovenia, taking the country in the top league.

Figure 2 chart compares the number of patents and researchers relative to the population, while also providing the view of the population welfare as measured by GDP per capita.

The lowest number of patents relative to the overall country’s population is exhibited by the developed nations with the large population. Though developed, Greece, Belgium and Spain are attractively different in terms of the number of patents, which leads to the need of further investigation of the laws regulating patent registration procedure. Patent-rich countries relative to the population size are rather new EU members – Estonia, Lithuania and Slovakia.

Analysis by the number of researchers relative to the population provides the possibility to create clusters once again - developed and developing nation, with the latter usually having higher number of researchers having some exceptions naturally. Top four countries in the number of researchers are Romania, Bulgaria, Italy and Poland, followed by Latvia and Hungary.

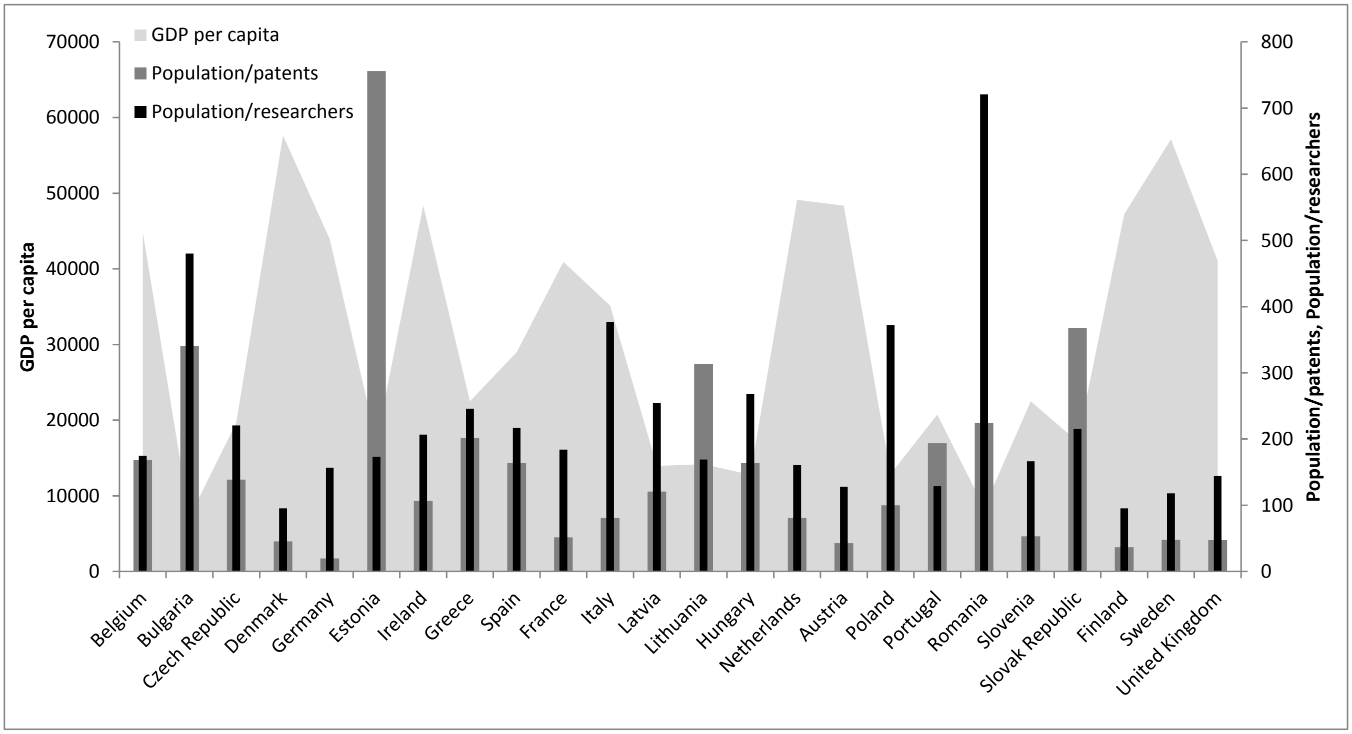

Figure 2. Number of patents and number of researchers vs. GDP level (2012)

Taking the number of the patents vs. the number of researcher, one concludes that according to this measure, the most ‘productive’ nations are the researchers from Estonia, Lithuania and Slovakia. The least productive, however, are developed countries with the extensive research bases – Germany and Italy as well as developing Romania.

The positive trend about the whole sample countries is increasing importance of the investments in research, applied research and experimental development (Figure 3), the growth of which exceed the rate of inflation in majority of the analyzed countries.

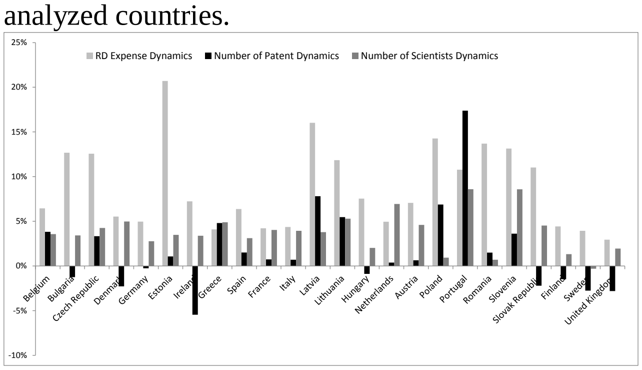

Figure 3. RD expenses, number of patents and researchers compound annual growth rate (2003-2012)

Annual growth in the number of scientists is similarly observed in all countries under review, which is a good sign. To add, the policy-makers on the macro and micro-levels have to ensure the efficiency of the research and the system overall.

Unlike growing R&D and the number of scientists, in several countries both developing and developed patents are in decline – in Ireland, Bulgaria, Hungary, Denmark, UK, Slovakia, Finland, Sweden.

B. Influence of Innovations on the Economic Growth Determinants

Innovation proxies – R&D expenses, number of patents and scientists – were first tested to eliminate cross-correlation to avoid multicollinearity problem. In both periods the correlation was lower than 50% with R&D ratio correlating the least with the number of patents and scientists.

The relationship of independent variables on the GDP growth according to the regression results appears to be the most significant (table 1) and the relationship importance didn’t diminish in the most recent time period as R^2 increased from 75.5% to 77% (table 2). Noteworthy, number of patents growth has a significant inverse relationship. Partially this phenomenon is explained by the decreasing number of patents in the emerging countries such as Bulgaria, Hungary and Romania, which all post very high GDP growth on annual basis.

Table 1

Regressions Statistics (1996-2013)

	Coeffi-cients	**t-stat**	**p-value**
Y=GDP%: **R Square=75.6%, F = 32.51**			
Constant	0.018	2.715	0.013
RD%	0.571	7.745	0.000
Nr. of patents %	-0.328	-3.918	0.001
Y=labour productivity: **R Square=62.4%, F = 17.43**			
Constant	-0.002	-0.481	0.636
RD%	0.321	5.793	0.000
Nr. of patents %	-0.151	-2.402	0.026
Y=TFP%: **R Square=8.2%, F = 0.94**			
Constant	0.182	0.339	0.738
RD%	4.950	0.829	0.417
Nr. of patents %	-8.480	-1.251	0.224

The similar relationship, but exhibiting lower significance, is obtained when labour productivity is tested as the dependent variable. Total factor productivity, according to the Table 1 results, is not dependent on either of the variables.

Shorter more recent time period increases the significance of all the regressions run in the research process - strong relationship with GDP and labour productivity, while again number of patents and number of scientists have inverse relationship, their influence becomes insignificant.

Table 2

Regressions Statistics (2003-2013)

	Coeffi-cients	**t-stat**	**p-value**
Y=GDP: **R Square=77.0%, F = 22.33**			
Constant	0.018	2.304	0.032
RD%	0.459	7.262	0.000
Nr. of patents %	-0.009	-0.128	0.899
Nr. of scientists %	-0.426	-2.993	0.007
Y=labour productivity: **R Square=72.8%, F = 17.86**			
Constant	-0.003	-0.684	0.502
RD%	0.214	6.851	0.000
Nr. of patents %	-0.006	-0.173	0.864
Nr. of scientists %	-0.037	-0.525	0.605
Y=TFP%: **R Square=21.3%, F = 1.804**			
Constant	-0.008	-1.584	0.129
RD%	0.097	2.247	0.036
Nr. of patents %	-0.020	-0.401	0.693
Nr. of scientists %	-0.036	-0.377	0.710
Y=stock index%: **R Square=22.4%, F = 1.93**			
Constant	0.026	1.080	0.293
RD%	0.223	1.162	0.259
Nr. of patents %	-0.128	-0.585	0.565
Nr. of scientists %	-0.726	-1.677	0.109

None of the independent variables have a significant relationship to the TFP or the local stock market.

Additional regression, which considered per capita data, was run on the most recent available data (table 3). F-significance of 0.00095 shows that the number of patents and number of scientists relative to the country's population size have a significant relationship to the GDP per capita, hinting that the higher is the number of patents or scientists, the higher is the welfare of the population.

Table 3

Regressions Statistics (2013): Analysis by per capita data

	Coeffi-cients	**t-stat**	**p-value**
Y=GDP per capita: **R Square=46.9%, F = 9.71**			
Constant	57837.89	8.801	0.000
Population/researchers	-72.07	-2.970	0.007
Population/patents	-0.62	-2.541	0.019

However, one might question the endogeneity of the economic indicators – whether it is the innovation power that led to the GDP being on the high level or whether the country having GDP per capita on a decent level can afford excellent scientific base.

5. CONCLUSIONS

The results obtained through the graphical analysis allowed to make the conclusion that there is a very positive trend in increasing R&D expenses, which points to the understanding of the society that innovations have a significant role in generating future benefits and the need to invest in long-term. The number of scientists is growing in all sample countries, but the number of patents in several states show a declining trend, which possibly demonstrates the diminishing productivity effect, but the statement need a further proof.

Intensity of R&D investments clustered the sample into the developing and developed nations, demonstrating that the latter on average invest more in R&D on relative basis. In opposite, the developing countries often have a higher share of researchers in total population than do the developed countries.

The primary goal of the research to test the hypothesis whether innovations add value to the economic development was achieved when running regression for longer period and more recent period of the last 10 years. Regressing R&D expenses on the GDP growth and labour productivity in time periods appeared to be significant. Number of patents' dynamics and number of researchers' dynamics did not show any significant relationship to the GDP growth (exc. in longer time period regression number of patents growth showed negative relationship to GDP development).

Selected as dependent variables, stock market growth and total factor productivity, were not proved as being depended on any of the innovation proxies.

Additional regression run by the author considered the indicators relative to the population size. Both variables, population/researchers and population/patents have negative relationship to the welfare of the nation.

Based on the above stated, the hypothesis of innovations value-adding effect was proved, but not on all of the independent variables' dimensions.

A number of challenges faced in this research can be considered in the further research on the innovation value adding effect. For example, to get more objective view on the R&D efficiency and its influence on productivity, it would be recommended to consider private R&D investments and public R&D investments separately in an attempt to compare the efficiency of both. The authors hypothesize that the private investment by far would be more efficient than public investments in R&D.

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7. REFERENCES

[1] D. T. Coe, E. Helpman, A. W. Hoffmaister (2008), **International R&D Spillovers and Institutions**. IMF Working Paper, WP/08/104.

[2] **The Economist** (2013), Has the ideas machine broken down?.

[3] R. J. Gordon, (2012a), **Is US economic growth over? Faltering innovation confronts the six headwinds.** NBER Working Paper No. 18315.

[4] R. J. Gordon, (2012b), Why innovation won't save us, **The Wall Street Journal.**

[5] A.G.Z. Hu, I.P.L. Png, (2013), Patent rights and economic growth: Evidence from cross-country panels of manufacturing industries. **Oxford Economic Papers**, Vol. 65, No. 3, 675-698.

[6] R. E. Lucas, (1988), On the mechanics of economic development'. **Journal of Monetary Economics**, Vol. 22, No.1, 3–42.

[7] P. Romer, (1986), Increase returns and long run growth. **Journal of Political Economy,** Vol. 94, No. 5, 1002–1037.

[8] D. Sinha, (2008), Patents, Innovations and Economic Growth in Japan and South Korea: Evidence from Individual Country and Panel Data., **Applied Econometrics and International Development**, Vol. 8, No.1, 181-188.

[9] L. Sveikauskas, (2007), **R&D and Productivity Growth: A Review of the Literature**. U.S. Bureau of Labor Statistics Working Paper No. 408.

[10] C.H. Yang, (2006), Is innovation the story of Taiwan's economic growth?. **Journal of Asian Economics**, Vol. 17, No. 5, 867–878.

[11] C. Wang, (2013). The Long-run Effect of Innovations on Economic Growth - http://www.murdoch.edu.au