International Journal of Economics, Commerce and Management
United Kingdom Vol. IV, Issue 2, February 2016
http://ijecm.co.uk/ ISSN 2348 0386

ROLE OF INNOVATIONS IN THE GLOBAL ECONOMIC SYSTEM OF THE 21st CENTURY: LINK TO ECONOMIC GROWTH

Oxana Mihailovsca
Professor of World Economy and International Economic Relations,
Bukovyna University, Chernivtsi, Ukraine
ooovvv@mail.ru

Abstract
The present paper is focused on the relationship of innovation and socio-economic development. A division of countries from the global innovation space viewpoint is carried out in terms of the core-periphery model. Under consideration is the ambiguous impact of innovation on economic development. The countries with a high level of innovation performed better in terms of economic development, as compared with the peripheral countries of the global innovation environment. Meanwhile, a lack of innovation impact on the macroeconomic dynamics in the 21st century is identified in short- and medium-term horizons. An economic-mathematical model of the impact of innovation on macroeconomic dynamics within the K-cycle is justified and empirically verified. This model suggests a phase of a significant impact of innovation on economic development and a phase of "innovation saturation", when the impact of innovation on macroeconomic dynamics becomes less apparent. The departure from this phase is only possible through a new radical innovation. According to the results of correlation analysis, a conclusion is justified that the world economy has just entered a phase of "innovation saturation", which corresponds to the final stage of the K-cycle, therefore the impact of innovation on economic growth is much lower than in the 1970s and the 1980s.

Keywords: Innovation, Economic Growth, Innovation Saturation, Radical Innovations, Horizontal Innovations, K-Cycles.

INTRODUCTION

The world as we know it is not to be imagined without computers, the internet, and mobile phones. For the most part, production has already become automated, and workers in the 21st century must possess an array of engineering and technological skills to operate complex equipment. These and other changes were influenced by the intensification of innovative processes. The term “innovation” is known to have been coined by Schumpeter, who defined it as a “new combination”, which means a different quality of production and is achieved not through modest improvements of old equipment or existing organizational structure, but a parallel introduction of new means of production and organization(Schumpeter [1911] 2008). It was Schumpeter who laid the foundation for understanding the role of innovation in economics, describing them as “creative destruction”, referring to creating the new by destroying the old. The researcher had identified five innovations for newly created objects (Schumpeter [1911] 2008):

- manufacturing of a new product (innovation);
- introduction of new means of production based on scientific discovery (process innovations);
- development of a new market (regardless of whether the market has been there or not) (marketing innovation);
- involvement of new kinds of raw materials in the production (raw innovation);
- introduction of new organizational forms of production (conducting business) (organizational innovation).

Other approaches to innovations classifications exist (Halecker and Hölzle K. 2014; Faria and Lima 2009), however the idea of innovations as the driving force of economic development, which had been piloted by Schumpeter, is never called into question by modern researchers. An endogenous growth model due to innovations by Aghion and Howitt (1992) and its numerous modifications can also be mentioned here.

A large chunk of theoretical and empirical research is devoted cycles in economics. Still a logical problem arises: any recurrence involves periods when various factors, including innovation, play a different role. This problem somehow remains largely ignored by scientists, and the idea that innovation is the main factor of economic development in the 21stcentury is perceived as a postulate without proper justification.

Therefore, considering the empirical data, the purpose of the present paper is to analyze the role of innovation as a factor of economic growth, and explore some other aspects of innovation in modern economic processes, primarily in the global economy.

REVIEW OF LATEST LITERATURE

Scholars have long recognized innovation as the driver of economic development. This approach is based on Schumpeter's innovation destruction theory, the main principles of which can be briefly summarized as follows: R & D cause ageing of products and technologies, while there is always a conflict between the old and the new, when progress is caused not by accumulation, but by replacement (Schumpeter 1934). Building on this approach, F. Aghion and P. Howitt developed a theory of economic growth where vertical and horizontal innovation was introduced (1992). Vertical innovations are ones that create new welfare. They give a new impetus to economic development. Horizontal innovations are ones that improve existing benefits. In the process of improving the new welfare a series of intermediate goods is produced. Horizontal and vertical innovations are interrelated. Vertical innovations are a platform for horizontal ones, where improvements are somewhat layered, when the vertical ones need the so called routine intelligence (term coined by Aghion-Howitt) that accumulates in the production of intermediate (improved) benefits (1992).

In this regard, innovations contribute to cyclical economic development. It can be maintained that the presence of cycles in macroeconomic dynamics has been theoretical studied and empirically evidenced (Oppers 2002; Nefiodow and Nefiodow 2014/2015). Also, Kondratieff pointed that innovations give impetus to every K-cycle, but did not provide any specific details for this aspect. L. Nefiodow and S. Nefiodow (Nefiodow) match "innovation impulses" to every K-cycle in certain spheres (Table 1).

Table 1: Innovation impulses of K-waves: the approach of L. Nefiodow and S. Nefiodow

# of К-cycle	Length	Key invention	Field of application
1	1780-1830	steam engine	textile industry
2	1830-1880	railway, steel production	Transport
3	1880-1930	electricity, inventions in chemistry	mass production of retail goods індивідуальних
4	1930-1970	automobile, oil	individual mobility
5	1970-2005	information and communication technologies	information and communication
6	2005-present day	biotechnologies, psychosocial health	comprehensive healthcare

Source: elaborated by the author according to (Nefiodow and Nefiodow 2014/2015)

While generally agreeing with the fact that innovation brings about “impulses” to the macroeconomic development, it should be noted that the end of the K-wave before 2005 and the transition to a new one today remain arguable. Revisiting the Aghion-Howitt’s theory, one must admit that no significant innovative breakthroughs (radical innovation) in any of the areas have occurred, including health care, which was marked by L. Nefiodow and S. Nefiodow as a field where a key invention had already been made, which gave impetus to macroeconomic dynamics. Rather, the crisis in 2008 and the very slow recovery in subsequent years suggest the absence (so far) of radical innovations (key inventions).

J. Modelski furthers this approach and notes that each Kondratieff wave corresponds to a basic innovation in a particular area, which brings it to the role of the driver of world’s development (Modelski 2012).

Given the above approaches, innovation’s link to economic growth should vary across time intervals. Innovations produce the biggest impact on economic growth within a certain time interval after vertical innovation when horizontal innovations give are most efficient. Over time, this effect becomes less tangible, the link of innovations to economic growth becomes almost imperceptible towards the end of the cycle, when horizontal innovations become so stratified over the vertical one (key invention) that each new innovation leads to no significant economic effect. The result is a situation which can be referred to as “innovative saturation” of the economy.

In this respect, as Nathan Rosenberg rightly observes, a chain link: cost of research → inventions and new results → growth of new merchandise → macroeconomic growth was visible in the 1930s and 1970s, but not in the 21st century (Rosenberg 2004). He mentions three reasons that break the above chain:

1. Research spending leads to fewer major scientific discoveries.
2. Even if discoveries are made, a few of them are applied in advanced technologies and products.
3. New technologies often improve products, but raise their prices, thus no major economic growth occurs (Rosenberg 2004).

In addition, it should be mentioned that the 1930s and 1970s are starting periods of the corresponding K-waves. In the latest wave, invention of the computer was vertical innovation, which was supplemented by the internet.

Gradually, the rapid development of ICT technologies in the late twentieth century came to a halt, hence the innovation regarded as horizontal (i.e. improve already existing benefits) impacts the economic development less. Unless a genuinely radical innovation is made, the impact of innovations that are being made today will be less obvious.

RESULTS

GII index of INSEAD business school, which is calculated against 81st indicator (grouped into two sub-indexes: "Innovative resources" and "Results"), was used for differentiation of countries in terms of innovation, The method of calculation and the list of indicators is described in detail in the source (Global innovation index 2014). Given certain ambiguity around GII index definition as simple arithmetic component, grouping of countries was made with regard to the idea that they form the global innovation environment, which comprises three zones: core, semi-periphery and periphery. Mean values of the both major sub-indexes were used as a differentiation criterion (Table 2).

Table 2: Zones of the Global Innovation System

Zone	sub-index «Innovation input»	sub-index «Innovation input»
Core	above average	above average
semi-periphery: subgroup 1	above average	below average
semi-periphery: subgroup 2	below average	above average
periphery	below average	below average

*Mean value was calculated for all countries

"Core" is formed by the countries that are characterized by high productivity of innovations as well as their high level of resource provision. This group is the central zone (driver) of innovative development in the global innovation environment. Countries that are part of this cluster are global leaders of the innovation process.

"Semi-periphery" consists of two groups of countries. Subgroup 1 (Sufficient resources for innovation, low productivity of innovation) comprises countries where "resources innovation" sub-index value is above average for the set of countries. Meanwhile, "productivity innovation" sub-index value in these countries is lower than average for all countries.

Subgroup 2 (lack of resources, adequate performance innovation) includes countries where "resources innovation" sub-index value is below average on aggregate, while "productivity innovation" sub-index value is above average.

Periphery of the global innovation environment comprises countries with minimum innovation productivity and innovative potential.

Group centers are shown in the Table 3, with the list of countries is represented in Annex A.

Table 3: Characteristics of Groups of Countries by GII Sub-Indexes in 2014

		Innovative Capacity			Innovation Productivity		
#	**Group**	**Center**	**Max**	**Min**	**Center**	**Max**	**Min**
1	core	56.1	73.6	44.5	44.0	63.1	32.7
2	semi-periphery	42.3	56.2	32.4	31.0	42.1	31.2
2.1	Sufficient resources. Low productivity	46.4	56.2	45.2	27.0	30.9	15.6
2.2	Lack of resources. Sufficient productivity	39.2	41.4	32.4	34.1	42.1	31.2
3	periphery	38.2	42.8	32.9	25.9	30.9	25.1

Source: calculated by the author according to Annex A

The “core” of the global innovation environment in 2014 comprised a relatively small number of countries - 48 or 33.5% of the aggregate. This group includes virtually all countries with high income levels.

Semi-peripheral zone comprises a group of 59 countries or 16% of the aggregate. Periphery comprises 44 countries or 50,3% of the aggregate. These are chiefly countries with low level of income (GNI per capita, Atlas method (current US$)).

Mean values of income across the above groups are shown in Table 4.

Table 4: Mean Values of Income Levels Across Innovation Groups

GROUP	Mean	Median	Max	Min.	Std. Dev.	Obs.
Perypheria	1350.909	1185.000	3170.000	260.0000	849.2481	44
Semiperypheria (subgroup1,2)	8563.559	7250.000	18950.00	3270.000	4447.732	59
Core	45621.89	43460.00	102610.0	20980.00	19608.02	37
All country	16090.71	6415.000	102610.0	260.0000	20809.03	140

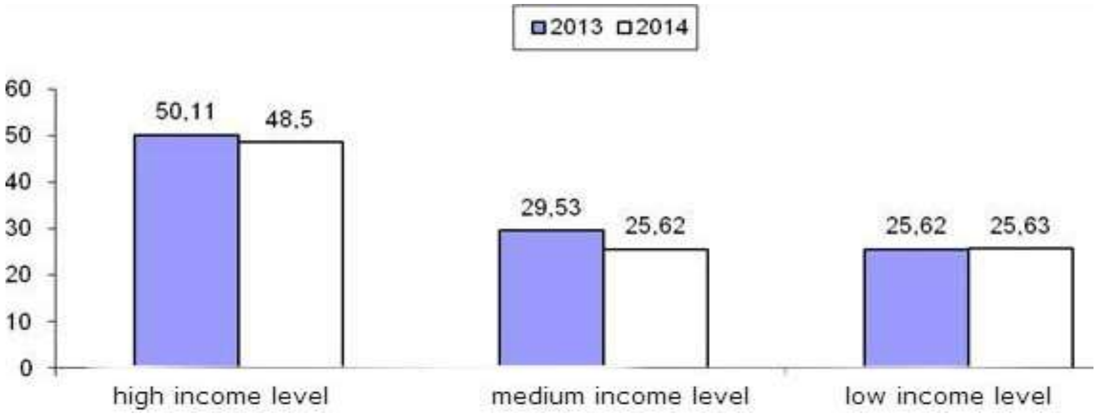
The source is calculated according to Annex A and data of the World Bank

(GNI per capita, Atlas method (current US$)

Based on F statistics and its p-values (Annex B), a conclusion can be made that mean values of income levels in the innovation groups are significantly different. They have the highest values in the “core” countries and the lowest ones in the “periphery” countries.

This to some extent correlates with the results shown in the «Global Innovation Index 2014» report regarding the relationship of GII index and an index that shows the level of economic development of a country as GDP per capita (Fig. 1).

Figure 1: Mean values of GII index across groups of countries in terms of GDP per capita



Source: elaborated by the author according to (The Global innovation index 2014).

As Fig. 1 suggests, a gap between countries with high and medium income levels exists (it was there in 2013), while the difference in GII index between countries with medium and low incomes is slight. Thus, a relatively high level of economy innovation ensures a high level of household income (which is one of the basic conditions of "sustainable development" of socio-economic system). At the same time, a low level of innovation ensures "medium" and "low" household incomes. A conclusion is possible to make that a certain "threshold" of innovation exists, where innovations produce a significant impact on macroeconomic development in terms of "sustainable development" approach.

Another conclusion, as results in Table 5 and Fig. 1 suggest, points to a long-term innovation impact on income redistribution in the global economic system of 21st century. Countries with advanced innovations have performed better in terms of development.

Nevertheless, let us try to determine the correlation between economic innovation and economic dynamics. The GII index will serve as global innovation indicator, whereas GDP growth rate will be chosen as a second indicator (GDP growth (annual %)). Correlation matrix for a set of variables $GDP(t-\Delta t_i)\ i=0,1,2$ and $GII(t-\Delta t_k)\ k=0,1$ is shown in Table 5.

Table 5: Correlation Matrix between Variables Considering an Assumption about Correlation between Macroeconomic Dynamics and Innovation Within AR-Model

	GDP_13	GDP_12	GDP_11	GII2013	GII2012
GDP_13	1.000000	0.661269	0.528557	-0.301969	-0.389644
GDP_12	0.661269*	1.000000	0.554161	-0.326537	-0.408418
GDP_11	0.528557*	0.554161	1.000000	-0.047609	-0.107181
GII2013	-0.301969*	-0.326537	-0.047609	1.000000	0.521847
GII2012	-0.389644*	-0.408418	-0.107181	0.521847	1.000000

*- values according to a bilateral criterion at 0,0005 (Fisher and Frank 1963)

The correlation matrix (Table 5) is based on assumption that the relationship between innovation and GDP dynamics can be feasible if taking current and past levels of innovation into account ($GII(t-\Delta t_k)\ \ k=0,1$) within AR-model (AR-ratio is frequently used in research as constituents of more complex models of macroeconomic dynamics (e.g. Hirata, Kose and Otrok 2013).

The matrix actually provides an answer to the question whether AR-model for the relationship between GDP dynamics and innovation of economy can be structured, where GII index is a supplementary one.

$$GDP(t) = c + b_1 GII(t) + b_2 GII(t-1) + b_3 GDP(t-1) + b_4 GDP(t-2) \quad (1)$$

where GDP(t, t-1, t-2) are growth rates over relevant years;

where GII(t, t-1) are GDP growth rates over relevant years – global innovation index in 2013 and 2014 (essentially, GII was calculated against 2012-2013 data, i.e. it holds for 2013);

$c, b_1, b_2, b_3, b_4, b_5$ are corresponding indexes of the model.

Looking at correlation matrix, the importance of the correlation ratios for all variables of the model (1) and its positive trend for the variables of autoregressive part (variables GDP_{2012}, GDP_{2011}) should be emphasized as well as a negative trend for factors related to innovation (variables GII GII_{14}, GII_{13}). This indicates absence of direct influence of economic innovation on macroeconomic dynamics in the current phase of the world economy development (early second decade of the 21st century) and is in conflict with the abovementioned results regarding the relationship of socio-economic development (household income indicator) and economic innovation. In addition, there is every reason to consider that countries with advanced innovations do not demonstrate great rates of economic development in 2010s.

However, given innovations are not the main driver of economic development in the 21st century in the short-term, then, perhaps, their influence will be more significant in the medium-term, especially for "core" countries of global innovation environment.

For this reason, let us research the correlation model of medium-term GDP growth (arithmetical mean of GDP growth for 2013, 2012 and 2011 is calculated according to (GDP growth (annual %) against mean GII indicator for the same period.

$$corr(GDP_{av}, GII_{av}) \quad (2)$$

where $GDP\_av = \frac{GDP\_13 + GDP\_12 + GDP\_11}{3}$, $GII_{av} = \frac{GII_{14} + GII + GII\_11}{3}$

Pearson's correlation index value for "core" countries of global innovative environment $corr(GDP_{av}, GII_{av}) = -0{,}27$ is negative, therefore there are grounds to maintain that innovations do not show a direct link to economic development. Moreover, the correlation between innovation and medium-term GDP dynamics is negative, which seemingly contradicts to the generally recognized approach regarding a positive impact of innovation on economic development and results of earlier research of the problem (Ulku 2004; Griliches and Lichtenberg 1984).

To resolve this conflict, let us examine the cyclic nature of macroeconomic dynamics and the role of innovations in economic development throughout different phases of the cycle. This role is significantly different at the beginning and in the end of Kondratieff cycle. As the base (vertical, radical) innovation is, in fact, the driver of the cycle, it is innovations that play a crucial role in macroeconomic dynamics at the initial phase, as there is a large “portion of market demand”, which encourages less important (horizontal, according to Aghion-Howitt) innovations, resulting in high added value.

The situation is completely different at the end of the K-cycle, when in fact all demands for innovations are satisfied, and thus new innovations are supported by lower demand.

Revisiting Table 1, it should be mentioned that 1930s and 1970s correspond to the initial phases of K-cycles. However, in the 21st, another K-cycle is reaching the end or at least enters a descending phase. Invention of the computer was a radical innovation in the last wave, which was supplemented by the internet. Gradually, the rapid development of information and communication technologies (ICT) in the late 21st century has halted and now the horizontal innovations (i.e. improve already existing welfares) have smaller influence on economic development.

Such influence of innovations on economic development can be represented through economic-mathematical model of the evolution of added value formed subject to innovations:

$$\frac{dY}{dt} = bY - aY^2 \quad (3)$$

where Y – added value formed subject to innovations (included in the innovative production);

a – parameter standing for the demand for innovative production from the socio-economic system:

b – parameter standing for the innovative subsystem’s ability to produce new innovations to meet the demand for innovative production.

Model (3) shows the evolution of the economic effect from innovations within one K-cycle, as each basic innovation sets its values of a and b parameters.

Let us divide variables in equation (3):

$$\int_{Y_0}^{Y} \frac{dY}{bY - aY^2} = \int_0^t dt \quad (4)$$

where Y_0 is potential demand for innovative production based on certain basic innovation at the time $t = 0$ (time of “innovative breakthrough”).

Integrating equation (4) we get the solution as follows:

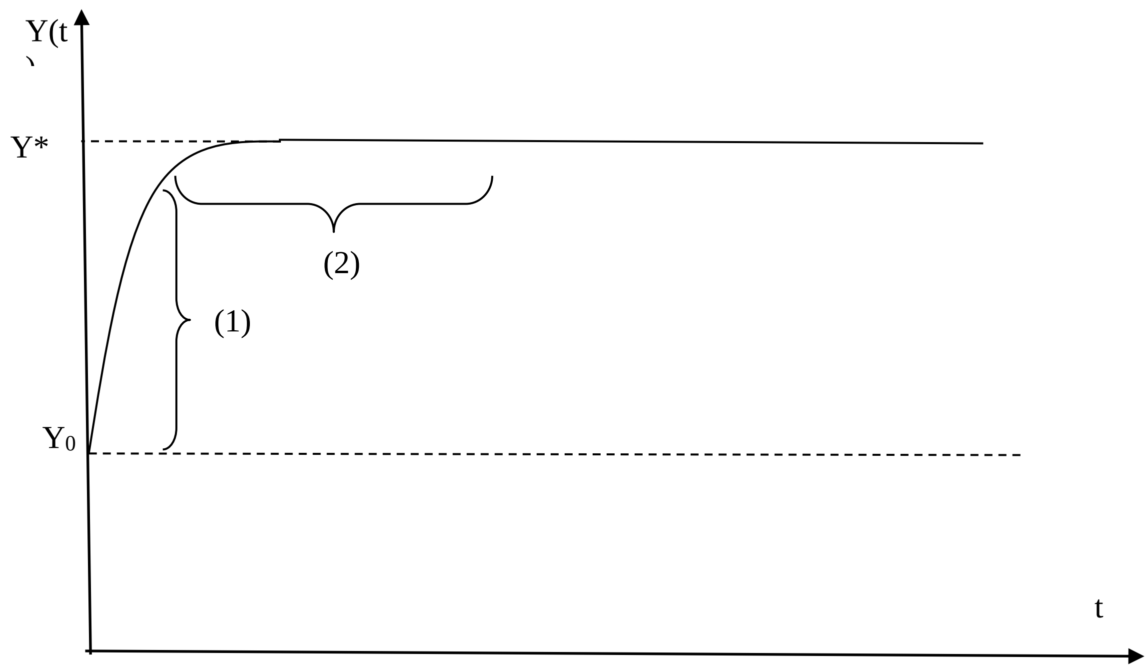
$$Y(t) = \frac{b}{a+\left(\frac{b}{Y_0}-a\right)e^{-bt}} \quad (5)$$

Dependence (5) implies “innovation saturation” of economy, which is manifested at $t \to \infty$ horizontal as a straight line (Table 3):

$$Y^* = \frac{b}{a} \quad (6)$$

Model (5) implies two significantly different phases of innovations’ impact on macroeconomic dynamics: a phase of significant effect (1) in Table 3 and a phase of “innovative saturation”, when innovations are no longer noticeable in economic development (2).

Figure 2. Dynamics of Gross Added Value Subject to Innovations



Source: elaborated by the author (parameter values in equation (5): b=5, a=0.2, Y*=20)

Within the phase corresponding to the beginning of K-cycle development, basic innovation sets up a platform for potential “layering” of horizontal innovations, due to which entire industries and markets are created (e.g. IT and ICT industries and markets in the last K-cycle). Over time, the potential of new markets wears out, and further modifications and products improvements due to horizontal innovations do not contribute to the economic effect as before, since growing demand saturation is becoming smaller in the market. The process evolves into a phase of "innovative saturation" of economy. Markets move into quasi-stationary state, exit of which is only possible due to new radical innovations, which will set new parameters in the equation (5) as well as limits of potential demand for radically new production of services (Y *).

Let us try to check the accuracy of the relationship (5) empirically. The main difficulty in this case is the lack of generalized indicators of innovation such as GII index on the historical horizon, which would correspond to the beginning of the last K-cycle (1970s-1980s). Therefore, we used an index that is indirectly connected with innovation: the number of articles in scientific journals per 1000 inhabitants (World Bank IP.JRN.ARTC.SC database index (Scientific and technical journal articles), data are available from1985).

To find out a different impact of innovations on macroeconomic dynamics, data interval was divided into two sub-intervals of 1985-1997 and 1998-2012. With approximation, one can assume that the first sub-interval (before the crisis in 1998) spreads mainly across phase (1), where innovations made a significant impact on macroeconomic dynamics, with the second covering phase (2), where this influence becomes scarce.

We evaluated the correlation ratios between GDP per capita (*T_GDP*) and the number of scientific papers per 1000 inhabitants (*V_article*) in the intervals of 1985-1997, 1998-2012 and 1985-2012 for the world as a whole, individual economic groups and across individual countries (183 countries):

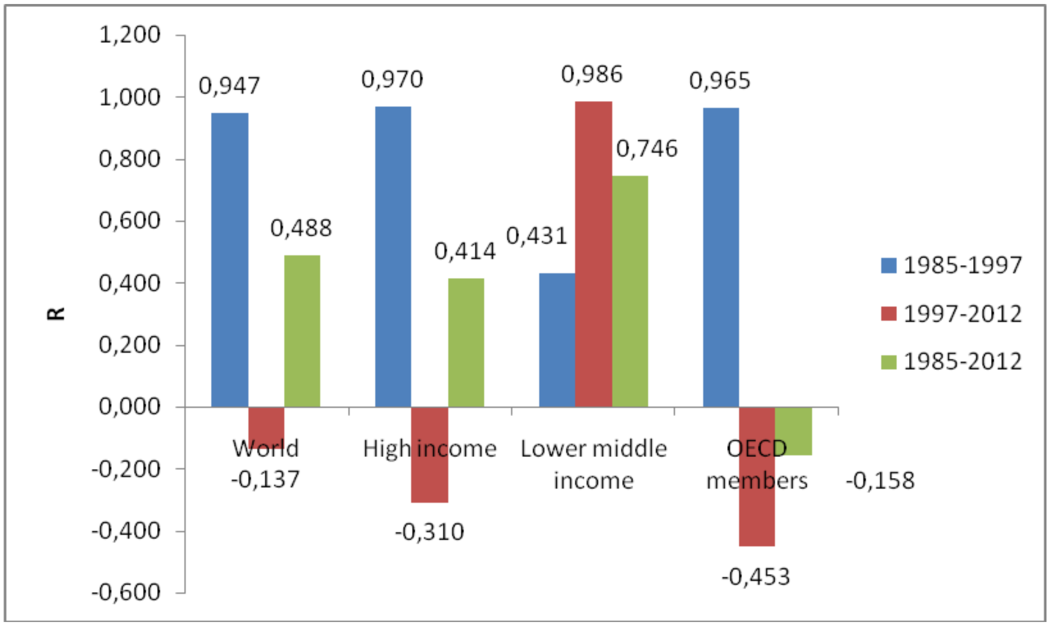
$$corr(T\_GDP, V\_article) \qquad (7)$$

Figure 3 shows evaluation results of relevant correlation ratios for economic groups (World Bank classification) in Annex B for some countries.

The results in Fig. 3 allow for a conclusion that regarding the global economic system as a whole and its more developed part, the correlation between the number of scientific papers per 1000 inhabitants and GDP per capita in the first time interval is rather high and positive (value according to a bilateral criterion is 0.0005). Instead, correlation ratios become negative in the second interval (value equals 0.1).

This correlation dynamics indicates that innovations did not significantly affect economic growth in the 1990s, unlike the first interval, where the link between innovations and macroeconomic dynamics is rather tight.

Figure 3: Correlation between Number of Research Papers per 1000 people and GDP per Capita

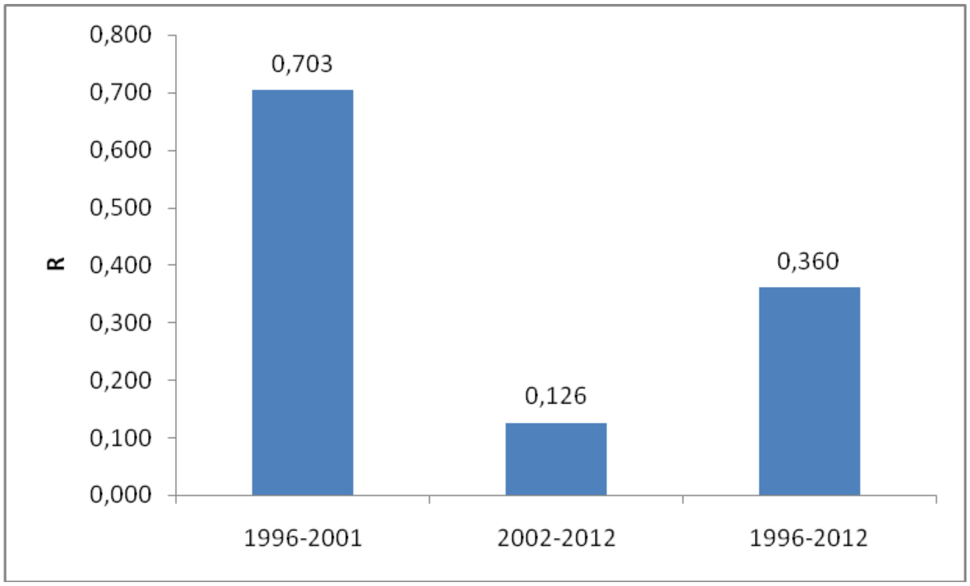


A similar pattern is observed in the world countries (Annex C), especially the US, Japan, Britain and other developed countries, which became the driving force of new industries and markets of the latest K-cycle. Instead, it is the opposite situation for less developed countries – in 1997-2012 many of them experienced positive relationship between innovation and macroeconomic dynamics, which exceeded the same value for 1985-1997.

This phenomenon, in our opinion, can be explained by "inclusion" of these countries into the global economic system, which took place relatively recently. However, these countries, despite being most heavily populated, belong to the "periphery" of the global innovation environment and their contribution to economic development through innovation is insignificant, as demonstrated by the dynamic link between innovation ("number of research papers per 1,000 people" indicator) and macroeconomic developments ("GDP per capita" indicator).

Additionally, correlation between R & D expenses per 1,000 people (calculated according to the World Bank data (Research and development expenditure (% of GDP)) and GDP per capita within the global economic system was studied. The time interval for available data on this indicator starts with 1996, so there is no possibility to distinguish a (1) "pure" phase, but to track the relationship between these parameters in the transition interval between phases (1) and (2) (1996-2001), and the phase (2) (2002-2012.). The results of correlation analysis are shown at Fig. 4.

Figure 4: Correlation between R&D Expenses per 1000 people and GDP per capita in the Global Economic System



Correlation index values in 1996-2001 in this case are lower than expected in the case of previous pair of indicators due to the fact that the 1996-2001 period can be attributed to the transition between phases (1) and (2) in Figure 3 (value of the correlation index is 0.25). In the second interval (2002-2012), correlation between R & D spending and macroeconomic dynamics is lost, which corresponds to "saturation" for the impact of innovation on economic growth.

CONCLUSIONS

To summarize, the impact of innovation on economic and social development is arguable. The results clearly suggest that countries with high levels of innovation ("core" of global innovation environment) performed better in terms of social and economic development than countries with less innovative economy. At the same time, empirical data indicate no correlation between innovation and macroeconomic dynamics in the 21st century.

Such ambiguity indicates that the impact of innovation on macroeconomic dynamics cannot be considered without taking into account the cyclical phase of economic development, in particular across the K-cycles. Each cycle is based on radical innovation providing a platform for new sectors and emerging markets with their potential scope. The formation and development of new markets and industries through innovation meets the horizontal phase of innovation impact on economic development. However, this process reaches a state of "saturation" over time and the innovation impact on macroeconomic development becomes less significant.

Despite a lack of empirical data to confirm this division, there is every reason to believe that indeed the impact of innovation on economic development was much higher in 1980s-1990s than in the 21st century. This conclusion is confirmed by correlation analysis between the level of research activity (the number of articles in journals and R & D spending and GDP per capita).

Thus, the world economy has reached the phase of "innovation saturation". With no perceived effect coming from innovations, such state of things will persist in the world economy until a new breakthrough innovation is made and new radical innovations set standard for new areas and markets. Yet another research is needed to define the feasible time frames and areas triggering the new K-cycle.

It requires additional studies of perspectives of different areas of science such as where potential breakthroughs that will give an impulse to the emergence of a new K-cycle. According to Global R&D Funding Forecast (2014), the most funds is spent on research in ICT, nanotechnologies, and biotechnologies. But there isn't correct evidence consider one as the basis for the next Kondratieff cycle emergence. It is a necessary more detailed investigation of the impaction of correspondent innovation for the global economy in future.

The nanotechnologies development is connected to the creation of quantum computers. But the estimate of the possibility of quantum computers to found radical innovation is needed.

It is difficult to determine the role of biotechnologies in the rising wave of the sixth Kondratieff cycle. In particular, it is difficult to assess the demand for cloning technologies that have been developed in recent years.

The third area of possible technological advances is the investigations in high-energy and the creation of alternative energy sources. But relatively small investment in the development of these technologies makes doubt the possibilities of a breakthrough in this direction in the coming years.

Also, further studies are needed for investigation of attracting and integration new markets in the global economy. Currently, the most attractive areas of world trade expansion are China and Islamic countries that tend to fundamentalism. These countries have consumption potential for "traditional innovation" that can increase the positive impact of innovation on the global economy for some time. The more detailed scientific investigations in future need for elaboration of this question.

REFERENCES

Aghion, Ph and Howitt, P. (1992). A Model of Growth Through Creative Destruction. Econometrica, 60 (2), 323-351. http://artsci.wustl.edu/~econ502/Aghion_Howitt.pdf. Accessed 27 April 2015

Faria, P., Lima, F. (2009). Firm Decision On Innovation Types: Evidence On Product, Process And Organizational Innovation, Paper to be presented at the Summer Conference 2009 on CBS. Copenhagen Business School http://www2.druid.dk/conferences/viewpaper.php?id=5590&cf=32. Accessed 27 April 2015

Fisher, R.A., Frank, Y. (1963), Statistical Tables for Biological, Agricultural and Medical Research, 6th ed., published by Longman Group, Ltd., London (previously published by Oliver and Boyd, Edinburgh), Table VII. https://digital.library.adelaide.edu.au/dspace/bitstream/2440/10701/1/stat_tab.pdf. Accessed 27 April 2015

GDP (current US$). http://data.worldbank.org/indicator/NY.GDP.MKTP.CD Accessed 27 April 2015

Global R&D Funding Forecast 2014. http://www.battelle.org/docs/tpp/2014_global_rd_funding_forecast.pdf?sfvrsn=4. Accessed 02 February 2016

GDP growth (annual %). http://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG. Accessed 27 April 2015

GNI per capita, Atlas method (current US$) http://data.worldbank.org/indicator/NY.GNP.PCAP.CD . Accessed 27 April 2015

Griliches, Z, Lichtenberg, F. (1984). Interindustry Technology Flows and Productivity Growth: A Reexamination. Review of Economics and Statistics, 66, 324–329.

Halecker, B., Hölzle K. (2014). Klassifikation von Methoden zur Geschäftsmodellinnovation entlang eines system-orientierten Gesamtkonzeptes. ZfKE. Zeitschrift für KMU und Entrepreneurship, 62, (2), 183-190.

Hirata, H., Kose, M.and Otrok Ch., (2013). Regionalization vs. Globalization. IMF Working Paper, WP/13/19, https://www.imf.org/external/pubs/ft/wp/2013/wp1319.pdf. Accessed 27 April 2015.

Modelski, G. (2012). Kondratieff (K-) Waves in the Modern World System. Kondratieff Waves: Dimensions and Prospects,. 65–76.

Nefiodow, L., Nefiodow, S. (2014/2015). Health: The Economic Growth Engine of the 21st Century. ICU, 14, (4), https://healthmanagement.org/c/icu/issuearticle/health-the-economic-growth-engine-of-the-21st-century-1#sthash.suIthgH0.dpuf. Accessed 27 April 2015

Oppers, S. (2002). The austrion theory of business cycles. IMF working paper. https://www.imf.org/external/pubs/ft/wp/2002/wp0202.pdf. Accessed 27 April 2015

Population, total. http://data.worldbank.org/indicator/SP.POP.TOTLю Accessed 27 April 2015

Research and development expenditure (% of GDP) http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZSAccessed 27 April 2015

Rosenberg, N. (2004). Innovation And Economic Growth. OECD. http://www.oecd.org/cfe/tourism/34267902.pdf. Accessed 27 April 2015

Schumpeter, J.A. (1939). Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process.2 vol, New York: McGraw-Hill.

Schumpeter, J.A., [1911] (2008). The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest and the Business Cycle, translated from the German by Redvers Opie, New Brunswick (U.S.A) and London (U.K.): Transaction Publishers.

Scientific and technical journal articles. http://data.worldbank.org/indicator/IP.JRN.ARTC.SC. Accessed 27 April 2015

The Global innovation index 2014. https://www.globalinnovationindex.org/userfiles/file/reportpdf/GII-2014-v5.pdf. Accessed 27 April 2015

The Long Wave has a Long Life [electronic recourse], available from http://longwavegroup.com/news/2009/_pdf/090408_CCF01042011_00002.pdf. Accessed 27 April 2015

Ulku, H. (2004). R&D, Innovation, and Economic Growth: An Empirical Analysis. IMF working paper, WP/04/185. https://www.imf.org/external/pubs/ft/wp/2004/wp04185.pdf . Accessed 27 April 2015

ANNEXURE

Annex A

GII2014 index constituent across groups of countries according to innovations level

# in group	countries	input	Output	Insti	Hum_ cap	Infrastructure	Market	Business	Knowl	Creat
	Core of global innovation system									
1	Switzerland	66.4	63.1	87.6	56.7	59.0	74.7	54.2	60.9	65.3
2	United Kingdom	68.2	56.5	88.6	60.3	60.6	81.4	50.2	56.4	56.6
3	Sweden	67.5	57.1	89.7	61.9	63.6	68.2	53.9	58.8	55.4
4	Finland	67.5	53.8	95.3	66.5	59.7	61.4	54.8	54.2	53.4
5	Netherlands	63.5	57.7	93.3	50.5	58.7	63.6	51.3	53.8	61.7
6	United States of America	67.9	52.3	86.2	58.3	57.5	83.8	53.7	58.1	46.5
7	Singapore	73.6	44.9	92.8	64.9	65.6	78.2	66.7	46.7	43.1
8	Denmark	65.5	49.5	93.6	61.5	59.1	67.8	45.6	46.6	52.4
9	Luxembourg	58.8	54.9	82.9	47.2	53.4	49.7	60.8	45.8	64.1
10	Hong Kong (China)	68.6	45.1	91.4	49.5	67.4	79.7	54.9	33.3	56.8
11	Ireland	63.3	50.0	90.4	53.2	45.3	70.3	57.4	53.2	46.9
12	Canada	66.3	46.0	92.7	56.4	58.4	75.9	48.0	43.7	48.3
13	Germany	60.3	51.7	82.7	56.3	56.3	60.1	46.1	53.1	50.4
14	Norway	62.4	48.8	94.1	52.6	63.9	57.9	43.2	40.1	57.5
15	Israel	61.8	49.1	67.7	61.9	53.7	67.5	58.2	54.3	43.9
16	Korea, Rep,	62.2	48.4	75.8	64.1	62.8	65.4	42.7	54.5	42.2
17	Australia	64.6	45.5	88.9	61.8	60.1	68.1	43.9	38.5	52.5
18	New Zealand	62.5	46.6	94.3	55.5	52.1	68.9	41.5	45.3	47.9
19	Iceland	56.8	51.3	88.6	49.4	47.4	54.1	44.4	36.6	66.1
20	Austria	61.3	45.5	88.8	61.5	53.7	57.2	45.5	41.1	49.9
21	Japan	62.2	42.6	84.1	54.4	58.9	66.8	46.8	47.2	38.1
22	France	59.5	44.8	78.6	55.9	54.7	61.0	47.4	44.2	45.5
23	Belgium	58.2	45.2	87.9	51.7	46.5	58.5	46.5	44.6	45.7

24	Estonia	56.8	46.3	78.6	46.3	57.4	55.4	46.3	39.1	53.4
25	Malta	50.6	50.3	79.2	34.6	44.7	48.9	45.5	45.1	55.5
26	Czech Republic	53.6	46.8	76.2	45.7	50.8	49.1	46.2	46.4	47.3
27	Spain	55.9	42.6	74.8	48.3	56.7	64.7	35.2	43.1	42.1
28	Slovenia	53.1	41.4	78.7	49.2	46.4	51.1	39.9	40.6	42.2
29	China	45.8	47.3	48.3	43.4	45.0	50.5	41.8	59.0	35.7
30	Cyprus	51.7	39.9	83.5	39.4	37.6	64.4	33.8	34.6	45.3
31	Italy	51.2	40.1	73.2	42.1	49.8	51.0	40.0	42.7	37.5
32	Malaysia	52.5	38.7	68.2	41.6	45.7	63.9	42.9	35.5	42.0
33	Portugal	52.6	38.7	77.3	51.3	46.6	53.2	34.5	32.7	44.7
34	Latvia	49.2	40.4	76.8	34.1	42.9	54.0	38.2	36.8	44.1
35	Hungary	47.0	42.2	72.3	37.9	45.6	42.1	37.2	41.9	42.5
36	Slovakia	46.7	37.0	74.5	32.9	43.5	48.6	34.2	34.7	39.4
37	Saudi Arabia	47.8	35.4	60.0	35.6	47.0	59.0	37.6	25.7	45.0
38	Lithuania	48.7	33.3	73.4	41.6	44.4	52.1	32.2	30.3	36.2
39	Mauritius	46.9	35.0	78.3	25.9	37.1	63.0	30.2	26.6	43.4
40	Barbados	48.3	33.2	78.5	31.6	27.9	48.7	55.0	38.0	28.5
41	Bulgaria	44.3	37.1	68.5	31.2	42.7	44.2	35.1	36.2	38.1
42	Croatia	45.1	36.4	69.8	35.3	45.4	42.5	32.5	34.9	37.9
43	Chile	48.4	32.8	71.7	32.4	48.2	53.3	36.6	27.3	38.3
44	Poland	47.3	34.0	74.7	37.9	41.9	48.2	33.7	31.2	36.7
45	Thailand	44.7	33.8	54.4	41.1	36.5	56.9	34.9	32.4	35.2
46	Russian Federation	43.8	34.5	56.4	44.5	41.1	42.5	34.3	37.6	31.4
47	Greece	45.9	32.0	66.6	43.5	41.1	47.9	30.6	30.6	33.3
48	Seychelles	44.5	32.7	67.0	21.6	49.6	41.7	42.4	22.4	43.0
	Semi-periphery of global innovation system									
	Subgroup 1 (Sufficient resources. Low productivity of innovations)									
1	United Arab Emirates	56.2	30.3	76.6	62.1	55.9	46.2	40.3	14.3	46.2
2	Qatar	50.4	30.2	75.5	33.6	53.1	46.3	43.4	20.4	40.1
3	South Africa	45.6	30.9	69.9	28.7	32.9	63.8	32.7	29.1	32.7
4	Mongolia	44.8	30.3	62.5	26.9	42.0	57.2	35.2	24.2	36.4
5	Montenegro	45.6	28.4	68.1	40.7	34.2	50.6	34.4	20.9	35.9
6	TFYR of Macedonia	43.4	30.4	65.8	33.8	36.3	54.6	26.8	28.2	32.6

7	Bahrain	45.5	27.1	67.9	27.0	48.1	48.5	35.7	28.4	25.8
8	Colombia	43.4	27.6	60.4	29.4	44.8	51.8	30.8	24.4	30.7
9	Brunei Darussalam	44.3	19.0	73.4	22.7	36.6	54.7	34.1	12.8	25.3
10	Fiji	45.2	15.6	57.9	38.9	31.2	46.8	51.3	16.8	14.3
	Subgroup 2 (Lack of resources. Sufficient productivity of innovations)									
11	Moldova, Rep,	39.4	42.1	58.4	28.6	31.9	51.4	26.8	40.8	43.3
12	Panama	41.4	35.2	59.7	25.1	40.5	44.1	37.7	25.4	45.0
13	Turkey	39.7	36.7	54.9	33.3	35.6	49.1	25.4	32.3	41.2
14	Romania	41.4	34.8	65.9	29.1	41.7	42.9	27.3	36.6	33.0
15	Costa Rica	41.3	33.3	66.7	25.0	38.1	40.7	35.9	30.3	36.3
16	Belarus	40.5	33.7	52.1	39.8	39.9	46.0	24.9	38.8	28.6
17	Ukraine	38.2	34.4	52.9	36.6	27.1	45.1	29.1	38.2	30.6
18	Jordan	40.3	32.1	64.3	28.3	31.1	39.9	37.8	29.4	34.9
19	Armenia	39.4	32.7	66.4	21.4	30.0	50.4	28.8	31.8	33.6
20	Serbia	40.1	31.7	61.0	31.5	41.0	37.0	29.7	33.8	29.6
21	Argentina	39.2	31.1	49.1	38.3	38.0	37.7	32.9	25.2	36.9
22	Viet Nam	35.8	34.0	46.6	24.2	28.6	45.0	34.4	32.2	35.8
23	Indonesia	32.4	31.2	38.1	22.8	33.1	45.3	22.8	23.2	39.2
	Periphery of global innovation system									
1	Brazil	41.7	30.8	53.9	31.1	39.2	45.2	39.3	28.1	33.6
2	Mexico	42.2	29.9	61.8	32.5	39.9	46.9	29.9	26.9	32.9
3	Kuwait	39.4	30.9	60.2	23.3	39.0	47.0	27.7	33.8	28.1
4	Uruguay	40.3	29.3	68.7	29.4	38.6	40.0	24.7	24.1	34.4
5	Peru	42.8	26.6	61.1	27.2	38.2	58.5	29.1	20.2	33.1
6	Georgia	41.1	28.0	69.7	23.5	33.3	55.2	23.9	30.0	25.9
7	Oman	42.8	24.9	70.8	28.3	39.8	48.1	27.2	21.2	28.6
8	India	37.0	30.4	50.8	22.7	32.1	51.2	28.0	32.2	28.6
9	Lebanon	42.2	25.0	58.1	34.4	34.9	44.6	39.1	22.6	27.4
10	Tunisia	39.7	26.1	61.8	37.8	37.0	39.9	22.1	21.2	31.1
11	Kazakhstan	41.1	24.4	61.1	30.0	43.8	44.1	26.4	24.8	23.9
12	Guyana	37.3	27.7	55.9	13.5	25.3	40.4	51.2	18.6	36.7
13	Bosnia and Herzegovina	39.4	25.5	59.5	18.1	29.4	51.9	37.9	29.2	21.8
14	Jamaica	39.2	25.7	67.9	25.1	26.8	44.6	31.5	21.9	29.4
15	Dominican Republic	34.9	29.6	53.4	7.1	34.0	50.4	29.9	22.8	36.4

16	Morocco	38.0	26.5	59.6	29.7	39.6	42.8	18.2	25.5	27.4
17	Kenya	34.7	29.0	53.6	15.8	21.1	54.4	28.5	26.9	31.2
18	Bhutan	39.8	23.9	62.6	17.0	44.0	45.9	29.3	2.8	45.0
19	Paraguay	36.0	27.2	47.9	25.3	27.6	50.2	29.1	17.5	36.9
20	Trinidad and Tobago	38.6	24.5	62.1	29.2	25.7	48.4	27.9	21.9	27.1
21	Uganda	36.3	26.0	56.7	17.3	28.1	43.7	35.8	24.3	27.6
22	Botswana	41.2	20.5	71.5	25.1	35.4	49.5	24.5	23.7	17.3
23	Guatemala	36.7	24.8	57.8	17.3	28.1	49.5	30.7	22.3	27.3
24	Albania	40.5	20.4	58.8	22.8	34.1	61.9	24.9	20.2	20.6
25	Ghana	33.5	27.0	52.3	22.8	20.6	42.5	29.3	31.1	22.9
26	Cabo Verde	38.9	21.3	59.6	17.9	39.3	47.3	30.3	14.6	27.9
27	Senegal	32.6	27.6	54.5	14.7	27.3	42.4	23.9	24.1	31.0
28	Egypt	34.1	26.0	42.1	27.8	36.1	35.4	28.9	25.4	26.6
29	Philippines	32.9	26.8	49.6	15.2	30.0	44.8	25.1	27.1	26.5
30	Azerbaijan	37.4	21.8	53.4	20.9	32.4	59.9	20.1	19.1	24.6
31	Rwanda	40.2	18.4	60.6	20.4	23.0	59.4	37.5	15.5	21.3
32	El Salvador	36.4	21.7	57.4	18.5	31.3	43.1	31.8	13.6	29.8
33	Gambia	32.9	25.1	45.8	15.5	22.5	47.4	33.3	29.4	20.9
34	Sri Lanka	30.9	27.0	40.9	17.1	36.6	40.2	19.8	26.5	27.6
35	Cambodia	32.9	24.5	46.6	14.1	21.0	55.8	26.7	26.4	22.6
36	Mozambique	36.4	20.6	49.2	20.5	27.5	49.9	35.0	26.9	14.3
37	Namibia	36.7	20.3	68.2	19.3	25.8	44.4	25.7	12.7	27.9
38	Burkina Faso	32.9	23.5	56.5	14.9	21.5	40.4	31.0	23.1	23.9
39	Bolivia, Plurinational St,	32.7	22.8	32.7	28.1	26.9	48.2	27.7	21.4	24.1
40	Kyrgyzstan	37.9	17.6	52.9	29.4	31.3	53.6	22.4	21.1	14.1
41	Nigeria	28.6	27.0	44.0	12.2	21.8	43.9	21.3	21.1	32.8
42	Malawi	33.0	22.2	54.2	11.7	24.1	39.6	35.3	24.7	19.8
43	Cameroon	30.6	24.5	46.8	17.9	20.0	45.0	23.3	21.8	27.1
44	Ecuador	33.7	21.3	43.6	21.6	35.9	43.7	23.8	14.4	28.1
45	Côte d'Ivoire	28.0	26.0	48.8	13.0	20.1	37.7	20.5	27.2	24.8
46	Lesotho	38.6	15.5	59.8	25.5	28.8	47.5	31.3	14.6	16.3
47	Honduras	34.8	18.6	46.1	19.7	26.6	48.9	32.9	16.2	21.1
48	Mali	28.7	23.7	47.8	13.9	18.1	38.3	25.1	18.7	28.7
49	Iran, Islamic Rep,	33.2	19.0	43.0	36.4	33.6	35.9	17.3	20.0	18.1

50	Zambia	28.7	22.8	50.7	3.6	20.4	47.0	22.0	24.3	21.2
51	Venezuela, Bolivarian Rep,	26.3	25.0	21.1	31.2	26.0	29.6	23.7	26.6	23.4
52	Tanzania, United Rep,	32.0	19.2	57.2	12.7	25.4	36.6	28.0	17.5	20.9
53	Madagascar	31.4	19.6	55.1	14.5	22.4	41.8	23.3	16.7	22.5
54	Nicaragua	33.2	17.7	53.4	10.5	28.1	47.1	27.0	12.1	23.4
55	Ethiopia	30.4	20.4	48.7	11.4	25.2	41.0	25.6	17.5	23.2
56	Swaziland	32.2	18.4	55.3	18.4	14.8	38.1	34.5	14.4	22.5
57	Uzbekistan	31.3	19.1	46.1	27.1	29.2	41.1	12.7	26.6	11.7
58	Bangladesh	29.0	19.7	45.2	14.1	26.7	44.1	14.9	22.2	17.2
59	Niger	32.3	16.2	49.6	11.8	28.8	43.2	28.3	31.3	1.1
60	Zimbabwe	27.2	21.5	26.7	12.4	22.8	46.4	27.7	17.4	25.5
61	Algeria	31.7	16.7	47.2	25.5	32.2	36.2	17.2	19.5	14.0
62	Benin	30.3	18.1	53.4	18.1	18.3	36.5	25.2	15.0	21.2
63	Pakistan	25.4	22.6	40.1	9.8	22.2	35.8	19.3	21.9	23.2
64	Angola	26.2	21.4	39.1	13.8	17.5	42.9	17.8	24.8	18.1
65	Nepal	31.8	15.7	46.1	15.5	23.2	43.1	31.3	11.2	20.3
66	Tajikistan	32.8	14.6	46.2	24.4	19.6	61.3	12.6	24.3	5.0
67	Burundi	30.6	14.2	45.5	17.5	16.1	47.3	26.7	12.3	16.2
68	Guinea	25.1	15.4	42.6	7.7	16.5	32.5	26.3	12.5	18.2
69	Myanmar	23.0	16.3	35.3	17.4	16.7	36.9	8.8	17.7	14.8
70	Yemen	24.4	14.7	36.6	15.5	16.3	40.7	12.7	13.7	15.7
71	Togo	28.3	7.0	47.9	14.5	15.4	42.7	21.1	13.4	0.6
72	Sudan	23.2	2.1	36.4	7.6	18.3	38.9	14.8	2.4	1.9

Annex B

Test for Equality of Means of GNI

Categorized by values of GROUP

Sample: 1 140

Included observations: 140

Method	df	Value	Probability
Anova F-test	(2, 137)	206.0075	0.0000
Welch F-test*	(2, 61.4127)	164.9117	0.0000

*Test allows for unequal cell variances

Analysis of Variance

Source of Variation	df	Sum of Sq.	Mean Sq.
Between	2	4.52E+10	2.26E+10
Within	137	1.50E+10	1.10E+08
Total	139	6.02E+10	4.33E+08

Annex C

Correlation between scientific and technical journal articles and GDP per capita

Country	1985-1997	1997-2012	1985-2012
Austria	0,880	0,783	0,837
Finland	0,508	0,147	0,682
Canada	0,615	-0,440	-0,485
Finland	0,508	0,147	0,682
France	0,913	-0,632	0,631
United Kingdom	0,879	-0,557	0,518
Japan	0,914	-0,807	0,694
United States	0,292	-0,464	-0,481
Sweden	0,739	-0,763	0,437
India	-0,743	0,979	0,928
Brazil	0,895	0,795	0,787
China	0,899	0,978	0,984
Russian Federation	0,366	-0,817	0,290