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Technology and knowledge transfer: international perspective

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***Abstract* — This article analyses patterns of technology transfer policy in connection with innovation development. It is argued that knowledge transfer plays the key role in efficiency of international technology acquiring. Statistical analysis is carried out based on data gathered from various international organisations including OECD and The WB.**

***Keywords* — technology transfer, knowledge transfer, technology balance of payments, innovative development, scientific potential, co-authorship, co-invention**

I. Introduction

New knowledge, products, services and technologies are considered to be among the main driving forces of innovative economy. Developed countries are increasingly separating from the developing world through technological excellence and effective national innovation systems. However, many of the developing countries tend to quickly make up for a lack of innovative capacity through implementation of effective scientific policy, often based on derived practical experience from abroad. In this regard, the importance of international technology transfer (ITT) is difficult to overestimate as:

a) the very essence of technology transfer (TT) implies a permanent process of technology motion, which mediates to innovation development in general;

b) contemporary TT triggers development of such elements of innovation infrastructure as intellectual organization, market-intellectual enterprises, TT centers, technological platforms, consulting in innovation, etc;

c) establishment and development of efficient TT should strengthen the state's position on the world stage and facilitate international cooperation.

Article analyses TT channels, focusing on transferring knowledge through labour turnover and collaborative international projects. The structure of the paper is as follow. First, definition of key terms are given to indicate the meanings in which they used in this research. Further on, ITT analysis in comparative perspective is held, specifying factors influence TT policy. Next section focuses on knowledge transfer and world tendency in science. The novelty of this study consists in regarding ITT as a key element of innovation development. The core contribution is to present evidence, based on statistical analysis of actual data.

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II. Concept of International technology transfer

Flows of knowledge is the most important condition for the formation and functioning of innovative activity. One of the most significant kinds of "knowledge flows" is TT.Before proceeding any further, it is worth defining the term technology in the light of this research, since various definitions abound, not to mention that it is key element for understanding term technology transfer. Various types of technology exist. It may be quite specific or encompass several sub-processes; it may be codified in formulas, blueprints, drawings, patent applications, and etc. However, quite often access to know-how are required. Galbraith refers to technology as "the systematic application of scientific or other organized knowledge to practical tasks" [7]. Two aspects in this definition is prominent: the consistency and practicalities. Advocate of this approach also define technology as the information necessary to achieve a certain production outcome from a particular means of combining or processing selected inputs [4].

Contrary, DeVore emphasized the peculiarity of technology that enable the man to produce new and valuable goods, devices, etc., which are related to explicit social aims [12]. Similarly, in spite of the division technology definition into 4 elements, namely "object, process, knowledge, and volition", Skolimowski highlighted human knowledge as a key factor [5]. Mitcham stresses even more important element which is human intention, i.e. when, how, and why technology will be used is determined by human will [3]. Throughout this article, the second way of defining technology will be implied for following reasons. Firstly, it reflects the tacit knowledge issue through emphasizing the significance of human aspect. Secondly, this approach underling correlation with social needs which is of paramount importance for technology transfer.

Michael Polanyi introduced the concept of implicit / tacit knowledge, which, in contrast to "explicit knowledge" difficult to verbalize and give it to another individual through formal instruction. The key aspect here is absorbing this information, which does not directly follow from the ability to understand instructions, but mainly prior skills and competence are needed to manage the technology. Tacit knowledge is largely the more essential category, as it often gives the competitive advantage. This implies that explicit knowledge that stands alone is not economically valuable, otherwise, especially in the light of technology transfer. The emphasis is shifting from know-what model of learning to know-who, i.e. again human factor is seemed to have a huge role [11].

Considering TT itself, the most common definition refers to it as "the development of a technology in one setting that is then transferred for use in another setting" [9]. The term TT generally covers all activities relating to the flow of technical knowledge, experience and equipment. In other words, TT refers to any process by which one party gains access to a second party's information and successfully learns and absorbs it into its production function. It is evident, that much TT occurs between willing partners in voluntary transactions. Especially, this aspect became extremely important in case of transferring abovementioned tacit knowledge. TT varies in accordance with level on which it happened. It could be universities, enterprises or state levels, and all of these subjects have their notable interest in TT. For instance, a key aspect for universities is knowledge sharing, while companies view it as a competitive advantage which could be derived from that technology.

ITT is a comprehensive term covering mechanisms for shifting information across borders and its effective diffusion into recipient economics. Thus, it refers to numerous complex processes, ranging from innovation and international marketing of technology to its absorption and imitation. Particularly, it encompasses technology, trade and investment policies that can affect the terms of access to knowledge. Policy making in this area is especially complex and needs careful consideration, both by individual countries and at the multilateral level. Furthermore, TT is a costly process and these costs are central to how information is traded [8].

Several channels exist through which ITT might take place. Firstly, trade in goods and services itself. Every export carries some potential level growth of the technological capabilities and information about the development directions. Import of capital goods and technologies may directly contribute to increaseing productivity through the introduction into production processes provided recipient's capacity is enough to absorb the procurement. Openness of trade policy is necessary but not sufficient condition for attracting technology. What is more important here is the possibility of adapting that technology.

The second channel is the foreign direct investment (FDI). Transnational companies, as a rule, transfer technological information with its affiliated companies, and consequently, some of them can 'spill over' to the host economy. This channel provides the necessary knowledge and skills for the transfer in the host country and therefore the question of implicit knowledge is solved [1].

The third major channel of ITT is direct trading knowledge through technology licensing. This can occur in the framework of its subsidiaries or between unrelated firms. What form is preferable for technologies owners depends on many factors, including the degree of intellectual property rights protection. Patents, trade secrets, copyrights and trademarks serve as direct channels of knowledge transfer [6]. However, each type of intellectual property has different level of impact on the innovative potential of the host country. Although buying licenses implies that the patent includes all the necessary information for new goods production, this market does not involve personal contact between buyer and seller, and therefore does not allow the full development of new production technology.

Next channel to be considered is labour turnover and collaborative international projects. The former could happen in two main ways in international perspective. First one is connected with people returning to the home country after spending limited amount of time abroad where they have acquired new knowledge and skills through education or job and what is more important implementing that in their country. Second way deals with attracting foreigners who carry relevant expertise. The core problem here especially for developing countries is preventing moving to permanent residence and foster home-coming so that advance local development. The latter channel slightly eliminate those problems at the same time preserving the key aspect, namely acquiring non-codified knowledge. That kind of education/training is significant for enhance the countries' capacity of transferring "invisible" parts of purchased technology and adapting it.

Irrespective of the channel, a decisive criterion of TT is whether it promotes further innovative development in the country-recipient.

III. International Technology transfer: practical perspective

Synthesis situation could be described by Global innovation index 2012, prepared by the international business school INSEAD and the World Intellectual Property Organization in the analytical report «Global innovation index 2012». The research covered 141 countries, which together produced 99.4% of world GDP [16]. Considering Brazil, Russia, India, China (BRIC) in general, it is suggested that they have to continue investing in innovations development in order to fully realize their potential. China's indicators in areas such as key knowledge and development of technologies are second only to Switzerland, Sweden, Singapore and Finland, however, like India, China has weaknesses in the innovation infrastructure. As far as leaders concerned, Switzerland has made great efforts to commercialize their scientific and technical potential. The Swiss government in 2004 - 2007, annually increased spending on education, research and technology sector around 6%. State Commission for technology and innovation is implementing the slogan: «Science to market» and supports carrying out applied Research and Development (R&D), promote new companies and business development in general. The "Swiss technology transfer association" was established in 2003 to promote TT between public research institutions and the private sector.

R&D is a basic element for determination opportunity of ITT. There is a direct relationship between R&D expenditure and TT activity. Fig. 1 illustrates that correlation: the more investments in R&D, the bigger technology export as well as import. However, that dependency is not obvious, as in Russia (yellow circle in the graph), for instance, R&D expenditure is quite significant while export and import are one of the smallest numbers among considerable countries.

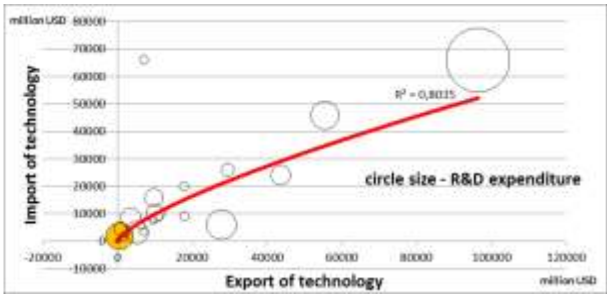

Figure 1. Correlation matrix: import, export and R&D expenditure

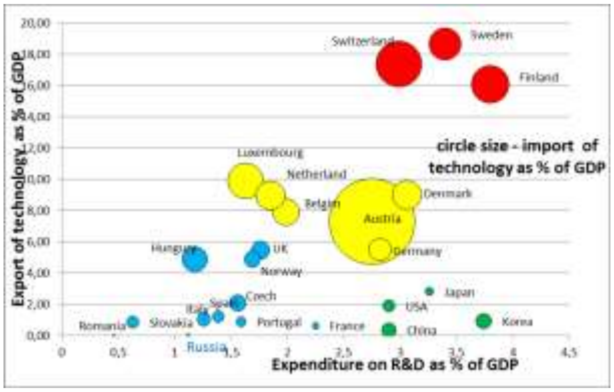

Figure 2. Countries classification on the basis of R&D expenditure, export and import (circle size) of technology, 2011

In order to eliminate the countries dimension influence every factor was taken as a share of GDP. Fig. 2 clearly illustrates the division into four groups. First cluster consists of high active countries in R&D sphere and at the same time vigorous exporters. That is EU leaders, namely Sweden, Finland and Switzerland. Second group includes predominantly small countries, such as Austria, Luxembourg, Denmark, Belgium, the Netherlands and Germany. This group spend less on R&D and export less than the leaders, but they buy slightly more technology, except Austria that shows incredibly high results in this aspect. In contrast, the third group records low output in both export and import. That relatively small indices could be partly explained by the methodology applied. The last group is characterized by the predominance of import over export and in general less expenditure on R&D. That indirectly confirms the hypothesis about transferring tacit knowledge, since this group's technology policy aimed at compensating own research insufficiency by means of transferring them from abroad.

Considering technology balance of payments, it is important to bear in mind that figures in the balance could be influenced by different aspects. For instance, in one case deficit might be caused by country's inability to adopt purchased technology, in another case it might result from lack of necessity in buying technology due to developed nation research capacity [2]. Accordingly, a constant deficit does not unavoidably mean low country's competitiveness level. Though it does require further qualitative research, it does not exclude or downplay the necessity and essentiality of technology balance of payment analysis.

Having examined the technological balance of payments, it could be noted that the USA and Japan export more than import for years, so called net exporter (fig. 3). In comparison, EU pattern was changed only in 2006, when the EU total balance change from negative to positive number, i.e. export started to exceed import. Mainly due to the contribution of such countries as Finland and Sweden [13].

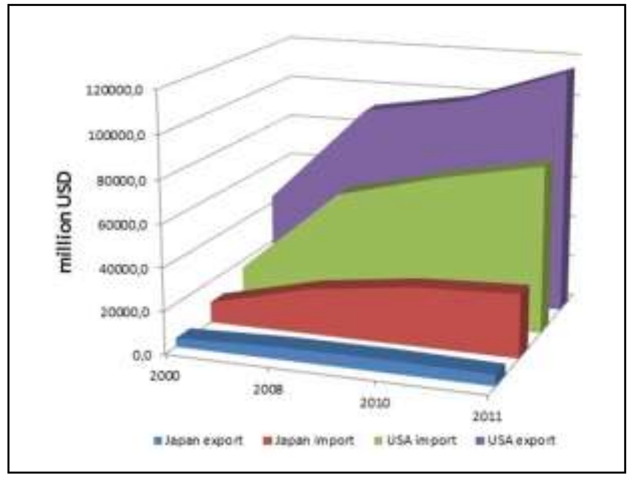

Figure 3. Export and import of technology in USA and Japan

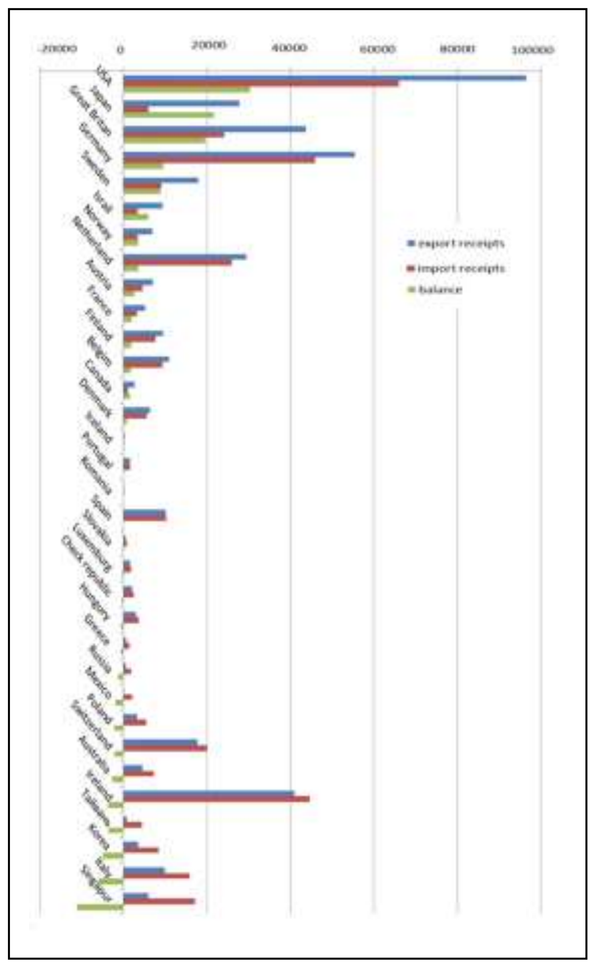

Figure 4. Technology Balance of payments, 2012

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Countries in declining order of the technological balance of payments are presented in fig. 4. Japan, the USA, the UK and Germany show the highest results in this index; however their patterns of the result indicator differ. For instance, despite having virtually the same balance, the absolute figure of the UK's export is almost twice as much as Japan's one. As for the import, it even 3 times bigger in the UK than in Japan. In addition, import of Netherland is quite the same as in the UK and export is relatively high, but the total balance is comparatively low. Contrary, absolute figures of export and import in Ireland are on the level of Germany, but their import slightly less than export, what results in negative balance.

Next step of the technology balance of payments analysis constitutes in examining transfer in geographical perspective. Considering the leaders, Germany import very actively from the USA as well as EU countries. In contrast, Sweden export more to EU country, but with the USA it experiences negative balance. Similarly, both countries are vigorous exporter to Asian countries, particularly to Japan and Korea. As far as the rest EU countries conserned, there is no common pattern. For example, Ireland has a negative balance with the USA and OECD countries and a positive balance with EU countries. Portugal exports more to African countries and import from EU and OECD countries. That could be explained by the fact that TTis highly depended on historical and (or) cultural relations. In addition, as it was examined earlier, expenditure on R&D also influences but not in a definite way. In order to deepen this study, factor analysis was conducted.

Data analysis was performed using SPSS 19 (Statistical Package for the Social Sciences). 32 counties were examined in this research in order to take account of various types of economic development, policies, cultural aspects, etc. Initially there were 10 indicators, 2 was excluded as insignificant. Among rest 8 factors high correlations was observed, what indicated multicollinearity. The aim of this factor analysis was to decrease the number of influenced factors by means of grouping them. In order to eliminate the differences in the way various initial indicators presented, the operation of standardization (conversion to standard scores) was held. On completion of these, factor analysis itself was conducted (table 1). Three factors were finally single out and could be shortly named as follow: a. Own research; b. Openness for collaboration; c. Active transfer policy.

Based on that factors countries were ranked from 1 to 4 within one factor, where 1 is correspond to the highest value. The percentage rank indicates the percentage of all observations having a higher rank. This analysis allows to divide countries into 4 groups depending on what factor influenced more. First group of countries, such as Finland, Japan, Switzerland, which relies more on their own research capability. In contrast, second group is actively cooperate with foreign partners in several ways (for instance, student mobility, research collaboration). This factor is directly accounted for transferring tacit knowledge. Taking into account that this group is presented by the most developed countries – the USA, the UK, Germany, Netherlands, Switzerland – that allows us to support our hypothesis. Switzerland is an interesting case as it happened to be included in both group, it is no coincidence. Moreover, third factor is also quite high this could mean that this country performed in every aspect at a high level. In the view of transferring implicit knowledge, third factor, which include active import and export policy, is not provide such environment compared to the one just described. Third factor determined next group of countries – Austria, Belgium, Sweden, Israel, Island and Slovakia. Thus, these countries are not the leaders in technological and economic development, though they can't be called lagging. The remaining countries form the last group are not characterized by one influential factor. Main conclusion that can be drawn from the present analysis constitutes in the fact that there is no one right solution for all counties as there are different ways in achieving desirable results.

TABLE I. *FACTOR ANALYSIS: MATRIX ROTATED COMPONENT*

Factor	Component		
	1	*2*	*3*
Z: Domestic expenditures on research and development as a percentage of gross domestic product	**0,914**	0,071	0,014
Z: state funding R&D	**0,958**	-0,134	-0,060
Z: Business funding R&D	**0,891**	0,118	-0,357
Z: Foreing funding R&D	-0,031	-0,079	**0,884**
Z: the share of publications in collaboration with foreign scientists	-0,088	-0,087	**0,822**
Z: Internationally mobile students	-0,018	-0,283	**0,830**
Z: import receipts	0,130	**0,931**	0,045
Z: export receipts	0,205	**0,954**	-0,045

IV. Knowledge transfer as a key aspect of International technology transfer

As it was mentioned above, a critical condition of TT is whether it promotes further innovative development in the country-recipient. Having examined ITT channels, the following statement could be put forward: efficiency of TT comes down to the effective knowledge transfer. This section analyses TT channels which allow to acquire knowledge necessary for beneficial new technology implementation.

Geographical and cultural proximity influences international scientific collaboration. The widespread use of English and information and communication technologies has helped to extend the scope of international research collaboration. While Europe increases scientific collaboration in the European research area, the rest of the world reaches out to emerging economies. Co-inventions are an indicator of formal R&D cooperation and knowledge exchange among inventors located in different countries. International co-inventorship is affected by countries' skills endowment and relevant conditions. International co-invention typically involves multinational corporations with units in several countries and joint research ventures between firms and institutions of various types (e.g. universities, public research organisations) [17]. While co-invention with the BRIC continues to increase, it remains limited as only about 1.7% of European patents and around 2.5% of US patents are co-invented with partners in BRIC economies (fig. 5).

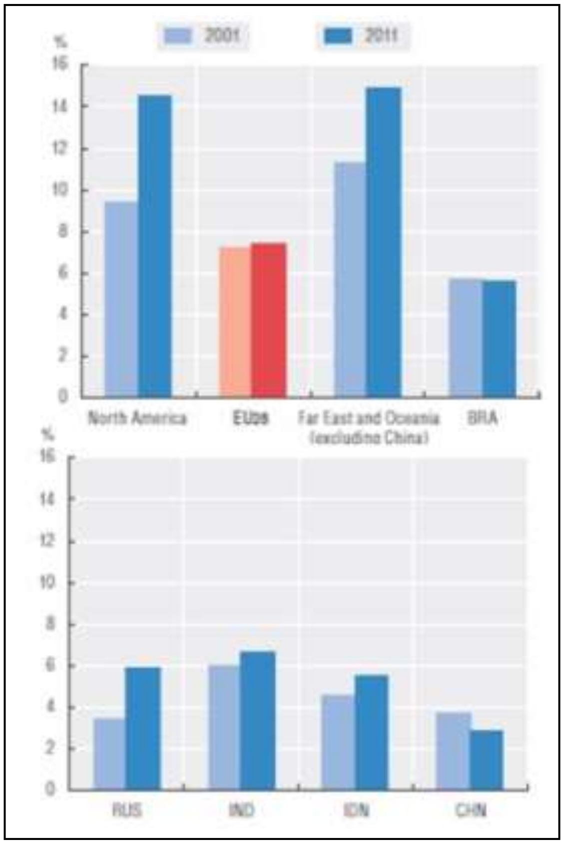

Figure 5. Scientific collaboration with BRICS countries

International scientific publications co-authorship is calculated as the share of articles featuring authors joined with foreign institutions in total articles produced by domestic institutions. Co-inventions is evaluated as the share of patent applications with at least one co-inventor located abroad in total patents invented domestically. Luxemburg shows outstanding results in both directions; more than 70% of publications involve co authorship with abroad institutions. In Russia the level of scientific co-authorship is slightly more than international patent co invention, which just exceeds 20%. Virtually all countries fall below the 45^{o} line (fig. 6); this indicates that they have more international scientific co-authorships than patent co- inventions.

In terms of open innovation, transfer contains all stages of innovation, including the stage of research. Forms of knowledge transfer in modern conditions are diversifying, but the most powerful stimulus to the contacts development in the research is the country inclusion into the science world based on knowledge (e.g. in the form of publications and patents). That might act as a stimulus for new contacts; expand cooperation, including foreign conferences, training, implementation of joint projects, and finally, the migration process.

The scientific personnel mobility determined by many factors, including social, institutional, and even demographic. In modern conditions, science has increasingly focused on the society needs. It is directly included in the production process and becomes a driver for economic development. It follows that the possibility of knowledge exchange does not depend on the physical distance between countries, but on the "economic" distance, which is primarily determined by the mutual interest for some kind of knowledge, i.e. the knowledge supply and demand.

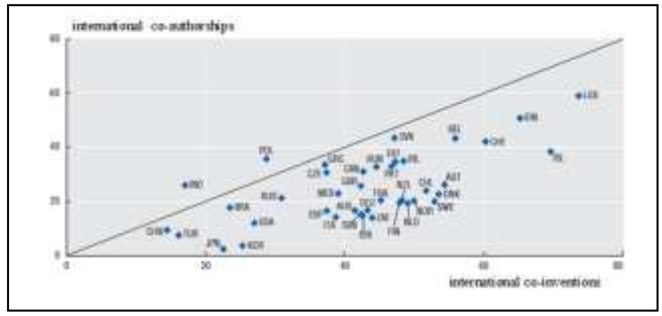

Figure 6. International collaboration in science, 2011

TABLE II. DEVIATION OF CITATION RATING FOR 22 FIELDS OF SCIENCE, 2004-2014

Research Field	Mean citation rate=100	Research Field	Mean citation rate=100
Multidisciplinary	307%	Geosciences	96%
Molecular biology&genetics	222%	Physics	91%
Immunology	171%	Materials science	80%
Neuroscience & behavior	156%	Plant & animal science	76%
Space science	147%	Agricultural sciences	68%
Biology & biochemistry	146%	Economics & business	62%
Microbiology	134%	Social sciences, general	54%
Clinical medicine	111%	Engineering	50%
Chemistry	109%	Computer science	45%
Pharmacology & toxicology	109%	Mathematics	34%
Environment/ecology	107%		
Psychiatry/psychology	104%		

In turn, the global scientific community demand on science is determined by government policy. Most developed countries are now completing structural shift to scientific disciplines, aimed at improving human well-being, including health-related science, ecology, and information technology. At the same time, the current state of the world's scientific potential characterized by a steady path dependency. Therefore, large military sector research, inherited from the cold war, has been preserved and continue to be restoring in the leading countries. In table 2 figures are calculated based on articles citations data in the leading scientific journals of the world in 22 scientific fields [15]. They characterize variations in citation in the directions of the average for all directions for 10 years from 2004 to 2014. In the left column research areas are listed which are cited more often than the average article in all directions, in the right column, areas which are cited less frequently . This table demonsrates the long-term trend of scientific production demand in the world. Quoting "hot" articles characterizes the demand on the part of the works, which corresponds to 1% of "new" scientific achievements that attracts the maximum scientists' attention. Countries' place in the scientific contacts reflected by quoting and their contribution to the dynamics of scientific research could be illustrated by the fig. 7.

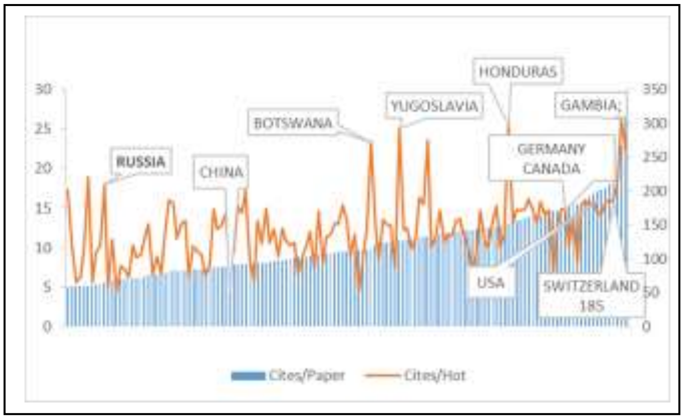

Figure 7. Cites/Paper and Cites/Hot Paper by Countries – 2013

First, most highly cited articles often appear in countries that do not belong to recognised leaders. In the number of links to hot articles, Gambia is in the same row with Switzerland, and Germany and Canada do with Honduras. Moreover, the demand on hot articles from developing countries is significantly higher than from science-leader countries. It should be noted that the reasons for getting articles in the number of hot so diverse that this leads to the risk of mechanical borrowing best practices to transformate science governing in countries facing the transformation to the knowledge economy [10].

V. Conclusion

In conclusion, it is worth outlining the countries' groups on the world map in TT perspective. The leader group consists of a few number of countries (USA, Japan, Germany, the UK, Switzerland), the next level is the candidate countries to increase their technological status (advanced EU countries, China, Russia). It is important to underline that emerging industrial countries are quickly making headway in the knowledge intensive sectors and rather than merely accumulating high-technology products they are now or have great potential to be producing them. The remaining countries are tend to not aiming at technological upgrade or realize policy of net importer of technologies. In this article significance of transferring knowledge was argued. Briefly, 'technological distance' plays a curtail role in the efficiency of absorbing purchased technology. In other words the greater this distance, the more difficult to implement it into production. Countries with local R&D programmes, own private and public research laboratories, sound base of technical skills and human resources create the prerequisites for more rapid international technology acquire. All listed aspects tend to reduce the expenses of innovation adaptation and increase efficiency.

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