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TECHNOLOGICAL INNOVATIONS AND TECHNOLOGY ACHIEVEMENT

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Abstract. The research paper is devoted to the analysis of technology achievement. The application of technological innovations by manufacturing and trade enterprises allows predicting technology achievement level measured by index TAI. Paper is aiming to propose the framework helpful for TAI's estimation. First, in the paper the territorial differences of the application of technological innovations are overviewed. Herein, technology achievement index for each country is introduced. Second, the framework used to predict TAI for European Economic Area (EEA) is presented. Multiple correlation method is used for the prediction. At the end of the study, the application of proposed framework is given. The findings of this research paper could be useful for policy makers and researchers.

Keywords: technology, innovations, trade, manufacturing, enterprises, TAI.

JEL classification: O30, O31, L81.

1. Introduction

The importance of technologies is immense and has a tendency to grow: under modern globalisation circumstances, the application of technologies has become a crucial factor of development economy in general. A huge dynamism is characteristic to technological change: it undergoes multiple and rapid alterations, therefore necessary to react single-mindedly to new conditions. Insufficient orientation of effectiveness of available theoretical solutions is treated as a problem of inadequacy of these solutions to new challenges.

Therefore, the successful and purposeful technological change has to be based on new scientific knowledge of circumstances and advanced scientifically-proved solutions. The possibility to examine technology achievement has to be reviewed.

The analysis of scientific literature, which is published by leading world publishers (such as Oxford University Press, Cambridge University Press, Harvard University Press, Springer, M. E. Sharpe, Routledge, etc.), shows that 7.9 thousand publications focus on technological change. Some of these authors presents human development index, productivity index (both total factor productivity and labour productivity), index that presents the progress of secondary industry; for measuring technological level of "catch-up" authors suggest to use historical investment and policy indeces.

Nevetheless, there are more other indices, which are used aiming to provide an picture of a country's situation regarding technological development; this analysis show that the best index representing the technological change, broadly defined as hardware and know-how, is technology achievement index suggested by UNESCO. It promotes the centrality of technology to economic growth and involves the creation and diffusion of technology and human skills for its calculation.

Based on initial methodology, which is developed by UNESCO, researches face difficulties to get a lot of data from different information sources. Thus, the results of such analysis show the importance of the research, which presents the results of investigations in this area.

The paper is aiming to find another (easier) way to estimate technology achievement index.

The study presented in the paper contains three different aspects. First, technological innovations and territorial differences are analysed; theoretical and practical review is delivered herein. Second, the framework for predicting technological achievement index is developed. Third, the results of the study and suggestions for further researches are presented. The methods of research: statistical, comparative, empirical, and systematic analysis.

The scientific novelty of the study – composed framework used for the technological achievement index's prediction in more simplier way.

2. Technological innovations and territorial differences

Technological innovations are arguably the most powerful determinant of economic future. The improvement in the Western standard of living during the past would not have been possible without technological innovations. The development of technological innovations also means that long distances are less important nowadays than in the past. Also, technological innovations play an important role in developed countries, and the transfer of technologies to less developed countries are important.

Technological innovation is enterprise's capacity to put new ideas into practice for the development of new products and processes. It has to be seen not only as development of single product or process, but also the interrelationship between these two has to be recognized. For example, incremental product and process improvement over the 16 years from 1880 to 1896 led to fall the price of a light bulb around 80%, and this ensured its widespread among users.

Technology is normally made from components; building technology must require two types of knowledge: knowledge of the components, and knowledge of the linkages (architectural knowledge). Architectural – components knowledge has not changed, but the knowledge of the linkage has. Such is mentioned in Henderson-Clark model. Technological innovation, which fails to meet user needs, may not be accepted; also the production of technology, which the market doesn't want, or implementation of processes, which don't meet the needs of end user, will get resistance during diffusion.

On the other hand, there is the wide set of territorial differences that influence the spread of technological innovations. First of all, there are differences in Europe and the US. The US and Europe differ significantly in terms of their innovative capacity: the former have been able to gain and maintain world leadership in technological innovations while the latter continues to lag. Based on this idea country gets a niche on the scale of products which is appropriate to its position as technology leader (Krugman 1994).

The European Union's (EU) territory could be divided into regions. Regions hosting high-technology sectors are considered as regions helping the transformation of the economy and labelled "technologically advanced regions". Those regions present simultaneous specialization in both medium high-tech manufacturing and knowledge intensive sectors. There are 58 regions all over the EU: 21 from 58 regions are concentrated in Germany, 17 are located in the UK, and the others – in France (8), Belgium (5), Sweden (3), Finland (2), and Denmark (2). On one hand, the production of technology in Europe is indeed highly concentrated, although some peripheral regions do play a major role, as well. On the other hand, the diffusion of the technology could be different in those regions.

Talking about the territorial differences of the application of technological innovations, Krugman (1994) has discussed innovating North countries and non-innovating (imitating) South countries. In North, new technology is introduced and produced immediately, but in South it is adopted with the lag. This presents the continuing process of technological innovations and technology transfer.

Further, it is interesting to know the effect, which leads technology transfer. Zon, Sanders & Muysken (1997) have suggested that, in North, there are the high-tech sectors and in South – low-tech sectors. Then the rate of imitation depends on the behavior of entrepreneurs who switch from high-tech to low-tech production technology.

The effect of technological progress could be analyzed in such cases: progress in advanced country that widens "technology gap" between it and another country, and progress in a less advanced country that narrows the "technology gap". In the first case, the technological progress of leader opens up greater opportunity to manufacturing enterprises. Technical advance it is the rise of export for the most advanced country and the gains from progress abroad for, the less advanced country. Each country shows the "technology intensity". Of course, the contribution of a single country to technology achievement varies e.g. manufacturing and trade enterprises, located in countries with the intermediate diffusion of old technical innovations, export the less.

2.1. Literature analysis

The way for lagging-behind country is to become competitive in international markets depends on its ability to "catch-up" technological level from more advanced countries. This ability is more important rather than trade gains from progress abroad. It is stated in theory that there are various channels through which technology can be transmitted across countries. One channel is related with the diffusion of technology. Technology is embodied in capital and intermediate goods, so, the direct import of these goods is one channel of transmission. These countries, which have faster growth, import more from the world's technology leaders.

Trade is an important linkage between countries. The implication of increased trade means that trading countries are engaged in heavier trade integration and linked with regard to their macroeconomic performance. On the contrary, imperfect competition and the economies of scale mean that trade flows are more likely to follow intra-industry patterns. Intra-industry trade, rather than inter-industry trade or the volumes of trade, is the main channel through which activity of trade partners become synchronized (Shin & Wang 2004).
However, the studies of Artis, Fidrmuc & Scharler (2008) show that trade integration goes usually hand in hand with financial integration, so these effects are often similar.

At a time when countries around the World are struggling due to the global recession, it is important for them to create environments that are called innovation-friendly. The policies that countries make can have a profound impact on companies to have them the innovation successful. In addition, more and more companies carry innovative activities outside their home country (in the 1990s, only 12% of the innovative activities were carried outside home country by the world's largest 500 technologically active companies) (Tidd 2006).

The topic of technological change is widely analyzed by Hekkert and Negro (2009), Hekkert *et al.* (2007), Suh et al. (2010), Veugelers *et al.* (2010) and others.

Talking about the way to market, technology push and pull is considered. If technology eventually found its way to the marketplace (when we call this "technology push"), but if the market signaled needs for something new which then drew out new solutions to the problem and the necessity becomes the mother of invention (when we call this "need pull"). Sometimes one of them ("pull" or "push") will dominate, but successful technological innovation requires the interaction between them both (Tidd 2006).

Since the 1950s till 1990s there are five generations of different models which involves technology pull and push. The first decade was characterized by successive waves of technological innovations. R&D push is highlighted in these models. The second decade stands out for market pull. The market is full of ideas and provides direction to research and development (R&D) activities. The third decade involves push or pull-push combinations. During the fourth decade, the integration between R&D and production is emphasized. Last decade involves customers-centered innovations and attention to corporate flexibility and speed of development (time-based development). Increased focus on quality and other non-price factors. This decade is famous because of the development supported by advanced development of information technology (Hobday 2005).

There is the number of case studies, where companies like Merck, Xerox, Intel, IBM, and Proctor & Gamble, etc. found that given open access to their technologies helped to create opportunities for further innovation and commercialization and to achieve an increase in overall value of their technologies. Let's start theoretical analysis from the Saint-Paul (2003) model. Here the technology for creating it is available for free (in the public domain); no licensing or royalty fees are associated with it. Supplier then charges only the marginal costs associated with manufacturing. One especially useful feature – that the overall technical change is ambiguous.

2.2. Technology achievement level in countries

Technological innovation is enterprises' capacities, which are located in different countries, to put new ideas into practice for developing new products and processes, which play the key role for economic development (Marquez-Ramos & Martinez-Zarzoso 2010). Such has to have the composite measure of technological progress that ranks countries on a comparative global scale or presents the technological development of the region. So, Boston Consulting Group ranks the Top 30 World most innovative countries. World Bank ranks countries based on scores representing ICT and innovation aspects. Bloomberg every year examines more than 200 countries to determine their innovation quotient. Seven factors: R&D intensity, productivity, high-tech density, researcher concentration, manufacturing capability, education levels, and patent activity are used to determine the index. The data for the index is retrieved from World Bank, World Intellectual Property Organization, Conference Board, OECD, and UNESCO. 20 % of the weighting is given to the first four factors; 10 % – to the fifth one; 5 % – for the last ones.

UNESCO presents the technology achievement index (TAI), which is used to measure how well each country is creating and diffusing technology and building a human skill base, reflecting capacity used for the technological innovations. Altogether there are 34 separate variables (OECD 2011).

There are more other indices, which are used aiming to provide an overall picture of a country's situation regarding technological development. One of such indices show the application of information and communication technologies (is called 'ICT development index' and created by United Nations International Telecommunication

Union; this index is based on 11 ICT indicators, grouped in three clusters: access, use, and skills). Another one is used to measure a country's capacity to create knowledge (is called 'Investment in the knowledge-based economy' and built by Directorate-General for Research and Technological Development DG RTD; this index involves expenditure on information technologies and the imports of high-tech products). The third one is used to measure a country's performance by converting the new knowledge into economic and technological progress (it's called 'Performance in the knowledge-based economy'; this index combines six indicators; some of them present production of high-tech exports, the employment in the high-tech production (Singh, Murty, Gupta & Dikshit 2009)). The fourth one indicator measures a country's ability to generate, adapt, and diffuse knowledge based on knowledge assessment methodology (is developed by World Bank; it takes into account 148 variables such as economic incentive and institutional regime, education and human resources, the innovation system and ICT). The last one is created to grasp major trends in Japan's Science and Technology activities and involves input representing technology import (is called 'General Indicator of Science and Technology GIST' and is created by The National Institute of Science and Technology Policy of Japan NISTEP). This analysis show that the best index representing the technological change, broadly defined as hardware and know-how are TAI. It promotes the centrality of technology to economic growth and development (James 2006). There is some criticism made by representatives Saisana, Saltelli & Tarantola (2005) from European Commission concerning ranking countries. Organizations, such as the United Nations, the European Commission, UNESCO and others have developed and used "composite indicators", which as single indicators, are aggregated into one index (Cherchye, Moesen, Rogge, Van Puyenbroeck, Saisana, Saltelli, Liska & Tarantola 2008). As composite indicators are increasingly used for benchmarking countries' performances, they identified the main pros and cons of using composite indicators. Doubts are often raised about the robustness of the resulting countries' rankings and the significance of the associated policy message. Composite indicators can be only used to summarize complex or multi-dimensional issues, which supporting decision-makers as they provide the big picture. They can be easier to interpret seeking to find a trend in many separate indicators. They also can help to attract public interest by providing a summary of performance and its progress over time (Saisana, Saltelli & Tarantola 2005). There are some cons about composite indicators, which are used for index estimation. They may send misleading, non-robust policy messages if they are poorly constructed or misinterpreted. For policy creation purpose, composite indicators should be used in combination with the sub-indicators. The construction of composite indicators is not easy. It involves stages where judgment has to be made: the choice of sub-indicators and their weighting, etc. Also, sub-indicators increase the quantity of data needed. All these judgments should be transparent and based on statistical principles. In addition, sensitivity analysis can be used to test composite indicators for robustness. Their correlation analysis of TAI reveals that 8 its sub-indicators have an average bivariate correlation of 0.55 and that six pairs of indicators have a correlation coefficient that is higher than 0.70. Their study result indicates that the phenomenon that is described by the set of the 8 sub-indicators is quite multidimensional. A higher correlation between the sub-indicators results with fewer indicators (Saisana, Saltelli & Tarantol 2005). So, this shows that necessary to find an easier way to estimate TAI. Talking about the usage of TAI, it is clear that TAI can be used to find trend only. Such is the objective of this study.

The TAI is calculated from four indicators: the creation of technology, the diffusion of recent technologies, diffusion of old technologies, and human skills. The range of the combined indicators is from 0 to 1, with higher numbers suggesting greater technology achievement:

- The indicators for creation of technology are patents granted per capita unit and royalty and license fees received from abroad per capital unit. The sources of these data are World Intellectual Property Organization (WIPO) and World Bank;
- The diffusion of recent technologies is calculated from the number of Internet hosts per capita unit and the share of high-technology & medium-technology exports as the percentage of all exports. Data collected by ITU (International Telecommunication Union) is used to estimate Internet dispersion and the data from the United Nations is used to calculate export share;
- Indicator for the diffusion of old technology is telephones (land line and cellular) per capital unit and electricity consumption per capita unit. Diffusion of old innovations is composed of the logarithm of telephone lines per capita and the logarithm of electricity consumption per capita. The data source for the early studies is ITU and for the latter – the World Bank;

– Indicator of human skills. It is calculated based on the average number of years of schooling and the gross enrolment ratio at the tertiary level in science, mathematics, and engineering. The data is abstracted from Barro & Lee (2000) for the mean years of schooling and from UNESCO for tertiary-level training.

Many elements can be used to present technology achievement in the region, but a composite assessment is more easily made based on a single composite measure than big range of different measures.

The index is calculated as the simple average of these four indicators. The indicators in each dimension are given equal weight, and the dimensions are given equal (one-quarter) weight in the final index. This means that for the diffusion of technology higher weight is given; since two of the four indicators deal with this.

The TAI represents the assessment of technological performance in the country (Table 1) based on its capability in creating and using technology but not on the overall size of technological development. Such measure is not related to country size.

The TAI is presented for 91 countries. For other countries, data were missing or unsatisfactory for one or more indicators, so the TAI is not measured (as it could not be estimated). Weighted average for all countries is 0.4 (UNESCO, 2010). The average TAI for European Union (EU) countries is 0.4967.

All countries need to have the capacity because the ability to apply technology can't be fully done without the capacity allowing adapting products and processes to local conditions (Desai, Fukuda-Parr, Johansson, & Sagasti 2002). All mentioned factors: the availability of human capital, the structure and flexibility of trade and financial institutions, the degree country's openness to foreign trade impact the TAI in the specific country. As the TAI is also incomplete and technology achievements are more complex in countries, it is impossible to reflect the full range of technologies – as wider as better.

Gani's (2009) regression results reveal that the high technology exports exert a statistically significant positive effect on the growth of countries. Also, results showed that low-income countries with lower technology achievement index and growth may need to focus on new product development with high technological content to be competitive in the global trading environment and enhance economic growth and development.

Table 1. The Technology achievement Index (TAI). Source: UNESCO (2010)

No	Country	TAI
1	Denmark*	0.704
2	Finland	0.677
3	Sweden	0.661
4	The Netherlands	0.612
5	Luxembourg	0.609
6	United Kingdom	0.569
7	Norway	0.544
8	Ireland	0.539
9	Germany	0.531
10	France	0.528
11	Iceland	0.527
12	Estonia	0.501
13	Slovenia	0.499
14	Greece	0.495
15	Spain	0.491
16	Belgium	0.491
17	Austria	0.489
18	Italy	0.482
19	Hungary	0.467
20	Malta	0.466
21	Portugal	0.439
22	Czech Rep.	0.436
23	Latvia	0.434
24	Cyprus	0.43
25	Poland	0.416
26	Slovakia	0.41
27	Croatia	0.403
28	Bulgaria	0.386
29	Lithuania*	0.38
30	Romania	0.363
	Average	0.4993
	* – Unesco (2011)	

Concerning technology achievement, there are a number of studies presented in the literature. Hill & Dhanda (2003) presented study where technology achievement and human development are particularly emphasized through the relationship.

Cherchye, Moesen, Rogge, Puyenbroeck, Saisana, Saltelli, Liska & Tarantola (2006) use TAI for benchmarking countries' performance. This measure was used to recognize technological development especially for countries facing deficits in technological advancement. They have a low diffusion for Internet technology (because of low spread of telephony and electricity, which is slowing down Internet connection).

3. Predicting technology achievement index

3.1. Framework used for the prediction

For the prediction of TAI the ratios, which represent the application of technological innovations by manufacturing and trade enterprises for countries involved in EEA, is used. Herein the application of technological innovation means the application of product, process, ongoing or abandoned innovation are analysed only by active enterprises. Technological product and process (TPP) innovation must be distinguished from organisational innovation, other changes in products and processes. Technological process innovation is the adoption of technologically new or significantly improved production methods, including methods of product delivery. These methods may involve changes in equipment, or production organisation, or a combination of these changes, and may be derived from the use of new knowledge. The methods may be intended to produce or deliver technologically new or improved products, which can't be produced or delivered using conventional methods, or essentially to increase the production or delivery efficiency of existing products (Eurostat 2010).

For ratio calculation only active enterprises, which sell products in local or regional markets in analysed period, are taken. The number of these enterprises shows that they were active during at least a part of the reference period.

To estimate TAI correlation method is used. In the research, it has been identified that it is dependence between both the application of technological innovations by manufacturing and trade enterprises and technology achievement level in the country (presented by TAI). The capability of the prediction is the main aim of the research. The study focuses on the use of a predictor variable and the criterion variable. A variable which is used to predict the value of the other variable is known as the predictor variable, and the variable whose value is being predicted is known as the criterion variable. So, correlation could help to identify one or another tendency between variables. To determine the relationship between two variables, a correlation coefficient is used (it is denoted by r). The range of the correlation coefficient is between -1 to +1. The value of the correlation coefficient tells us two things about the nature of the relationship between multiple variables, the intensity and the direction. Ideally, for no correlation between these variables, the value of r should be 0 and for a perfect correlation, the value of r should be 1.

These are very rare scenarios and ideally, if the value of r is above 0.70; then the relationship is considered to be 'almost always significant'. Direction signifies the manner in which the two variables move in respect to each other.

A positive correlation means that both the variables are moving in the same direction.

A negative correlation, on the other hand, implies that the two variables move in opposite directions.

Out of the various correlation research design types, explanatory design model and prediction design model are widely used. The explanatory design model examines the correlation of two and more variables with data being collected at one time only. After the collection of data, at least two scores are recorded, and the researcher draws out inferences from the available statistics only.

The correlation r is calculated according to the formula (1) (Pabedinskaite 2008):

$$r = \frac{\frac{1}{n-1}\sum(x_i - \bar{x})(y_i - \bar{y})}{S_x S_y}, \qquad (1)$$

where:

$\bar{x}, \bar{y}$ – averages of relative features,
S_x, S_y – sq. average of relative features,
n – number of observations.

Through the magic of mathematics, it turns out the outcome of the correlation. Findings are presented in table 2.

Table 2. Correlation results
(source: compiled by author)

Results	Text
Correlation coefficient	0.998
T statistic	2.52
T table	2.12
Coefficients	
a0	0.38
a1	0.69
a2	0.55
The adequacy of equation	
F statistic	3.58
F table	0.95

The equation used for TAI prediction is calculated according such formula (2):

$$y = 0.38 + 0.69x_1 + 0.55x_2 \qquad (2)$$

The average number of manufacturing enterprises, which apply technological innovations, is 8.7%, of trade enterprises – 4.9%.

Among manufacturing enterprises, Sweden, Germany, and France enterprises and among trade enterprises – Belgium, Sweden and Denmark enterprises are the most active in the application of technological innovations.

The application of technological innovations is analyzed for different levels. Among enterprises, the application is measured also for enterprises that are engaged in any type of cooperation; also for enterprises, for which the suppliers of equipment, materials, components or software are a highly important source of information. In addition, the analysis according turnover show that enterprises having higher turnover are more oriented to the application of such innovations.

By using the last formula, it is estimated that if the application by both enterprises would rise by 5%, TAI would have value increased by 6.3%.

3.2. Reliability of data

For the ratio calculation, the data of manufacturing and trade enterprises is used. The data for EEA is retrieved from Eurostat (2010), which is collected using the questionnaire. The data about the application of technological innovations for manufacturing and trade enterprises is collected in close collaboration between Eurostat and national statistical institutes from EU Member States and EFTA countries.

The sample size is determined by statistical analysis. The results of the analysis of survey sample show that it is sufficient.

Findings show that 0.95% manufacturing enterprises have to be questioned. This gives 99% reliability of statistical data and 1% of allowable inaccuracy. During Eurostat survey, 2.13% of manufacturing and 2.24% trade enterprises have been interviewed.

For aggregation purposes (the euro area and EU28 aggregates), missing data concerning specific countries and sectors are estimated by Eurostat but are not separated.

4. Suggestions for future researches

Future researches may include more on the following directions:

1. Sensitivity analysis is suggested for future. For such another time-period data is required. As technology achievement level is the slow process, probably such data could be accessible after 5 years.

2. Expansion of suggested framework for different regions. In addition, these indicators could be examined in constructed frameworks.

5. Conclusions

The literature analysis shows that the contribution of single country to technology achievement varies. There are around ten indices, which are used to provide an overall picture of a country's situation regarding technological development. Usually these indices are used to rank countries. Due to criticism made by representatives from European Commission concerning ranking countries different indices could used to find trend only. For the study index, TAI is selected; as it highlights an aspect of technology to economic growth and development.

Based on initial methodology, which is developed by UNESCO, index TAI is estimated by using 4 composite indicators, which consists of sub-indicators. The usage of sub-indicators rise question towards their selection increases the quantity of data needed, and difficulties to get it from different information sources. On the other hand, critics toward sub-indicators, inspires to find another way to measure technology achievement. The author of the paper provided insights that have resulted in smaller number of single indicators used for TAI calculation.

So, the definition of technological innovation, which represents the enterprises' capacities to put new ideas into practice for developing new products and processes, suggested such investigations. Author developed framework used to predict TAI. Multiple correlation method is used for framework development.

The study results show that, for the TAI estimation, two single indicators could be used only. Such requires the ratio that represents the application of technological innovations by manufacturing and trade enterprises. Such framework is applied for European Economic Area. The conducted empirical study has shown that the offered framework can be applied seeking to predict the TAI value.

The analysis of the application of technological innovations shows that there is a big gap between manufacturing and trade enterprises: EEA manufacturing enterprises are the most active in the application of technological innovations. So, their inputs to TAI are the most important. This gives the idea that, for TAI estimation, the ratio that represents the application of technological innovations by manufacturing enterprises could be used only. Such possibility should be tested for another region.

At the end suggestions for further researches are formulated.

The findings of this research paper could be useful for policy makers and researchers. Looking from the perspective the better understanding of manufacturing features is important in formulating public policy towards the technology achievement.

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