University doctoral (PhD) dissertation abstract

THE DUALITY OF TECHNOLOGICAL PROGRESS: THE INSTITUTIONAL FEATURES OF INNOVATION- AND IMITATION-BASED ECONOMIES

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1. The relevance of the topic, research motivation

"Failures of technology are often the failures of institutions"
Mokyr (2003:60)

One of the basic principles of contemporary economics is the thesis that technological progress is the driving force of economic growth. The worldwide dynamic development of technology started more than 200 years ago, with the Industrial Revolution. According to *Mokyr* (2004) the complementarity of radical innovations, i.e. macroinventions, and incremental innovations, i.e. microinventions, accounted for the enormous economic impact of Industrial Revolution, which launched not only technological progress, but also an increase in the incomes of the world's countries. Based on the summarized empirical evidence of *Williamson* (2009:183), the standard of living in the countries of the world did not change prior to the Industrial Revolution and there were no large income differences among the countries either. Thus, economic growth and technological progress occur in close interaction. At the end of the 20th century, the appearance of new information and communication technologies gave a new impetus to development. Due to this, the analysis of technological changes was in the centre of economics' interest again.

Technological progress is a dynamic process which, through the use and the widespread adoption of new technologies, generates the improvement of efficiency and productivity and it thereby becomes an engine of economic growth. The ideas embodied in technology as a new form of knowledge, with extensive practical application allows more efficient operation of the economy, leading to growth, but that alone is not sufficient for development. As *North* (1990:133) pointed out, much of the world has still failed to capture the potential benefits of technology, which suggests that some additional factor is necessary for technological development to be able to generate growth. Therefore, in analysing technological progress, the role of institutions has been increasingly appreciated. The institutional environment is an especially important factor in this process, because it creates incentives for innovation. As a result, in addition to growth theory, institutional economics is showing an increasing interest the role of institutions economic growth and technological progress. In summary, technological progress is realized in a special combination of technology and institutions, which generates growth, and growth in turn has its own effect on technological progress. *Figure 1* shows the theoretical framework of technological progress.

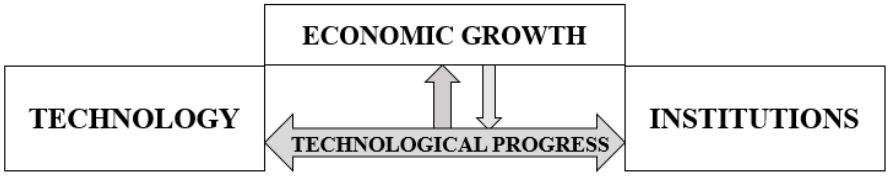

Figure 1. The relationship between technology, institutions and economic growth

Source: *own construction*

The theoretical framework, shown in *Figure 1*, highlights the interaction between technology and institutions to ensure the macroeconomic impact of technological progress on economic growth. This finding is important, because the income and technological gap between countries is due to the differences in the institutional environments. *Which institutions can, and how can they, influence the process of technological progress?* This question has induced a great deal of research both in the field of growth theory and in institutional economics. The present research is also aimed at developing our understanding of the role of institutions in technological progress.

2. Identifying the problem and the research question of dissertation

Institutions, as the rules of the game in North's (1990) terminology, appear in many forms in the economy and define the conditions of economic operation through a complex mechanism of action. Institutions create the incentives of innovation, which influence the creation, application and spread of new technologies. The income and technological development disparities can be derived from differences in the spread of technology and the systems of incentives.

The differences in the spread of technology are reflected in differences in countries' technological development, which strongly correlate with their income levels. Several empirical studies confirm that the higher-income countries are typically technologically more advanced, their innovation activity is more intensive and they create the majority of the innovations, in contrast to the lower-income countries, which are typically technology followers, and can adapt new technologies through the imitation of technological leaders (*Barro–Sala-i-Martin*, 1997; *Acemoglu-Aghion-Zilibotti*, 2006; *Basu-Weil*, 1998; *Jerzmanowski*, 2006). Based on this, technological progress happens in different ways in different countries of the world, depending on their income levels. Therefore, *technological progress may require different incentives in technological leader and technological follower countries*. This is the basic assumption of my research.

Technological progress can be realized in a country either in an innovative way, through independent research and development activity, or in an imitation-driven way, through the adaptation of innovations which have been successfully operating in other countries. This is the duality of technological progress, where innovation is the invention of new technologies, while imitation is the adoption of existing technologies *(Acemoglu* 2009:745*).* During my research, I would like to answer the question whether the institutional environments of innovation- and imitation-driven economies are typically different, and if so, which are the key elements of a favorable institutional environment for technological progress, depending on the level of economic development. *Szalavetz* (2010:461) pointed out that the relationship between innovation and growth is different depending on the distance from the technology frontier. Most countries of the world imitate, so technological progress is based on technology import and imitation, and there are only a few countries where innovations are created, which, therefore, may be regarded as true innovators. Based on this, the research question of my dissertation is as follows:

> ***Are institutional features of innovation-driven economies different from imitation-driven economies? If the answer is yes, which institutional features are important?***

The aim of the research based on the literature is to identify the institutional features of technological progress, in other words, how institutions feature in this process. Institutional features of technological disparities can be examined based on the economic characteristics of technology, through major discoveries of growth theory modeling.

The contribution of technological progress to economic growth is hard to question, but it is not a well-defined and precisely-defined process, which makes it difficult to analyse with the tool kit of economics. The starting point of growth theory is the Solowian conception, which is based on the Solow residual. This is the contribution of technological progress to economic growth defined as a residual by growth accounting method. This can be interpreted as the part of the economic growth which cannot be explained by the accumulation of labour, physical and human capital. Therefore, technological progress is everything which is beyond factor accumulation. That is why *Abramovitz* (1993:218) called Solow's residual the measure of ignorance. During the research, first we need to find a place of technology in the economic framework in order that it may subsequently be brought under analysis.

3. Structure of the thesis and methodology

The first step of research based on literature was to explore the nature of technology and its economic characteristics which laid the basis for an analysis of the relationship between technological progress, institutions and economic growth in a novel aspect. In the standard microeconomics framework, technology can be interpreted as an input of the production process, but it is different from the classic production factors. Technology is a resource that is created during a special production process, typically as a result of a directed research and development, and it can only be improved with new ideas. So, an idea can be regarded as a good, which, through the technology, facilitates the production of outputs that meet advanced needs and allow customers to realize higher utility through their consumption.

In the last century, the Solow model (1956) determined the direction of growth theory research, because it highlighted the relevance of technological progress compared to classical production factors, as labour and capital. This model confirmed that long-term economic growth can be achieved by technological progress manifested in total factor productivity growth. In Solow's model, technology is exogenous, so it is free to use and available to everyone. In this case, technology is a public good that anyone can use without having to bear the costs of its creation. This is the most critical point of this model, because technology is like "manna from heaven", which provides productivity growth for economic actors.

Based on the foundations of the Solow model, *Romer* (1990) created his own growth model in which technological progress is also the engine of economic growth, but in which technology is not given but, instead, it needs to create by the economic actors, i.e. it is endogenous. New knowledge is thus created in the conscious effort of economic role players, as a result of research and development. Owners of new technologies and inventions may acquire monopoly power and monopoly profits, which motives them to conduct research. The basic idea of Romer's model, therefore, is that technological progress will only occur if the profit-maximizing firms are interested in innovation, i.e. implementing new ideas, and if researchers will benefit from their inventions (*Jones*, 1995). By endogenizing technology, it became apparent that technology appropriability may at least in part be achieved through institutions. It is for this reason that the role of institutions in the realization of technological progress is increasingly appreciated.

Goods can be classified according to rivalry and the degree of excludability. Ideas embodied in technology are nonrivalrous and they vary in their degree of excludability. Technology is nonrivalrous, because once an idea has been created, anyone can use it and reap its benefits. Nonrivalry yields an increase in returns, which cannot be fitted with price-taker behaviour characterized by perfect competition. Instead, an imperfect competition, typically monopolistic competition is formed, due to institutions that instigate technological progress. The economic attributes of technology and their impact on market mechanism can be summarized as in *Figure 2*.

Figure 2. *The logical structure of technology's economic attributes*

Source: own construction based on *Jones* (1998:73)

The creation of new technologies is encouraged by the acquisition of potentially realisable benefits. It is because research and development can be regarded as conscious economic activities. Because of the uncertainty which accompanies innovation, economic actors are only willing to take investment if they can expropriate the potential benefits which can be realized as a result of efficiency improvement. This justifies that the protection of property rights is essential to realize technological progress. Protection enables innovators to gain temporary monopoly power and monopoly rents. Their creation and economic effects can be analysed following the model of market welfare comparison, where invention is modelled such that new inventions are treated as a cost-saving factor.

The theoretical model of *Arrow* (1962) and *Nordhaus* (1969) pointed out that the monopoly created by property rights generates a static deadweight loss, which is converted to the dynamic welfare gains where the protection expires. Based on this, temporary monopoly restricts the short-term effective operation of the market, but in the long-run, all actors gain from the benefits of innovation. *Arrow* (1962:619) concludes that actors are less encouraged to innovate in monopolistic conditions than in competition, so competition is basically more conducive to inventive activity, while monopolist competition rather inhibits innovation.

Technological progress is based on creating new technology, which is followed by practical application, but the macro-economic effects only apply if the new technology is widely spread in the economy. The separation of invention, innovation and diffusion determines the research directions of technological progress.

Diffusion is the most important part of this process, because only the maximally wide use of innovations will make the impact of innovations tangible on a macro-economic level. Diffusion provides the opportunity for the adoption of new technologies in such countries which do not have the ability to innovate. Imitation can thus be realised as a result of diffusion. Although it is not easy to identify and tell factors that do from factors that do not affect diffusion, some causal relationships do emerge, which divert further research towards the importance of the institutional environment. Based on the nature of technology, institutions are relevant, because they influence decisions relating to innovation, the behaviour of economic actors, including their relationships, as well as temporal and spatial characteristics of the use of new technology. The spatial diffusion of technology is affected by country-specific institutional structure including formal and informal elements.

According to *North* (1990:3), institutions are the rules of the game, while *Hodgson* (2006) called institutions rules in general, which can be present both as barriers and as incentives of technological progress. The presence of new technologies in a country alone cannot guarantee that technological progress is really achieved, because the adaptation and the spread of innovations can be impeded by institutional factors. According to *Czeglédi* (2010:40), institutions as barriers are costs from formal and informal elements, which appear to new entrants, but do not affect incumbents. The power, and power-sharing, the conflict of interest between the owners of old and new technology, and the monopoly rights of the incumbent firm may all be obstacles to progress. However, these constraints are uncertain, because the question is how long they can actually keep away innovators. Because of this, it is worthwhile to analyse the role of the institutions on the other side, where they can appear as an incentive to innovate. *Hámori and Szabó* (2010:889) said that not only one institution, but also the complexity of social interactions is important to innovation. The innovativeness is not exogenously given, but also it is explained by the country's institutional arrangements.

Integrating diffusion and the institutional aspect, the concept of the World Technology Frontier (WTF) allows us to differentiate innovation and imitation-based strategies and thus the analysis of their institutional characteristics. WTF represents the most advanced level of technology in the world and it offers a convenient way to characterize countries depending on the distance from this frontier. Countries on the frontier and close to it are technologically more advanced than countries farther away from it. The farther away a country is, the lower the level of its technology. The economic development of a country is closely linked to its technological development, resources necessary for innovation and the appropriate institutional environment are available in developed countries.

Therefore, the lower-income countries typically adopt new technologies from developed countries to improve their technological level, which also creates the possibility of economic catch-up. In an empirical analysis conducted as part of the research reported here, this theory was investigated by two- and multivariate statistical methods to find out which institutions and how they affect the form of technological progress in particular countries. In this way, I examined the characteristics of the institutional environment in innovation- and imitation-driven countries.

In the study of economic growth, it is generally accepted that the protection of property rights is essential to technological progress. This is in part explained by the fact that investments into the creation and spread of technologies require protection against expropriation by the state and interest groups. It is because innovators will only invest in research and development activities if they can acquire the benefits from their invention. Therefore, the protection of property rights is a priority among the institutions, whose importance is increasingly being challenged nowadays. The innovator is in monopoly situation by enforcement of property rights, where reducing competition is also an incentive for him. New research – especially *Boldrin and Levine* (2004, 2005) – thus highlights that competition is conducive to development, because it constrains the formation of these temporary monopolies. Monopoly power allows rent-seeking, and that is why competition is a better incentive for the innovative activity. However, it is necessary to protect of property rights, because without it, economic actors will not have an incentive to invest in expensive and risky research and development activities.

Evaluating the relevance of the protection of property rights in countries probably depends on the form of technological progress as well. Protection is more important in countries where new technologies are created, because it allows innovators to capture the benefits of new technology by preventing copying. This is precisely the reason why followers do not favour protection. Imitation cannot be prevented entirely by providing property rights, because it is not possible to exclude all potential users from the use of a technology. Nowadays, the protection of property rights and monopoly power which accompanies it seem to be essential for technological progress, which is regarded as the engine of economic growth. This paradox brings a classic competition-monopoly conflict to the surface during technological progress. The dissertation sheds some light from a new perspective on the opposing viewpoints concerning the role of property rights in technological progress.

4. Results of the dissertation

My doctoral research has focused on examining the role of institutions that influence the process of technological progress. The literature review revealed that institutions play a variety of roles in technological progress, because they determine the possibilities of creation and application of technology, and the direction of diffusion as well. The income and technological gap resulting from differences in institutional environment is due primarily to the spatial characteristics of diffusion. At a theoretical level, countries can be differentiated by the World Technology Frontier in terms of their technological level, and the chief institutional characteristics of these groups can also be observed.

In my empirical research, I examined the institutional conditions of technological progress. The index of technological-institutional environment created by principal component analysis is a good indicator of the conditions of technological progress in different countries and the index is also able to distinguish between innovator and imitator countries. The novel indicator includes property rights, human capital and financing conditions of the creation of technology, furthermore innovative willingness and market structure as well. The property rights institutions have a great explanatory power in the principal component. Using discriminant-analysis, the biggest difference between innovator and imitator countries is caused by PCT patents. The correlation-analysis showed a strong positive relationship between the index of technological-institutional environment and GDP per capita, so it allows us to create homogeneous clusters of countries along these dimensions. The new scientific results of the thesis can be summarized in four theses.

4.1. The index of technological-institutional environment

International organisations use composite indicators for measuring innovation performance and competitiveness, but a specifically technology-oriented institutional environment index is not available because few people attempt to create one. My goal in applying principal component analysis was to compose an indicator from closely correlated variables which can be used in characterizing the technological and institutional environment of countries. The index structure based on qualitative features collected by international databases may be unique in that it does not attempt to measure the conditions of technological progress with conventional research and development and innovation (R&D&I) indicators. In selecting variables, I focused on qualitative elements instead of the classic quantitative measurement. For technological progress, the essential factors are property rights and human capital, while the business, legal and regulatory environment is also important through the possession of power.

The market structure and market possibilities influence the invention and diffusion of new technology. In my opinion, the aggregate index must include six separate areas, such as (1) conditions for the invention of new technology; (2) business and legal environment for technology progress created by government; (3) firm's role in the technological progress; (4) technological possibilities; (5) the effect of market structure on invention and diffusion of technology; (6) the possibilities of international technology diffusion.

MAIN RESULT (THESIS) 1. ***The index of technological-institutional environment created from elements of institutional environment of a country represents well the conditions of technological progress. A country needs to do well in all areas in order for it to become a technological leader.***

In empirical analysis, the index of technological-institutional environment has been created by principal component analysis based on 28 variables from the Global Competitiveness Index made by World Economic Forum and 5 ones from Economic Freedom of the World Index made by Fraser Institute. Finally, the novel index includes 19 elements, shown in *Table 1*, it represents well the relevant institutional features of technological progress.

Table 1. *The elements of technological-institutional environment*

Conditions for the invention of new technology	Intellectual property protection
	Availability of research and training services
	Property rights
	Quality of scientific research institutions
	Quality of the education system
	PCT patents
	Availability of scientists and engineers
	Capacity for innovation
	Availability of latest technologies
Firms' role in the technological progress	University-industry collaboration in R&D
	Firm-level technology absorption
	Company spending on R&D
	Extent of staff training
Business and legal environment for technology progress created by government	Judicial independence
	Impartial courts
	Favouritism in decisions of government officials
The effect of market structure on invention and diffusion of technology	Effectiveness of anti-monopoly policy
	Extent of market dominance
	Intensity of local competition

Source: own calculations based on *WEF* (2016) and *EFW* (2016)

The criterion values of the principal component are methodologically adequate. In the correlation matrix there is significant and positive correlation between the variables. Finally, the principal component includes 19 variables, the KMO value is 0.95 (excellent), the Bartlett test is significant and the explained variance is 75.798%. In anti-image correlation matrix, all MSA values exceed 0.9 (excellent) and the principal component is stable. In correlation matrix, all correlation values are significant, reflect positive correlation and exceed the threshold of 0.3.

In summary, the principal component is methodologically robust. This index reflects the relevance of property rights, characteristics of market structures, and human and corporate conditions of research and development as well. Based on the strong correlation of elements, it concludes that the whole institutional structure, rather than particular institutions, must operate well to realise the innovation-driven technological progress. The novel index represents well the institutional conditions of technological progress, and the relationship between elements too. The newly created index is suitable for measuring the relationship between economic and technological development which can be examined by correlation analysis. Regression analysis is not applicable to illustrate the mathematical nature of the relationship between metric variables, because they have strong interaction.

Based on the technological and institutional index, standardised values are available for 139 countries which can be used for further analysis. The distribution of countries based on these values is shown in *Figure 3*. The histogram shows that the distribution is skewed to the left, the value of asymmetry is 0.6527. It means that the majority of countries in the sample have below-average value on the basis of their technological and institutional environment. The value of the index is the highest in classical innovative countries, such as the United States of America, Western European countries, Scandinavian states and Japan, which create the most efficient institutional conditions for technological progress. The emerging Asian countries and the countries of Central Europe follow them, while Africa and Eastern Europe make up the group of laggards. This observation anticipates a smaller number of countries whose institutional environment favours technological progress.

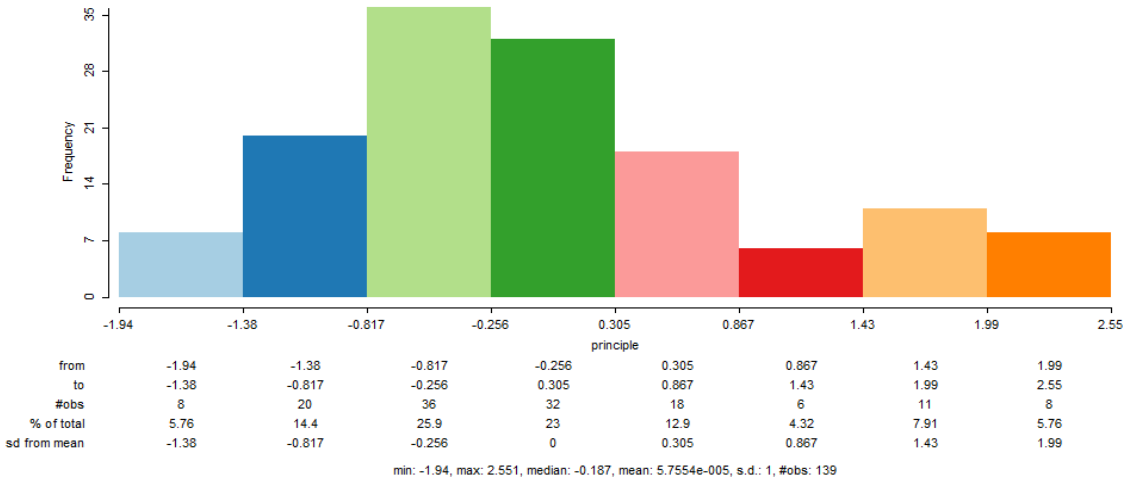

Figure 3. *The distribution of countries on the basis of technological and institutional index*

Source: own calculation based on *WEF* (2016) and *EFW* (2016)

The fundamental premise of the research is that technological progress is the driving force of economic growth. In connection with this statement, the relationship between the technological-institutional environment index and GDP per capita can be examined by correlation analysis in the observed countries. The value of the Pearson correlation coefficient is 0.786, so there is indeed a strong and positive relationship between the variables. Consequently, the higher value of the technological-institutional environment index is typically coupled with higher values in per capita income. If the principal component is divided into elements, the higher values are favourable for technological progress and economic growth as well.

4.2. The differentiation of innovator and imitator countries

Based on the relationship between the index of technological-institutional environment created principal component analyis and GDP per capita, the countries can be classified. The purpose of cluster analyis is to sort countries into homogeneous groups along these two factors. This differentiation allows us to investigate the differences of institutional background in innovation- and imitation-driven countries. Based on the results of cluster analysis, innovator and imitator groups can be shown in *Figure 4*. The first, high-level cluster includes 23 countries from 139, while the second one characterized by lower values consists of 116 countries. In the innovative cluster, the value of technological-institutional environment and GDP per capita are also high. In the imitative cluster, there is less variance in respect of GDP per capita than technological conditions.

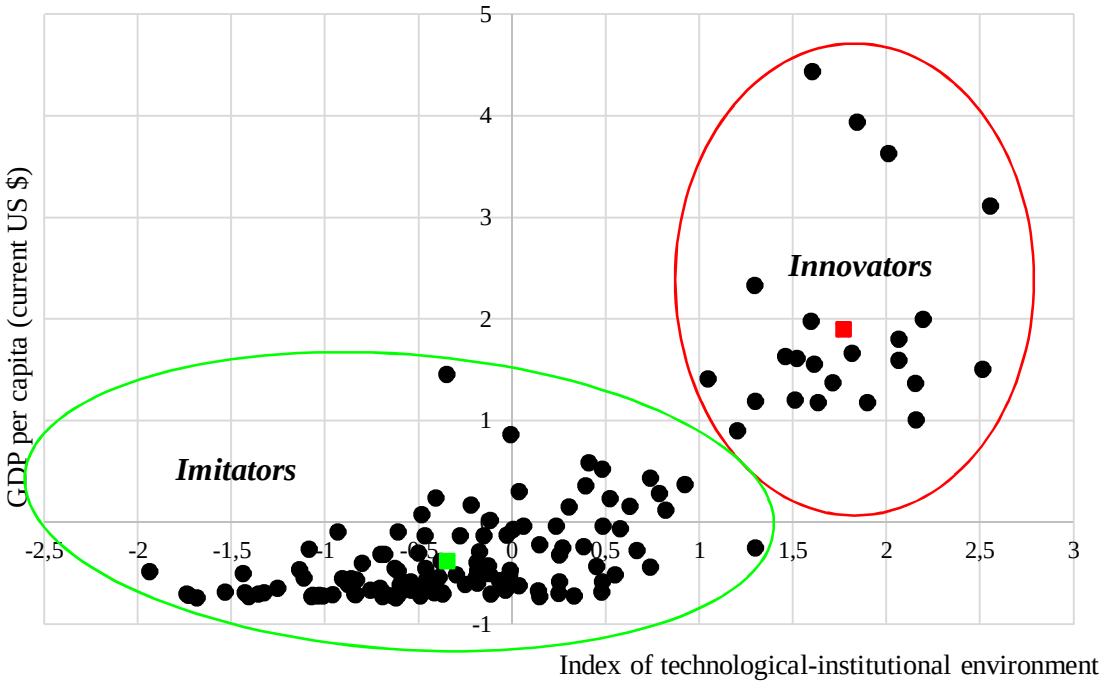

Figure 4. *The separation of innovator and imitator countries with cluster analysis*

Source: own calculation based on *WEF* (2016), *EFW* (2016) and *World Bank* (2016)

The cluster analysis conducted along the index of technological-institutional environment and GDP per capita has allowed us to confirm the most explicitly assumed innovator and imitator differentiation with multivariate statistical methods. So this means that countries can be differentiated in terms of institutional features which are relevant for technological progress.

MAIN RESULT (THESIS) 2. ***Examining the institutional features of technological progress, innovator and imitator countries can be differentiated. It is shown that there is no significant difference between institutional conditions between innovation- and imitation-driven economics, but the quality of institutions is different.***

The majority of the countries examined belong to the imitator cluster, and there are only a few countries where technological progress is intensive and is realised in an innovation-driven way. However, the assumption that if technological progress is achieved in different ways, then that is due to the differences of institutions is only partially confirmed. The same institutional mix provides for technological progress in both country groups, but the values of variables are higher in innovation-driven economies than imitation-driven ones. It allows us to conclude that there is no significant difference with respect the structure of institutional environment between technological leaders and followers. The quality of institutions is typically lower in lower-income countries, but what is required for imitation is the development of priority areas rather than specific given conditions.

4.3. The relevance of property right protection

The protection of property rights is essential to innovation because without it the potential benefits of innovations cannot be expropriated. Without property rights, anyone can apply the new technology as a free rider and immediately enjoy its benefits without contributing to the cost of production, which is paid for entirely by the inventors. One can argue that protection is important also because it delays imitation through increasing the cost of copying. The creation of new technologies requires high R&D expenditures which can be avoided or reduced if a country imitates, because it is cheaper and easier than innovation (*Chen* 2009). According to the empirical analysis of *Mansfield, Schwartz and Wagner* (1981:909) on the average, the ratio of the imitation cost to the innovation cost was about 0.65, and the ratio of imitation time to innovation time was about 0.70. Ensuring the protection of the property rights, imitation will be more difficult because copying requires more time and more money. Consequently, imitating is less worth doing, because the additional time and cost of innovation declines compared to imitation, so the gap is reduced. The difference between the cost and time of innovation and imitation will never completely disappear despite protection of property rights. This protection is important mainly in technologically leading countries, where new technologies are created. It is because it allows innovators to capture the benefits of their innovations and it is one of the most efficient tools against imitation.

> **MAIN RESULT (THESIS) 3.** ***The protection of property rights, an especially significant element of the institutional environment, creates the basis of technological progress, so it is equally important in technological leader and follower countries.***

The protection of property rights is essential to innovation. This is supported by the results of my empirical research, because the principal component includes all three indicators in this field, i.e. property rights, intellectual property rights and PCT patents. The intellectual property rights variable has the strongest explanatory power because innovation is mainly implemented in immaterial form nowadays. In addition, the property rights and PCT patents are also important. The protection of property rights is equally important in technological leader and follower countries, because it creates the basis of technological progress, regardless of whether it is realised in an innovation- or imitation-driven way. The reason for this is that imitation also requires R&D expenditures to adapt new technologies in a local environment, which comes with its own risks, but these costs are lower than in innovation. In developed countries, the protection of property rights is stronger, as indicated by all three variables.

This could be explained by the fact that innovators are more interested in the protection of their innovations against imitation, to make the latter more difficult.

The question I attempted to answer in the discriminant analysis was which variables of the principal component are the ones that primarily determine whether a country belongs in the innovator or in the imitator cluster. Independent metric variables are the elements of the principal component while the dependent non-metric variable is the cluster type. In the discriminant analysis, I used the step-by-step method based on Wilks' Lambda and Mahalanobis distance method. Each procedure in three steps set down the same three statistically acceptable best discriminating indicators, as shown in *Table 2*. The conclusion to be drawn from the fact that for each indicator the significance level of the F test is 0.000 is that all three variables significantly discriminate the groups. However, based on the Wilks' Lambda values, it is apparent that PCT patents have the biggest discriminant impact, which was followed by the quality of research institutions and impartial courts.

Table 2. *The evaluation of discriminating impact of variables*

Variables	***Wilks' Lambda***	***F value***	***Standardized discriminant coefficients***	***Correlation coefficients between variables and discriminant function***
PCT patents	0.350	254.508	0.707	0.767
Quality of scientific research institutions	0.444	171.853	0.278	0.630
Impartial courts	0.495	139.819	0.497	0.568

Source: own calculations based on *WEF* (2016) and *EFW* (2016)

Based on the group centers received in the analysis, we may conclude that there is a significant gap between imitator and innovator countries in the field of PCT patents, the quality of the research institutions and impartial courts. Therefore, imitators should develop in these areas, if they want to become innovators.

In the era of information and communication technologies (ICT), new technologies are mostly created in immaterial form, so protection of intellectual property rights is necessary to realise technological progress. Patents are the most common form of this. *Szűcs* (2014) summarizes the changes in the role of patents in economy and actual theoretical and empirical evidence. He points out that patent systems will need to be reformed in order for this form of protection to fulfil the function it traditional plays in the protection of innovations. According to *Mansfield, Schwartz and Wagner* (1981:913), although patents do not offer complete protection against copying, they do have a preventive effect on imitation because they increase imitation costs, making patented products more expensive to copy.

What the authors also found in their study was that within 4 years of their introduction, 60 % of patented successful innovations were imitated. According to *Gallini* (1992), this means that the patent time is too short to effectively inhibit imitation. So in brief, patents can delay, but cannot stop imitation. Nowadays, although the intensive technological progress and long procedures of patenting are difficult to reconcile, patents still remain the most common form of the solution to the problem of protection.

The role of protection of property rights in innovation is often modelled by patents. Analysing the invention, i.e. creation, of new ideas, a temporary monopoly of the innovator can be interpreted through the institution of a patent. The costs and benefits can be analysed, and competition and monopole position can be compared as well. The patent activity is still intense in developed countries and although the willingness is decreasing, this is the most common form of avoiding imitation.

MAIN RESULT (THESIS) 4. ***Patent activity is more intense in innovation-driven countries, which may be due to the fact that patenting is one of the most important tools for preventing imitation.***

The spread of innovations has accelerated due to the information and communication technologies, globalization and firm's expansion, which may predict a decrease in patent activity, as confirmed also by some empirical studies. During my research, I did not conduct time-series analysis, but I examined the differences of patent trends in two clusters for the base year. Based on the results of the discriminant analysis, PCT patents mostly differentiate the innovator and imitator clusters. This supports the hypothesis that patent activity is more intense in innovator countries, where new technologies are created. *Figure 5* shows the intensity of PCT patents.

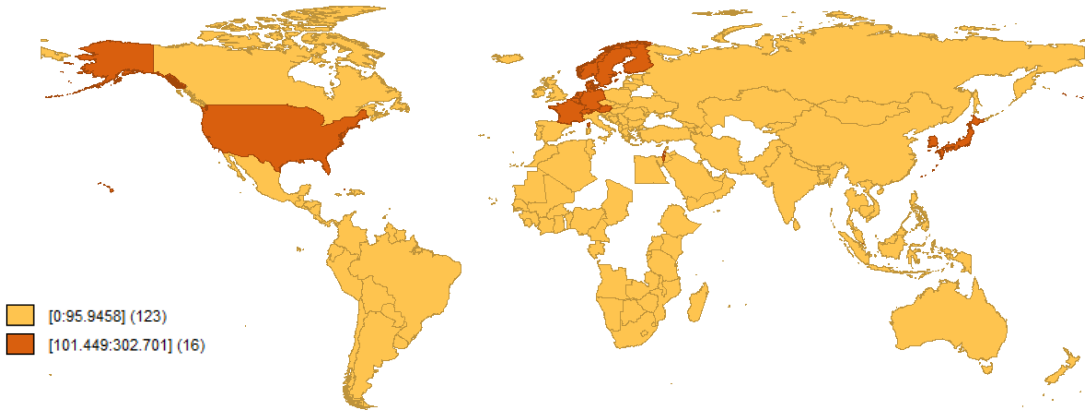

Figure 5. *Spatial distribution of PCT patents in the countries of the world*

Source: own calculation based on *WEF* (2016)

In patenting activity, 16 countries are active, such as the United States of America, Japan, Scandinavian states and Western Europe. It must be concluded that PCT patents, the key indicator of the discriminant function, is indeed suitable for the differentiation of countries. In the first cluster, there are countries with higher levels of technological-institutional environment, the so called innovators. Patents are more important in innovation-driven countries, because they can delay imitation and they allow innovators to capture the benefits of innovation.

5. Conclusion and further research directions

The role of institutions is appreciated in the investigation of technological progress regarded as the driving force of economic growth. My doctoral research focused on the relationship between technology and the institutional environment in a novel approach. I was looking for the answer to the questions of whether and how institutions can influence the realisation of technological progress in particular countries. The basis of the problem identification is the duality of technological progress, which appears in the distinction between innovation- and imitation-driven types of growth. The diffusion of new technologies allows imitation, so this is the critical part of technological progress, which determines the technological gap between countries. Based on empirical evidence, new technologies are mainly created in high-income countries, and they may become available in lower-income countries due to the intended or spontaneous diffusion. Most of the countries are unable to innovate, because adequate resources are not available and because the institutional environment is not conducive to innovation either. Even so, technological progress can be realised in these countries too, in an alternative way, called imitation, which is based on the adoption of technologies that exist elsewhere. *Are there any detectable institutional features that characterise countries in the two different clusters defined in terms of the manner in which technological progress is realised?* This was my research question.

The main assumption of the dissertation was that if technological progress is realised in different ways in the countries, the institutional environment of technological progress must also be different. This hypothesis was tested by literature and empirical analysis, which was aimed at determining elements of the institutional environment which are conducive to technological progress and their interaction. Based on the differentiation of innovator and imitator countries, it can be concluded that the protection of property rights is one of the most important elements of the institutional environment, because not only does it allow innovators to capture benefits from innovation, but it can also prevent imitation.

Consequently, the issue of property rights played a central role in the research, which is due, in part, to the increasing debate nowadays about whether it is or is not necessary. It is not clear that the protection of property rights is necessary for technological progress, because it generates monopoly power and rent seeking behaviour. Recent studies point out that encouraging competition favours innovative processes. My research contributes to this debate by examining the issue of the necessity of property rights from a perspective of differences in how technological progress is realised in different countries.

The results reported in the present work raise a number of further questions, some of them left open, which point in directions in which this research may continue. One of the directions of future research is the time-series analysis, because in some fields adaptation is continuous and although institutions change slowly, tendencies can be investigated in the long-run. This approach is particularly interesting in regard to the patenting activity because there are interesting results in short-run due to the economic catch-up accompanying intensive patenting in China. Meanwhile, decrease in patent activity is forecasted in technological leader countries due to rapid technological progress. In this context, weakening or strengthening of the protection of property rights can be analysed not only with patents but also other institutional indicators, especially in developed countries. Another research question can be formulated in this area, whether the decline in patenting propensity can mean conversion to competition-oriented environment as Boldrin and Levine predict. Is there a convergence between developed and developing countries in the field of protection of property rights? To answer this question, the monopoly vs. competition conflict will need to be analysed in detail.

Another direction of future research is the analysis of the role of competition in technological progress. Measuring competition is harder and more specific than property rights, nevertheless, conditional antithesis of the intensity of competition and protection of property rights combining the innovator and imitator characteristics may offer another direction for potential new research. Competition is important from the perspective of the incentive and stimulation of innovative activity, while for imitation the less competitive environment can be beneficial, with some variation determined by the size of the technological gap and the strategic importance of imitation.

From a methodological point of view, the present research can be continued in a way that country-level data is supplemented industry-level data. The extent of technological progress in particular countries is influenced by the performance of technology-intensive sectors.

The institutional environment can be analysed in more detail with the help of sectoral data. The three variables revealed in discriminant analysis may further be studied, for example, by examining the robustness of the effect of institutions and the discriminative effects of some additional elements.

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