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Institutions and Ideas as the Drivers of Economic Growth

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Introduction

In the last three decades the difference between the poorest and richest countries increased significantly. When one looks at the United States and Zimbabwe, the difference in GDP per capita in 1970 was 92-fold[1]. That gap has increased by a factor of 3 in the last 29 years. Comparing Zimbabwe with the richest countries[2] in 1970 and 2009 indicates that income in the richest countries increased by a factor of five relative to Zimbabwe. For that reason economists have spent a great deal of effort addressing the question of what causes such huge differences. What is more, they have started to search for factors that could give a recipe for policy makers to help boost their economy and sustain growth in the long run. The latest approaches focus on geographical, cultural and institutional determinants. The latter of these has been given special attention among economists, and has opened a new chapter in economic growth research – institutional economics. As Rodrik (2004) stated, the clue is not whether institutions matter, but which ones and how to acquire them.

Institutions are the set of rules in society or more formally – the restrictions imposed on humans, which formulates the political, social and economic interactions. They are built by humans, enforce a particular behaviour and their effect – positive or negative – is perceptible through incentives. Favourable for an economy, institutions protect property rights and provide appropriate laws and regulations that prevent the sources and diminish the consequences of market imperfections. As a result, they lead to a stable and efficient micro- and macroeconomic environment. In particular, they influence technology creation and diffusion – a special kind of knowledge spillover. This happens by ensuring the motivation for innovators in the guise of property rights and a good environment for imitation.

This thesis will follow the institutional economic approach and address which institutions matter. In most papers, authors proved the significant role of institutions in shaping both economic growth and economic performance as measured by GDP per capita. In this thesis however, the author will examine the indirect effect of institutions upon economic growth through technological progress (measured by patents stock changes) and will investigate the 5 particular freedoms separately. What is more, the model will

[1] Real GDP per capita in 2005 USD constant prices. Source: PWT 7.0.
[2] Switzerland in 1970 and Luxembourg in 2009.

be extended by considering the possibility of international knowledge spillovers from bordering countries. A further novelty in comparison to other papers is to divide the sample into two subsamples (Advanced Economies, and Emerging and Developing Economies) and to include the interaction of institutions with the patent stock.

Using 3SLS on 2 simultaneous equations the author will examine the group of 95 countries over the period 1970-2009 in order to verify the following hypotheses:

- Hypothesis 1: *institutions, through technological progress, impact positively upon economic growth*;
- Hypothesis 2: *technology spillovers influence positively the technological progress of neighbouring countries and in turn their economic growth*.

A first equation will explain economic growth in terms of initial GDP per capita, the rate of investment, population growth, the average years of schooling attained (as a proxy for human capital), and the change in the patent stock (proxy for technological change). The second equation will examine technological progress defined as the change in the patent stock in terms of institutional quality, population size, average years of schooling attained and the stock of patents in border countries (as a proxy for ideas spillovers).

The thesis starts with a chapter discussing the theoretical background. The author provides a survey of the literature that pertains to the relationships between economic growth, institutions and international knowledge spillovers. The chapter begins with a review of theoretical models, starting from neoclassical models, in which institutions can be seen as an exogenous parameter – technological progress. In the next class of models presented, New Growth Theories (NGT's), institutions are merely an intermediate channel which helps the diffusion of technology. Afterwards, a conceptual framework of institutions, their definitions and its interaction to the economy will be presented. This chapter will finish by explaining the role of international knowledge spillovers and the importance of institutions for spillovers.

The second chapter will be devoted to a survey of empirical papers. The author will start by presenting the prevailing trends in economic growth empirics. The chapter will proceed to a discussion of papers that examine quantitatively the role of institutions in an economy. Besides that, the issue of two way causality will be mentioned – from institutions to economic growth, which can lead to a bias. The last section will present the papers that pay attention to international knowledge spillovers. The author will further discuss the location of this thesis among the mentioned literature.

The third chapter will present the theoretical model of Uzawa and Lucas (1988). This model was chosen due to the fact that it belongs to NGT's, and in the closed economy case there is no particular technology function assumed. What is more, the model incorporates human capital, what is an important part of ideas production and establishment of institutions. The author will extend the model by using a similar function of technology to that proposed by Jones (1995b), where it is a function of cumulative R&D effort. Despite the fact that the proposed modification makes the model unsolvable analytically, one obtains two equations which will serve as the basis for the econometric investigation.

The fourth chapter examines quantitatively the above-mentioned hypotheses of the thesis. It will begin with a short introduction in which the author explains the analytical form of the model and expectations of the estimated coefficient signs. The next section will be devoted to details of the variables used and the data description. After that will be presented the preliminary results based on extreme cases, correlations coefficients and Granger causality tests. Then, the results of the econometric estimation in the basic specification and its extension (by using the interaction of institutions and patents stock, and additional variable GDP per capita in patents stock equation) will be discussed. The following part will present the answer to the question of which institutions matter the most in shaping ideas. The last part will be devoted to present the results of sensitivity analysis, where the author examines the impact of country and time specific effects, outliers, fluctuations of GDP per capita, educational attainment, change in patent variable and the inclusion of depreciation of patents.

The quantitative analysis will prove partially the hypothesis of the thesis. In the main model specification the first hypothesis will be confirmed only for Emerging and Developing Economies. However, both hypotheses will be fully confirmed in the extended model by interactions of institutions and the patent stock. In the examined samples conditional convergence is also observed. Considering other variables, it turns out that population growth and size matter positively but only in the case of Emerging and Developing Economies. However, population growth has a positive sign which is inconsistent with theoretical predictions and other papers. This may indicate some new direction in research which emphasises the importance of the raw labour force in the case of poorer countries. The impact of investment is positive but not in all models. The impact of educational attained is positive in the extended model. The impact of other variables can be neglected. Sensitivity analysis will prove that the results depend on including country and time specific effects, on the depreciation of the patent stock and partially on used educational attainment variable. The results are not sensitive to outliers, unsmoothed GDP per capita, or the use of the volume of new patents instead of the stock.

Chapter I. Theoretical Background

The aim of this chapter is to provide a survey of the literature that pertains to the main topic of the thesis – the impact of institutions on economic performance. This chapter will initially discuss relevant theoretical models, starting with the Solow-Swan (1956) model, and its extension by Mankiw-Romer-Weil (1992). In this first section new growth theory models will also be discussed. One of them, the Uzawa-Lucas (1988) model, will provide the theoretical background for the econometric investigation that follows. In those models the author will identify the role of institutions and knowledge spillovers.

In the second section the author will define institutions and provide a description of the channels through which they affect the economy and its performance. Special attention will be placed on technological change, as well as physical and human capital.

Section three will be devoted to international knowledge spillovers and their role in shaping economic growth. The author will focus on the division into within and between spillovers. Among between spillovers is technology diffusion, which is discussed in detail in the part dedicated to institutions. The final section will sum up the findings and emphasise the common features of institutions for all papers.

1.1. Growth Theory – a Brief Review

This section will discuss the theoretical models of economic growth, starting from the seminal model of Solow (1956) and Swan (1956). This model belongs to the exogenous class of models where technological improvements are assumed to be exogenous. The extension of this model through the incorporation of human capital into the production function, made by Mankiw-Romer-Weil (henceforth MRW, 1992) will then be discussed. Afterwards, a class of models that do not explain the growth pattern in terms of exogenous technology will be presented, namely NGT's. These models focus on the new sources of growth, or on account of existing ones but with new features. In details will be offered the models that assume non-diminishing returns to scale and violate the Inada conditions (AK models), then models that introduce the human capital that is produced as a good and finally models that derive the growth pattern from technological improvements.

A first canonical model of economic growth, made by Solow (1956) and Swan (1956), opened a class of exogenous growth theories. That model assumes decreasing marginal productivity of capital and the Inada conditions[3]. As a result one observes conditional convergence and a long-term growth rate equal to zero in the case of no technological progress. It means that improvements in technology are the only factor that determines long-term growth. However, this parameter is not explained in the scope of model. Simultaneously, it is recognized a Solow's residual, that is the left impact on output per capita after substracting the effects of two other inputs (labour, capital). Another feature of Solow-Swans's model is to assume a constant saving rate and not take into consideration any consumers' optimization. Consequently, one cannot predict what the impact of taxes or the interest rate is. However, having a very simple approach and implications consistent with stylized facts, Solow's model was a basis for consecutive research and extensions.

MRW (1992) extended the basic Solow-Swan model with an additional input: human capital. Incorporation of a new factor into growth analysis allows one to better understand the differences in economic performance between countries. Particularly, the rate of convergence is lower in comparison to Solow's model, which is more consistent with observable rates. The explanation for this is that the absolute values of the elasticity

[3] The value of marginal productivity goes to infinity when capital approaches zero, and goes to zero when capital approaches infinity.

of savings and effective depreciation are much higher in MRW model in comparison to Solow's model[4]. Still, both models assume a constant saving rate and exogenous technological change which is the only determinant of long-term growth. These models, despite their restricted ramifications, are still used by many contemporary researchers. Aron (2000) suggested that the Solow's residual – which is the part of growth that cannot be explained by standard inputs – can be explained by the institutional environment. The broader concept of the parameter *A* from Solow-Swan's model is presented by Romer (2000), who interpreted this as education, qualifications of the labour force, property rights or even infrastructure. For the scope of this thesis it is important that institutions are seen as a long-term exogenous factor that determines growth.

Scientific concerns led to a new concept among growth theories[5], namely new growth theories. According to Capolupo (2009) this class of models was initiated by the work of Romer (1986) and Lucas (1988). The role of these models is to find sources of economic growth other than exogenous technological progress. Therefore, economists have derived the growth pattern from new variables like innovation, human capital, physical capital externalities or a "new" feature of them, namely increasing returns to scale (Arrow's [1962] mechanism of learning-by-doing). The other distinguishing mark is to move towards imperfect competition, instead of perfect rivalry. It is worth briefly presenting a few of the NGT models, namely the AK model (see, Barro, Sala-i-Martin 1995), the Uzawa-Lucas model (see, Uzawa 1965, Lucas 1988) and models with product innovation (see, Spence 1976, Dixit and Stiglitz 1977, Ethier 1982, Romer 1987, 1990).

The AK models assume non-diminishing returns of scale[6] with respect to physical capital. That assumption is true only if one uses a broad definition of capital which includes both physical and human capital. In these type of models, the economy does not converge to the steady-state. As Barro and Sala-i-Martin (1995) suggested, the theoretical predictions about convergence are non-consistent with reality. The growth rate of all the per capita variables depends on the savings rate, technology, population growth and depreciation. That implication is contrary to neoclassical model predictions, where growth per capita depends

[4] Convergence coefficient for Solow-Swan (1956) model is $[1-\alpha](n+g+\delta)$, in MRW (1992) $[1-\alpha-\beta](n+g+\delta)$, where α is the share of capital in production, β is the share of human capital; n – population growth, g – rate of technological progress, δ – depreciation rate. The elasticity with respect to physical capital savings equals: $(\alpha)/(1-\alpha)$ for the Solow-Swan model and $(\alpha+\beta)/(1-\alpha-\beta)$ for MRW (1992); the elasticity with respect to effective depreciation equals: $-(\alpha)/(1-\alpha)$ for the Solow-Swan model and $-(\alpha+\beta)/(1-\alpha-\beta)$ for MRW (1992).

[5] The sforementioned two streams in economic growth theory do not exhaust all the classes of models. For the need of this study it was crucial to mention only those two. For a broad survey of economic growth theories refer to Helpman (1991) or Barro, Sala-i-Martin (1995).

[6] Or at least are diminishing but asymptotically approaching a positive constant.

only on technological progress, which is exogenous. Furthermore, the non-diminishing returns to scale imply a violation of the Inada conditions (which are satisfied in neoclassical models). This allows one to conclude that the economy can maintain long-term economic growth, even without technological progress, which is a novelty in economic growth models.

The Uzawa-Lucas model incorporates into the production function human capital, which together with physical capital does not lead to diminishing returns to scale. In that model, the creation of knowledge is possible through human capital, not physical. What is more, in this model physical and human capital are produced by different technologies (different production functions). This model's prediction of the rate of growth of output is that it depends on the imbalance between human and physical capital. The essential implication for the economy is that human capital plays a more significant role than physical capital. Furthermore, the presence of human capital contributes to the non-diminishing marginal productivity of physical capital. Finally, the long-term per capita growth rate is a function of the parameter B that follows the quality of the sector producing the human capital. This is the major difference of the model in comparison to other where sustainable growth rate does not depend on the effectiveness of the education sector. The Uzawa-Lucas model is especially vital for the current thesis because it will provide the theoretical background for empirical analysis.

Both the NGT's models presented above portray the economy with long-term growth as a continuous phenomenon. That was possible due to non-diminishing returns to scale. The next class of product innovation models tries to deal with that issue. Therefore, the process of technological improvement is endogenized by an expanding variety of products or by quality improvements. Furthermore, through spillovers of knowledge between and within producers, one obtains a higher productivity of firms. Between firms spillovers come from imitating others, while within spillovers come from learning-by-doing. This approach was obtained by saying that each investment in firm i's capital stock leads to a corresponding increase in the level of the technology stock, A_i. What is more, changes in A_i affect the whole economy by increasing the level of the capital stock, K. The prominent difference in comparison to previous models is that one departs from perfect market competition. Here also the long-term growth rate is a function of additional factors like cost of research, technology and raw materials stock (labour stock or human capital). For the scope of this thesis the crucial point is that these models assume a non-rival characterisation of ideas or knowledge. This is contrary to the features of the endogenous models of human capital, where human capital (identified as skills embodied in workers) is a rival good. The author of this thesis tries to focus on this feature and combines it with the spillover of ideas at the international level[7].

To sum up, the first canonical models of economic growth derive the growth pattern from capital accumulation and technological progress, which is assumed to be exogenous. Solow-Swan's model extended by human capital implies lower convergence. Nevertheless, the growth rate of output per capita is zero without technological progress. That problem is solved in NGT, where new variables are incorporated and features of existing ones emphasised. As a result, non-diminishing returns to scale and a violation of the Inada conditions leads to a lack of convergence in the case of AK models. The other important implication of this model is that even without technological progress long-term per capita growth can be positive. Inclusion of human capital provides an additional dependence of long-term growth on the quality of the education sector. In models with human capital produced separately, one also removes the assumption of a diminishing return to capital. The models of innovation imply scale effects and influence of innovation costs on economic growth. The essence of these models is the non-rival character of innovation, which leads to spillovers across economies.

1.2. The Role of Institutions in Growth Theory

This section emphasises the impact of institutions on economic growth and channels of diffusion. Initially, the author will provide a short discussion of the main streams in economic growth determinants and will try to place institutions in this literature. The next part will focus on the definitions of institutions, beginning with North's (1991, 1992) explanation, which is treated as the first attempt to deal with that issue. Aron's (2000) study tried to limit the definition to the set of indicators that is valuable for other researchers. On the contrary, the approach of the IMF (2003, 2005) provides an enormously holistic definition which covers too broad a range. The series of works by Acemoglu et al. (2004) and Acemoglu, Robinson (2008) splits institutions into two types: political and economic

[7] The ideas can spur also on the national level, both within one company and across companies.

ones. Finally, the author will show that institutions can be incorporated into broader concepts like: social infrastructure, investment climate, or growth strategies.

Then chapter will proceed to consider the impact of institutions on the economy through the channel of ideas (a proxy for technological change). At first, the author will focus on the creation of ideas which depends on the stock of the labour force. This implies an imbalance between the creation of new ideas and resource scarcity, an imbalance which institutions may overcome. Then, the investor's perspective and rewards for ideas will be discussed. Afterwards the role of human capital in ideas creation and its dependence on institutions will be presented. Finally, the role of institutions in shaping the diffusion of technology, which is very similar to that in the creation of ideas, will be discussed.

In the last subsection will be presented a conceptual framework of the impact of institutions on: physical capital, human capital and finally – on long-term economic performance.

1.2.1. Institutions as a Conceptual Framework

When one focuses on the fundamental sources of economic growth in the broader sense, there can be found a reference to three views: institutional, cultural and geographical (Capolupo, 2009). In the institutional belief the organization of societies, which is volatile, is responsible for human prosperity. On the contrary, in the cultural view culture and social capital cannot be changed. The other difference between these two views is the determination of social outcome. The first ideology is based on the conflict between choice of group and individuals, and in the second – there is present a common tone. The third approach – geographical – depicts a surpassing character of physical and geographical environment over institutions and culture. However, as argued by Capolupo (2009) it is generally criticized. That arises from the fact that followers of the institutional view (see, Rodrik et al. 2002) stated that geography (natural environment) influences output per capita through institutions. Contrary, the supporters of the geographical view insist that climate or disease ecology impacts on technology and in turn – institutions. In this paper, the author will follow only the institutional view as a fundamental source of economic performance in the broader sense, which seems to have the broadest support among economists.

1.2.2. Institutions Definition in Literature

The meaning of institutions in economic growth has been a topic of economic research for couple decades. Particularly, the last 25 years have brought a renaissance of the institutional view. The effort of researchers was appreciated when in 1993 Douglas North and Robert Fogel were awarded the Nobel Prize for their research on economic and institutional change. According to North (1991, 1992) institutions are the set of rules in society or more formally – the restrictions imposed on the human, which formulates the political, social and economic interactions. They cover the spheres of culture, ideology and politics. Acemoglu and Robinson (2008) indicated the three fundamental features of that definition: institutions are built by humans, they enforce a particular behaviour and their effect – positive or negative – is perceptible through incentives.

Aron (2000) emphasized the role of institutions and politics in affectingeconomic growth. However, she defined more precisely what institutions are by pointing out which indicators belong to those categories. As a result, one obtains a range of indicators which could be used as a measure of institutions, namely: *institutional quality (the enforcement of property rights), political instability (riots, coups, civil wars), characteristics of political regimes (elections, constitutions, executive powers), social capital (the extent of civic activity and organizations), and social characteristics (differences in income and in ethnic, religious, and historical background)* – (Aron, p. 100). In this thesis the econometric part author will focus on the business environment, labour markets, trade freedom, government, and sound money as the indicators of institutional quality.

The broadest term of institutions can be seen in the IMF (2003, 2005) study. For them the definition is holistic – it shows the institutions as a wide spectrum, starting from incentives structure that promotes efficiency and reduces uncertainty. At the second tip, there are organizational units, procedural apparatus and regulatory framework. What is between those two tips is not mentioned. For the scope of the paper the most important is to depict those elements of institutions that affect positively the economic growth. Thus, in the view of IMF (2005) good institutions are those that provide three results: ensure equal access to economic chance, warrant the relevant reward for capital and labour, and provides a property rights for them.

Acemoglu *et al*. (2004), and Acemoglu, Robinson (2008) separated institutions into two categories: economic and political ones. The first include economic solutions that lead to the most efficient allocation of resources (physical and human capital, technology, and the organization of production). Furthermore, they determine the beneficiaries of the distribution through incentives and restrictions. The second group – political institutions – is analogous to the previous but in that case they impact on the political sphere and the one in power. The authors indicated to which type institutions belong: the government type and the degree of constraints on political sphere.

Interesting approaches are presented in three studies, where the authors placed institutions in broader economic categories. For Hall and Jones (1999) institutions are included in social infrastructure, which is a determinant of output per capita. In their depiction, social infrastructure are *institutions and government policies that determine the economic environment within which individuals accumulate skills, and firms accumulate capital and produce output* (Ibidem, p. 84). Stern (2001) incorporated institutions into the investment climate which influences the returns and risk of investment. According to Rodrik (2004) institutions are a part of thegrowth strategy, besides economic policies. The aim of the growth strategy is to converge with the standards of highly developed countries.

One shall consolidate the abovementioned definitions. Institutions are a design that results from common human decisions and actions, and their interaction with economy. On top of this is the fact that they happen through incentives and restrictions. The overriding aim of institutions is to determine the effective allocation of resources in an economy, as a consequence of economic calculations of profit and losses. In those definitions appear some channels that impact on the economy and some sources of volatility, that will be presented in the next sections.

1.2.3. Impact of Institutions on Ideas

There are two ways through which institutions can affect technology, via its creation and diffusion. When considerating uts creation it turns out that institutions can overcome the imbalance between ideas production and resource scarcity of other inputs, repay the cost of ideas and encourage investors to participate in ideas market and make the human capital more productive in creating knowledge. If one considers that ideas depend on the labour stock[8] (as is presented in Jones, 1995b; Jones and Romer, 2010), then in a production function given by $Y = F(A, X, L)$, where A is the ideas stock, X is a nonrival input, and L is the labour stock, one can substitute A with L. Assuming that one observes constant return to scale to the nonrival input, one gets output per worker as $Y/L = F\ (L, X/L, 1)$. As a result output per worker is an increasing function of L (proportional to A, nonrival input) and decreasing with respect to other rival inputs per worker, $X/$L. The first effect will dominate the second if institutions will provide the sufficient environment to do that. It means that institutions have to help to cover the decreasing capacity of rival resources.

While Smith's invisible hand works properly in an environment with well-defined property rights and perfect competitions, it does not work in the ideas market (Jones, Romer 2010). The nonrivarly of ideas leads to the situation where this input cannot be sufficiently paid by output. As a result prices have to exceed the marginal cost in order to provide incentives for firms to invest in ideas creation. However, the prices are not the only incentive to allocate the goods in the most efficient way. In order to repay the cost of investment in ideas creation one needs a mixture of intellectual property rights, public subsidies for science, private voluntary provision and secrecy. These, collectively known as the institutional environment, seem to be the optimal choice for a good investment climate.

In the previous paragraphs were discussed the incentives to invest in ideas as an input. Now, think over the role of human capital, which produces the ideas. Therefore it is important that institutions will provide a sufficient environment for human capital to be more effective in this process. Things brings forward four issues: high quality universities; low costs of innovation; good governance and transparent policy; and respect of inventors' rights. Universities should provide two functions: create the ideas and educate future inventors and imitators. That is impossible without mentioned other factors. Thus, institutions should also provide the motivation to the inventor in the guise of tax exemptions or low bureaucracy. They also should strengthen the degree of respect for contracts (Aron 2000). And, similar to investor rights, the inventor should also be assured by personal security and private property (Coe et al. 2008).

The diffusion of technology depends on institutions similar to technology creation. A country that produces an idea, provides an opportunity for others to imitate and use the foreign patent, hence triggering their own growth. But that will be possible under four

[8] The labour stock is divided into two parts: one that is devoted to the nonrival input (ideas) and the second – devoted to rival inputs (like physical capital). Hence, for the constant over time share of workers employed in each sector, one obtains a positive relationship between the stock of labour and production of ideas.

conditions. Firstly, inventors' rights have to be appropriately protected in the imitating country. Secondly, there must be a highly qualified labour force which is able to imitate new products/patents. Thirdly, there must exist connections between the inventor and imitator that are low-cost (Jones, Romer 2010). And finally, there must exist enough incentives to do that: low transaction costs, low red tape, an easy and transparent tax system (Aron 2000).

All things considered, it seems that institutions can provide an incentive to create ideas, even if markets do not provide the appropriate reward for that input. They can also influence the efficiency of human capital in creating and imitating the ideas. They can overbalance the positive effect of creation of ideas over the resource scarcity. When taking into account diffusion, institutions play a role in ensuring that both sides of game about the efficiency and by providing incentives to the imitator.

1.2.4. Impact of Institutions on Physical and Human Capital

Effective utilization of physical capital depends on many factors, among which are market incentives (e.g. possibility of rent extraction) and transaction costs. The capital stock is deployed in a rational way if it is rewarded with an economically justified amount. That should be the aim of institutions (IMF 2003). The question is: in what way? According to Hall and Jones (1999) the clue is social infrastructure. As was mentioned before, it consists of government policies and institutions. Social infrastructure has an impact on effective employment of physical and human capital (discussed in detail in the next paragraph). It is caused by stimulating incentives to prevent destructive behaviour such as rent-seeking, fraud or theft. As a result, institutions determine the appropriate rewards to the owners of production factors and in turn – output per capita. Additionally, another possible channel of impact is through transaction costs. When property rights are not enforced, transactions costs increase and a black economy emerges. That could result in further bribery and rent-seeking, which together leads to a reduction in capital investment and therefore a worsening economic performance (Aron 2000).

A special role in shaping the economic growth is devoted to human capital. As was mentioned in the previous section – it influences the deployment of technologies, its creation and diffusion. Here, one will focus on the part of human capital that is employed in producing rival output. Prittchet (1999) argued that well educated people are employed in counterproductive activities. What is more, the current institutional environment is too weak to provide sufficient demand for highly-educated people. As a result, there is no transmission of education into the creation of human capital. And here lies the role of institutions – they should provide a stable and strong environment that leads to better incentives to deploy people into more productive activities, and into creating human capital that is used to produce a rival output.

It is common knowledge that an economy has two aims: to boost the growth rate and to sustain it. A lot was said about the first, so now one focuses on sustainable economic performance. In the view of Rodrik (2000, 2004) the aim of policy-makers should be to create a solid institutional environment that could be a shelter for macroeconomic shocks and a channel to maintain the production dynamics. Rodrik mentions three factors that should assure these aims: sound money, fiscal balance and prudential regulation of financial sector. Sound money allows the economy to absorb the over-liquidity in the financial sector that is caused by changes in money demand. The fiscal balance provides the appropriate conditions for sustaining debt in relation to other aggregates. And finally, prudential regulations prevent the financial sector from taking over the excessive risk.

To sum up, good institutions provide a stable environment for investment in physical and human capital. They lead to a decrease in transaction costs and the elimination of destructive actions, so they provide a good environment for capital investment. When one looks at human capital, it turned out that institutions could be the only force to provide sufficient utilization of education in the process of the creation of human capital. Finally, they can be a force that through money and financial markets can sustain long-term economic performance.

1.3. The Role of International Knowledge Spillover in Growth Theory

This section will discuss briefly the reason why knowledge spillovers impact upon economic growth, based on the previously presented theoretical models. The author will indicate two types of spillovers: between and within. A short discussion of both categories will be provided and finally, the impact of knowledge spillovers on the economic growth.

As was mentioned in growth theories review, spillovers of knowledge – both between and within producers – leads to higher productivity both for individual firms and at the aggregate level. Within producer spillovers come from learning-by-doing. Particularly, when a worker is repeating his productive activities every day, he tries to find the pattern for the fastest possible way to perform the task. In this way, the worker is improving the process of production and development of the product. As a result, one obtains a self-improving character of production, where every investment in capital (used in production) is related to improvements in technology.

Between producer spillovers are possible for two reasons: the non-rival character of knowledge and the low-cost character of imitation in comparison to innovation. In economic growth models it is assumed that the knowledge stock is available for all players in the market and is without diminishing returns to its use. The only institutions that can restrict access to knowledge are property rights and patents (partially excludable character of knowledge). If the innovator invents a new product, it appears immediately on the market and can be imitated or adopted by other producers (imitators). As the process of innovation requires R&D effort and spending on the security of property rights, so the imitation is perceived to be typically less costly. The imitator does not have to focus on R&D, but has to adjust the product to the local environment and – in some cases – pay the fee to the inventor. As a result, both the innovator and imitator gain from the "exchange".

The described processes of innovation and imitation have the influence on an economy and its convergence. The mentioned structure of costs implies that the imitator will grow faster when it is further from the innovator. What is more, this convergence will depend on the local institutional environment, that is the circumstances that determine the rate of return of imitation. The other implication of that setting is the diffusion of technology leads to the equalization of return rates across countries in the long run, even if the global capital market is very poor. Finally, one can see at this juncture the role of institutions which should provide the appropriate motivation for the innovator in the guise of property rights and a good environment for imitation. Consequently, the whole economy will take advantages from international spillovers of knowledge.

1.3. Summary of Chapter

The presented theoretical models provided the background for factors that determine economic growth. Both neoclassical models assume exogeneity of technological progress which is the only determinant of long-term growth. In NGT that problem was solved by incorporating new variables or through using new features of existing ones. Therefore, even with a lack of technological progress, one could observe a long-term growth. The growth rate depends on the quality of the education sector, innovation costs, technology, population growth, the savings rate and the depreciation rate. The crucial issue for this thesis is that institutions are seen as an exogenous factor that could determine the long-run growth.

Institutions, as a conceptual framework, are presented in various aspects and approaches. Some papers tried to define them (North 1991, 1992), find the most suitable measures (Aron 2000), while others provide the concept of how institutions affect an economy, its players and the allocation of resources. Rodrik (2004) suggested a recipe for policy-makers to create the sufficient micro- and macro-environment. However, the most influential works are proposed by Acemoglu et al. (2002a, 2002b, 2004) where authors provided the vast conceptual framework for an interaction between institutions and the economy.

Institutions, seen as the rules, restrictions, indicators of social quality, social choice, structure of incentives, organizational units and expectations, are undoubtedly among the fundamental sources of growth in the broader sense. They are well recognizable in economic literature and their meaning in economic growth research is still increasing. There are many definitions and divisions of institutions which make the topic very broad and sometimes one is not convinced where institutions “start”. This leads to the situation that one can hardly find a reference point. However, the author has indicated many papers that narrowed the definition of that category and mark the starting point for our research.

The impact of institutions on economic growth takes place through three channels: the creation and diffusion of technology, physical and human capital. With increasing numbers of researchers, an economy has to deal with resource scarcity of non-rival inputs. It can be solved by institutions which will eliminate the imbalance. The creation of technology is affected by providing the appropriate environment for investors and inventors in terms of property rights, low costs, subsidies, good governance and transparency. In turn, the diffusion of technology needs also a highly qualified labour force and human capital. Those interactions lead to the conclusion that without basic institutions there will not be any innovation and much less their diffusion.

Besides the impact on technology, institutions shape the incentives for physical and human capital. According to the presented conceptual framework, institutions ensure an equilibrium between political and economic institutions, in order to shape the effective allocation of resources. It is possible through the promotion of efficient behaviour and the prevention of destructive ones. Institutions are perceived as the only force which ensures education to be effectively used in the creation of human capital.

To sum up, good institutions are a stabilizer, guard and guide for economic policies. Their aims are to protect property rights, provide appropriate law regulations that prevent the sources and diminish the consequences of market imperfections, support macroeconomic policies, and promote social stability. All these lead to a stable and efficient micro- and macroeconomic environment. In particular, they influence technology diffusion – a special kind of knowledge spillovers – and its creation. It is hard not to consent that good institutions determine long-term economic performance.

Chapter II. Empirical Background

The aim of the following chapter is to provide a survey of the literature that pertains to economic growth, institutions, and international knowledge spillovers. The first section will be devoted to a brief review of general trends in economic growth empirics. The next section will focus on empirical papers that examined the role of institutions on economic growth. A minor part will discuss the problematic issue of reverse causality, that is the relation from economic growth to institutional quality. The last section will show the motivation for additional factors in the form of R&D spillovers. A final summary will conclude and place this thesis among the mentioned literature.

2.1. Growth Empirics – An Overview

Generally one can split the economic growth literature into two streams: one pertaining to the convergence phenomenon and one to growth determinants and factors responsible for differences in economic performance between countries (Capolupo 2009). The division of different approaches with respect to convergence is presented by Islam (2003), where the author divided the convergence category into seven notions[9]. The determinants of economic growth can be split into fundamental sources (like broad capital, human capital, education, R&D), fundamental in the broader sense (like institutions, geography and culture) and proximate ones (Capolupo 2009). When one considers the econometric approach one can encounter five methods[10]: informal- and formal cross-section, panel approach, time series approach and a distribution approach (Islam 2003).

It would be meaningless to provide the survey of all the aforementioned. However, it is worth to mention the dominant trends. Most of studies considered both the convergence issue and the determinants of performance, as is applied in this paper. The majority of essays concerned the notion of β-conditional convergence in terms of growth rates and across economies. When one looks at factors that determine growth, typically there are fundamental variables (initial GDP, investment, population growth, school enrolment) and additionally – fundamental variables in a broader sense. The same can be said about the prevailing methodology: it tends to be either a cross-section or panel approach. This thesis will follow the prevailing methodology: β-conditional convergence in terms of growth rate across economies; determinants of growth in the guise of fundamental sources and those in broader sense (institutions), and a panel approach. The novelty is to provide two equations, where in one there will only be the fundamental sources of growth and in the second institutions as a determinant of TFP. The author will also divide the sample into two groups: Advanced Economies, and Emerging and Developing Economies. What is more, the econometric model will be extended by an incorporation of an interaction between institutions and ideas, and the additional variable GDP per capita in explaining technological progress.

[9] The division is as follows: convergence within vs. across economies; convergence in terms of growth rate vs. income level; β-convergence vs. σ-convergence; absolute convergence vs. conditional convergence; global convergence vs. local or club-convergence; income-convergence vs. TFP-convergence; deterministic convergence vs. stochastic convergence.

[10] A comprehensive review of econometric approaches to study economic performance is also presented by Temple (1999) and Durlauf et al. (2005).

2.2. Institutions and Economic Growth

The first subsection pays attention to the empirical analyses of institutional quality and their impact on economic performance. One of the first seminal papers that touched the fields of institutions and their impact on GDP per capita was provided by Hall and Jones (1999). The next study worth a mention was provided by Rodrik et al. (2002), where the authors, having tried to study a new trend in GDP per capita determinants, examined the roel of institutions, geography and trade. It is worth emphasising that these initial papers did not examine growth directly. The researchers used GDP per capita as the dependent variable, which is a measure of economic performance and a kind of very long-run growth measure. One of the broadest studies that emphasizes the role of institutions in shaping the level of economic performance, growth rate and the volatility of an economy, was made by the IMF (2003). A somewhat different essay is provided by Commander and Nikoloski (2010), where the authors besides having presented the relationship between institutions and the economy focused on the impact at the firm level, and examined the effect on revenues of companies. The latest motivating approach is presented by Fatas and Mihov (2011), who studied the meaning of institutions in influencing economic growth through government policies.

The next subsection presents examples of two-way causality, in order to show the determinants of institutions. Among those factors will be presented: initial conditions (culture, geography and history), rent-seeking and external environment (external anchors, external aid and transparency). Next, the reader will be acquainted with other sources of institutions endogeneity: the bias as regards the way in which institutions are measured.

2.2.1. Institutions as an Empirical Investigation

The scope of the seminal study presented by Hall and Jones (1999) is based on two problems: why some countries invest more in physical and human capital; and why some countries are more productive than others. To answer these questions, the authors refer to social infrastructure, which is defined as an economic environment, shaped by institutions and government policies, in which consumers and firms operate and make decisions. The empirical method was OLS and a group of 79 countries, with the relationships between GDP per capita and social infrastructure studied. The authors analysed also the impact of social infrastructure on three different inputs: physical capital per capita, human capital per capita and technology. It turned out that social infrastructure has the largest positive impact on the last factor (measured as a Solow's residual). Furthermore, the authors obtained a significant positive impact of institutions on economy. This essay opened a new chapter in the analyses of economic growth and has become a motivation for further research.

Rodrik et al. (2002) studied the relationship between income (from 1995) and institutions, geography and trade, having tried to find the answer which of those has the largest effect. What is more, they tried to discover through which of four channels these three factors affect an economy the most, namely: income per worker, capital per worker, human capital per worker and total factor productivity. The authors used instruments for trade and institutions. The experimental approach is impressive, with authors using many different variables for institutions, geography and trade, making a regression on four different groups, with a lot of effort devoted to sensitivity analysis and robustness checks. The results are astounding: among the three variables of interest, the undisputed lead goes to institutions. They have the most significant positive impact on all mentioned channels: income, capital, human capital and productivity. The effect of trade is also positive but minor, while the influence of geography can be neglected. In comparison to Hall and Jones (1999) work, the authors did not confirm the biggest influence of institutions on TFP.In their research the variable mostly affected was physical capital. However, here is used another econometric approach which seems to be more justified.

The broadest study that provides statistical interference and interactions of institutions, economy and policies was written by the IMF (2003). The novelty in comparison to previous papers was to investigate, not only the impact of institutions on the level of GDP, but also on the economic growth rate and its volatility. The covered sample is similar to that from Hall and Jones (1999) and the method similar to Rodrik et al. (2002). Econometric modelling was made with two stage least squares, the dependent variables were GDP per capita 1995, the average growth rate between 1960-98, and the volatility of growth over the period 1960-98, with the sample covering 88-93 countries. The average aggregate governance measure of the six sub-indices reported in Kaufmann et al. (2002) were used as the institutional quality indicators , with property rights and constraints on executive power also included. The results were interesting, and in particular the results confirmed previous results on the positive impact of institutions on GDP per capita and additionally the authors obtained a positive impact of institutions on growth and a negative impact on the volatility of economic growth.

One of most recent essays was provided by Commander and Nikoloski (2010). Apart from having investigated the relationship between the economy and institutions, the authors put an emphasis on the interaction of business, investment environment, performance of companies and business constraints (institutions). The uniqueness of the paper is to include additional variables of economic performance, like credit/GDP, exports, imports, stock market turnover, size of the shadow economy and many more. The performance of firms was represented by its revenues – data was collected at the firm level for 70 countries. The sample of economic variables covered 159 countries over the period 1960 – 2009, which is the biggest sample among all the aforementioned studies. The quality of political institutions was measured by 10 different indicators, while the constraints on firms were measured by 13 indicators. The econometric methods used were OLS and GMM, and contrary to previously presented papers, the authors used panel data. The results were far from expectations: none of the political institutions mattered, and there were almost no significant relationships between revenues and constraints on firms. The authors argued the lack of significant interaction by the poor measure of institutions and subjective evaluation of indices. However, it cannot be true, because most papers that examined the role of institutions obtained a significant positive relationship. The author of this thesis suggests that it can be caused by an inappropriate econometric approach: the authors used the panel sample but did not take into account country fixed effects. In addition, they also made transformations of institutional quality variables, which is rarely done in the literature. The other possible explanation is the distinction between short-run growth rates in the panel study, applied in Commander and Nikoloski (2010), and the long-run growth rates used in the income studies used in other papers. However, that paper indicates some future directions and suggestions to apply other approaches in investigating variables other than the growth rate or GDP per capita.

Many researchers tried to argue that institutions do not affect an economy directly. However, that was taken very rarely into account in the econometric analyses. That gap was filled by Fatas and Mihov (2011) who proposed a channel for institutions in the form of government policy volatility, which in turn affects the economy directly. Research was made for 93 countries for the period 1960-2007 (it covered a similar sample to that used by Hall and Jones (1999), Rodrik et al. (2002), and IMF 2003, though there is a broader time span till 2007). Having used instrumental variables and the panel approach, they examined the impact of the quality of 4 institutional variables on policy volatility (measured by variation of government share in GDP), and then its impact on economic growth. It turned out that good institutions lower the volatility of policy. When taking into consideration the impact of policy volatility on performance, it turned out that the causality is strong (1% level of significance) and negative, as expected. The results are very robust for many control variables and many types of models. The paper showed that institutions can affect an economy indirectly through intermediate channels which in this case were government policies. Given this the authors confirmed a positive impact of institutions on an economy as has been shown in most papers.

Before a concluding remark will be provided, one should find out which measures of the quality of institutions were used in the abovementioned research. Hall and Jones (1999) used a mixture of two indicators: government anti-diversity policies (GADP) from the International Country Risk Guide and openness to trade (Sachs, Warner 1995), Rodrik et al. (2002) used four different sources (the Fraser Institute, Polity IV, International Country Risk Guide, and Kaufmann et al. 2002), the IMF (2003) used the World Governance Indicators, Commander and Nokoloski (2010) used 3 different databases (the Polity IV, Fraser Institute and Cheibub), while Fatas and Mihov (2011) used the dataset from Henisz (2000). This thesis will use a dataset from the Fraser Institute, which covers the longest time period of all sources.

To sum up, the first seminal paper of Hall and Jones (1999) brought interesting results concerning the positive impact of social infrastructure on economic performance. When one takes into account the composition of GDP, it turns out that the biggest impact was observed through TFP. That inspired other economists who tried to extend these path-breaking papers. Rodrik et al. (2002) included geography and trade and based their research on the IV method. However, they did not confirm the results of Hall and Jones (1999) and they obtained the strongest impact of institutions on physical capital. The IMF (2003) investigated the influence not only of economic performance, but also economic growth and its volatility. Using a similar sample and time span as previous studies they confirmed the results of a positive impact of institutions on economic performance. The attempt of Comander and Nikoloski (2010) to investigate the impact of institutions on entrepreneurships outcomes did not provide satisfactory results: most of the variables seemed to be insignificant. The most recent paper by Fatas and Mihov (2011) tried to show the intermediate impact of institutions in the guise of government policies. That approach yielded satisfactory results and proved that institutions impact the economy not only directly.

2.2.2. Is There A Reverse Causality? How The Institutions Are Shaped?

In the above mentioned literature one can find dozens of cases where one researcher believed institutions are shaped by factor X, and another argued that factor X leads to a change in institutional quality. This kind of two-way causality is seen by Barro (2000), who gave an example of relationships between rule of law, suffrage and economic performance. Society, when it votes, is usually opting for a party which assures the fair and effective redistribution of income, which leads to higher incentives to invest and work (and higher economic growth). On the other hand, democracy and elections are cost-intensive. It means that the richer the country is the higher quality of legal rights (Hall, Jones 1999). The second significant example is technological progress. According to IMF (2005) it leads to across-sector industrialization keeping away those rent-seeking zones (rent-free environment is seen as basis for good institutions). On the contrary Acemoglu and Robinson (2008) stated that institutions shaped technological improvements (through e.g. costs and rent structure can leads to better use of technology). There are many other examples, but it would be pointless to mention all of them.

Undoubtedly, there exists reverse causality between institutions and economic performance. Now one focuses on the other sources that may shape institutions. As the main determinants of institutional quality are mentioned: initial conditions, rent-seeking and the external environment (IMF 2003, 2005). Initial conditions are the framework (in the sense of culture, geography and history) in which a country is operating. One cannot neglect the geographical position of a country (latitude, longitude, climate, access to sea) or its past. For that reason, a legacy of those will be a kind of initial conditions which impose both barriers and opportunities. Together they determine a specific behaviour and activities of players in the market.

The next factor, rent-seeking, is a channel through which distribution of resources in the economy is made. As a result, the degree of access to rent-seeking behaviour will determine the beneficiaries and the “losers” in an economy. What is more, it implies the chance for institutional improvement (rent-extracting firms may not allow the country to build new good institutions).

The last element, the external environment, consists of three aspects: external anchors, external aid and transparency. The external anchors are the arrangements of foreign authorities that provides a motivation to the country to improve the quality of institutions (e.g. introduce a better protection of property rights), simultaneously indicating a benefit from them (e.g. then EU will open for that country). Generally, external anchors must provide the non-financial incentives with the aim of making substantial reforms. This can be extended by the second external determinant, aid. Financial support (in the guise of subsidies, tax exemptions, etc.) is an accurate supplement to the external anchors. However, the impact of monetary impulses does not have to bring the intended effects. The beneficiary of a subsidy may not have the motivation to use it properly which could lead to excessive rent-seeking. For that reason, one needs a third factor: transparency. That provides perfect information to the markets (or at least tries to do so) and imposes a restriction on policy-makers. Furthermore, it facilitates the recognition of rent-seeking behaviour and can counteract its extraction.

As was mentioned before, the problem of the endogeneity of institutions may also be caused by the way it is measured, as suggested by Aron (2000). Firstly, an institutional indicator may present intermittent volatility which corresponds with the current state of economy. Such a situation is observable especially during the economic crisis or simply during slowdowns of an economy. Thus, such factors as: *political instability, terms of trade or climate shocks, policy reversals, or even fiscal austerity programs* (Aron 2000, p. 114) can imply a periodic change in the quality of institutions. Secondly, the measure of institutions is burdened with a bias of the agency that provides such data. For instance, political events or the state of the economy may lead to excessive optimism and therefore to inflated results.

Concisely speaking, institutions have a lot of determinants. Their present arrangement has foundations in history, culture and geographical conditions. That implies an initial ambient state which imposes some barriers and chances. Institutions are shaped mainly by rent-extraction behaviour and external factors, like external anchors, international aid and transparency. However, its only the tip of the iceberg and one can find many other factors that shape institutional quality. The other problem that may create the endogeneity of institutions is simply its measure: one cannot avoid the bias connected with a subjective assessment of that category. For that reason, one should use the initial level of institutions in examining its impact on economic growth.

2.3. International Knowledge Spillovers and Economic Growth

One of the first substantial studies identifying the role of international spillovers upon economic growth was provided by Coe and Helpman (1995). In this paper the authors examined the impact of the domestic and foreign R&D stock on total factor productivity. Using pooled time series with cointegration techniques, they studied 21 OECD countries plus Israel over the period 1971 – 1990. TFP was measured as the difference between output and labour reward (the role of physical capital was neglected). The foreign stock of R&D was derived as the average of the domestic R&D of partner countries weighted by the import share. They obtained a significant relation of both the domestic and foreign R&D stock on TFP. What is more, the impact of domestic R&D is stronger than foreign R&D in the case of large countries. On the contrary, the situation is the reverse in small countries, where the elasticity of TFP with respect to foreign R&D is higher than that for domestic R&D. This can be explained by the fact that more open countries have a higher reliance on foreign R&D stock.

As Coe and Helpman (1995) based their results on a statement that R&D depicts a trade-related pattern, so Keller (1998) performed a robustness check of their results having used a Monte Carlo simulation of trade. Inclusion of artificial trade relations among countries showed that import composition does not matter for international R&D spillovers. It means that weights attributed to partner countries by the import share are not justified. Keller (1995) proved that if one applied the unweighted sum of the foreign R&D stock, there still exists a significant relation between the R&D stock and TFP. The author did not neglect the role of international trade, but emphasised the uncertainty in R&D and TFP data. That paper has very substantial meaning for subsequent research, because it showed that besides examining the importance of trade in R&D spillovers, it is justified to include other trade-unrelated patterns.

Other papers focus only on the R&D spillovers into an economy and differ from the mentioned one in view of the concept used for weights assigned to each country[11]. Those weights are based on the shares of bilateral exports (Funk, 2001), based on the ratio of exports to output (Lichtenberg, van Pottelsberghe de la Potterie, 1998), based on FDI flows (Lichtenberg, van Pottelsberghe de la Potterie, 2001) and many others. The other approach of measuring spillovers is through the distance from neighbours. That was applied in e.g. Bottazzi and Peri (2002). In this thesis will be followed the approach of Keller (1998) of equal weights to all countries. The difference from most of the mentioned papers is that the author will use patents instead of the R&D stock as a proxy for technological change. The same was used in Bottazzi and Peri (2002), where the authors justified that choice by the fact that patents are a decent representation of the technological externalities in R&D. One can also consider R&D the major input to innovation, and patents the major output.

One of the most recent papers which extended the mainstream in examining the role of R&D was written by Coe et al. (2008). In that paper, the main focus was placed on international R&D spillovers. They are measured as a weighted average of R&D stock of all partner countries, having used bilateral import shares as weights. The other aim of the study, which provided the chief value added, was to examine the impact of institutions on TFP. The authors did not base their research on any theoretical model but they used an advanced econometric approach. In their study they use panel cointegration techniques. This approach deals with omitted variables, simultaneity and endogeneity. As a result, there is no need to find valid instruments. The empirical part looks at the impact on TFP of domestic R&D, foreign R&D, R&D from G7, the interaction of import and R&D foreign spillovers (and some variations), human capital and institutional variables. The results are satisfying: the authors obtained positive relationships between TFP and domestic R&D capital, and foreign R&D capital, the ease of doing business, the quality of tertiary education, level of patent protection and legal system based on French or Scandinavian law. Referring to this work is important because it performs a similar analysis to this thesis The author will also investigate the spillover of knowledge (ideas) from neighbouring countries and, above all, the relationships between economic growth and institutions. Moreover, the sample used is broader and contains all countries around the world for which data are available over the period 1970 – 2009.

[11] To see the broad review of R&D spillovers literature, refer to Keller (2004).

To summarize, the seminal paper of Coe and Helpman (1995) opened a new chapter in researching the determinants of economic growth in the guise of knowledge spillovers. The authors used the domestic and foreign R&D stock as factors that explain the difference in TFP among countries. The spillover pattern was based on the import arrangement. Later papers extended the research by using different channels of spillovers like exports, trade, distance and many others. Results showed no independence of the used methodologies. The latest study by Coe et al. (2008) included important for that thesis category – institutions. As it turned out, institutions matter for the returns of R&D to TFP.

2.4. Summary of Chapter

The empirical models that examined the role of institutions differ meaningfully, on the grounds of the explained and explanatory variables, the time span and the methods. Early attempts investigated the role of institutions in shaping GDP per capita. Later papers included the impact on the different components of GDP like physical capital, human capital and technological progress. It turned out that institutions influence physical capital and technological change most. The introduction of new dependent variables like economic growth and its volatility also yielded positive relationships between institutions and economic performance. Authors also incorporated other fundamental (in broader sense) sources of economic growth like geography or culture. The results showed the primacy of institutions over the other sources. The combination of institutions and entrepreneurship did not seem to be the right idea. However, it does not exclude future research. The embodiment of intermediate channels in the guise of government policies showed that institutions could also affect the economy in an indirect way.

Despite the incontestable impact of institutions on economic performance , one cannot forget about reverse causality. Due to the fact that good institutions are a cost-intensive-solution, the current quality is due to monetary outlays. These depend on the wealth of an economy. What is more, institutional quality indicators are subject to high volatility caused by the subjective way of measurement and correlation with current economic performance. For those reasons, one has to be careful in providing profound conclusion or unambiguous recommendations for policy-makers.

The next category studied in this thesis is the relation between knowledge spillovers and economic growth. The pattern of spillovers is perceptible as a function of distance, trade, technology or cultural similarities. Generally, the results of research shows the lack of independence of the used methodologies, and one observes the significant impact of R&D on TFP or economic growth. One of the latest studies by Coe et al. (2008) included important variables for this thesis – namely institutions. As it turned out, institutions matter for the returns of R&D on TFP, as was presented in theoretical prediction discussed in chapter 1.

At this instant, one can make a connection of this thesis into the existing literature. The dissertation will provide research on convergence across economies in terms of growth rates, with the author studying income β-convergence and conditional convergence. The author will split the examined sample into two subsamples: Advanced Economies and Emerging and Developing Markets. The results will show that this division is fully justified but not often met in literature. The study will examine the determinants of economic growth in the guise of institutions and ideas spillovers. For that reason it will be similar to the study offered by Coe et al. (2008) but will take institutions and spillovers into one equation which defines technological change. What is more, the empirical investigation will include the interaction of institutions and ideas, which is one aspect of the value added of the thesis. Taking into considerations the explanations of the New Kaldor Facts (provided by Jones and Romer 2010), the author will also try to examine the impact of population size, human capital and the current level of technology stock on technological change. When regarding the knowledge spillover pattern, the author will follow Keller (1998) of equal weights to all countries. The difference from most of the mentioned papers is that the author will use patents instead of the R&D stock as a proxy for technological change.

Chapter III. The Uzawa-Lucas Model

The aim of this chapter is to derive the growth pattern for an economy. The Uzawa-Lucas (1988) model serves as an example, which allows human capital to be produced as a good. Consequently, the growth rate of an economy depends on the quality of the education sector. The author of this thesis wants to show that technological progress in this model can be seen as an invention of ideas and institutions. Therefore, one obtains motivating equations, which will be used in the econometric investigation.

The chapter starts by presenting the basic framework of the model, that is the assumptions, the form of the production functions and their components. The next section will show the analytical solution based on the maximization problem. In turn will be discussed the growth rates of variables, the steady-state level of variables and the growth rates in steady-state. Then, will be discussed the growth rate in the proximity of state-state and the dynamics of the main variables of interest. All that will lead to the presentation of the growth rate of output, for which the following section is devoted. In the penultimate section, the author will also refer to Jones (1995a, 1995b) in order to derivetechnological progress, which in the basic form of the model is exogenous. The last section will summarize the findings.

3.1. The Basic Framework

One considers the case of a closed economy[12], where output, $Y(t)$, is produced with two types of capital: physical capital, $K(t)$, and human capital, $H(t)$. Consumers maximize their utility with respect to consumption, $C(t)$, which is represented by the utility function that satisfies constant relative risk aversion and constant intertemporal elasticity of substitution:

$$U\big(C(t)\big) = \int_0^{\infty} e^{-(\rho-n)t} \frac{C(t)^{1-\theta}-1}{1-\theta} dt \tag{3.1}$$

where ρ is the rate of time preferences, n is the population growth rate, and θ is the preference parameter. It is assumed that $\rho > 0$, which means that consumers value current consumption higher than future consumption. To bound $U(\cdot)$ for constatnt $C(t)$ over time in equation (3.1) one assumes that $\rho > n$. Also θ is assumed to be greater than 0 and smaller than 1, which implies that the elasticity of marginal utility is negative.

The production function is of the neoclassical type, given by:

$$Y(t) = A(t)\, K(t)^{\alpha} \big(u(t)\, H(t)\big)^{1-\alpha} \tag{3.2}$$

where $A(t)$ is technological change, $u(t)$ is the fraction of human capital used in production, α and $1-\alpha$ are the shares of physical and human capital in output. The production function exhibits constant returns to scale, that is $0 \le \alpha \le 1$.

In the model one has two sectors of the economy, one producing physical goods and one producing human capital. The production function of physical goods is given by:

$$\dot{K}(t) = A(t)\, K(t)^{\alpha} \big(u(t)\, H(t)\big)^{1-\alpha} - C(t) - \delta K(t) \tag{3.3}$$

where δ denotes a depreciation rate of physical capital. For simplicity, it equals the depreciation rate of human capital, which is produced according to the function:

$$\dot{H}(t) = B\big(1-u(t)\big)\, H(t) \; - \delta H(t) \tag{3.4}$$

where B denotes the technological parameter – following the quality of the educational sector – which is assumed to be constant over time.

[12] The presentation in this chapter follows section 5.2.2 in Barro, Sala-i-Martin (1995). The author of the thesis includes additionally population growth, does not neglect technological progress and expresses the model in per worker terms.

3.2. Equilibrium of Model for the Close Economy

For further elucidation, it will be useful to present the model in per worker terms. The assumption of constant returns to scale allows one to derive the formula of output per worker:

$$y(t) = A(t)\, k(t)^{\alpha} \left(u(t)\, h(t)\right)^{1-\alpha} \tag{3.5}$$

where lowercase letters denote the value of variables per worker.

The maximization problem of the economy described at section 3.1 can be depicted by:

$$\max_{C(t)} \int_0^{\infty} e^{-(\rho-n)t} \frac{C(t)^{1-\theta}-1}{1-\theta} dt \tag{3.6}$$

subject to:

$$\dot{k}(t) = A(t)\, k(t)^{\alpha} \left(u(t)\, h(t)\right)^{1-\alpha} - c(t) - (\delta+n)k(t) \tag{3.7}$$

$$\dot{h}(t) = B\big(1-u(t)\big)\, h(t) - (\delta+n)h(t) \tag{3.8}$$

The Hamiltonian expression for this model is:

$$\begin{aligned} H = e^{-(\rho-n)t} \frac{C(t)^{1-\theta}-1}{1-\theta} + \lambda_k \left\{A(t)k(t)^{\alpha}\big(u(t)\, h(t)\big)^{1-\alpha} - c(t) - (\delta+n)k(t)\right\} \\ + \\ +\lambda_h\left\{B\big(1-u(t)\big)\, h(t) - (\delta+n)h(t)\right\} \end{aligned} \tag{3.9}$$

Parameters $c(t)$, $u(t)$ are the control variables; $k(t)$, $h(t)$ are the state variables; λ_k, λ_h are the co-state variables. Parameters λ_k and λ_h represent the marginal shadow price of physical and human capital, respectively.

The first order conditions are given by:

$$\frac{\partial H}{\partial c} = 0 \tag{3.10}$$

$$\frac{\partial H}{\partial u} = 0 \tag{3.11}$$

$$\frac{\partial H}{\partial k} = -\dot{\lambda}_k \tag{3.12}$$

$$\frac{\partial H}{\partial c} = -\dot{\lambda}_h \tag{3.13}$$

The transversality conditions are:

$$\lim_{t\to\infty} \lambda_k k(t) = 0 \tag{3.14}$$

$$\lim_{t\to\infty} \lambda_h h(t) = 0 \tag{3.15}$$

For further calculation it is necessary to derive the expressions for the growth rates of $k(t)$, $h(t)$, and $k(t)/h(t)$; and denote them as γ_k, γ_h, $\gamma_{k/h}$, respectively:

$$\gamma_k = \frac{\dot{k(t)}}{k(t)} = A(t)\, u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} - \frac{c(t)}{k(t)} - (\delta + n) \tag{3.16}$$

$$\gamma_h = \frac{\dot{h(t)}}{h(t)} = B\big(1 - u(t)\big) - (\delta + n) \tag{3.17}$$

$$\gamma_{k/h} = \gamma_k - \gamma_h = A(t)k(t)^{\alpha-1}\big(u(t)\, h(t)\big)^{1-\alpha} - \frac{c(t)}{k(t)} - B\big(1 - u(t)\big) \tag{3.18}$$

The derivations for first order condition are as follows:

$$c(t)^{-\theta} = \lambda_k e^{(\rho-n)t} \tag{3.19}$$

$$\frac{\lambda_k}{\lambda_h} = \frac{B\, h(t)}{(1-\alpha)A(t)k(t)^{\alpha}u(t)^{-\alpha}h(t)^{1-\alpha}} \tag{3.20}$$

$$\frac{\dot{\lambda}_k}{\lambda_k} = -\alpha A(t)u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} + (\delta + n) \tag{3.21}$$

$$\frac{\dot{\lambda}_h}{\lambda_h} = -\frac{\lambda_k}{\lambda_h}(1-\alpha)A(t)u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha} - B\big(1 - u(t)\big) + (\delta + n) \tag{3.22}$$

If one substitutes in equation (3.22) for λ_k/λ_h the value from (3.20), one obtains:

$$\frac{\dot{\lambda}_h}{\lambda_h} = -B(1-u) + (\delta + n) \tag{3.23}$$

Now, one can proceed to the calculations of the growth rates of the main variables of interest. Differentiating equation (3.19) with respect to time, substituting for $\dot{\lambda}_k/\lambda_k$ from equation (3.21), one obtains an equation for the growth rate of consumption per worker:

$$\gamma_c = \frac{\dot{c}(t)}{c(t)} = \frac{1}{\theta}\left(\alpha A(t)u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} - (\delta+\rho)\right) \tag{3.24}$$

To derive the rate of growth for $c(t)/k(t)$, one should subtract equation (3.16) from (3.24):

$$\begin{aligned}\gamma_{c/k} &= \frac{\dot{c}(t)}{c(t)} - \frac{\dot{k}(t)}{k(t)} = \\ &= \frac{\alpha-\theta}{\theta}A(t)u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} + \frac{c(t)}{k(t)} - \frac{1}{\theta}(\delta(1-\theta)+\rho-n\theta)\end{aligned} \tag{3.25}$$

To obtain the rate of growth of $u(t)$ one should differentiate equation (3.20) with respect to time. , One substitutes the results from equations (3.18), (3.21), and (3.22) for $k(t)/h(t)$, λ_k, and λ_h respectively:

$$\gamma_u = \gamma_{k/h} - \frac{1}{\alpha}\left(\gamma_{\lambda_k} - \gamma_{\lambda_h}\right) = B\ \frac{1-\alpha}{\alpha} + B\,u(t) - \frac{c(t)}{k(t)} \tag{3.26}$$

To derive the steady-state values for $k(t)/h(t)$, $c(t)/k(t)$ and $u(t)$, one has to set the equations (3.18), (3.25) and (3.26) to zero. For transparency of results, one shall denote the additional parameter $\psi = \delta(1-\theta)+\rho-n\theta$. Then, the steady-state levels of the variables for this model are given by:

$$u^* = \frac{\psi}{B} - \frac{1-\theta}{\theta} \tag{3.27}$$

$$\left(\frac{c}{k}\right)^* = B\left(\frac{1-\alpha}{\alpha}\right) - B\left(\frac{1-\theta}{\theta}\right) + \psi \tag{3.28}$$

$$\left(\frac{k}{h}\right)^* = \left(\frac{\alpha A(t)}{B}\right)^{1/(1-\alpha)}\left(\frac{\psi}{B} - \frac{1-\theta}{\theta}\right) \tag{3.29}$$

The author defines a new variable, the gross average product of physical capital:

$$z(t) = \frac{y(t)}{k(t)} = A(t)u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} \tag{3.30}$$

The steady-state value for $z(t)$ is derived from equations (3.27) and (3.29):

$$z^* = \frac{B}{\alpha} \tag{3.31}$$

The steady-state growth rate of consumption can be calculated from equation (3.24), where for the first expression in the bracket ($\alpha z(t)$) one shall substitute its steady state value, which is equal to B/α:

$$\gamma_c^* = \frac{1}{\theta}\big((B-\delta)-\rho\big) \tag{3.32}$$

The steady-state growth rate of consumption is the inverse function of the preference parameter, θ. It means that the higher the value of this parameter, the lower the willingness for inter-temporal substitution of consumption over time. In other words, for larger θ, one observes larger decreases in marginal utility in response to higher $c(t)$. Also households are less willing to consent to the deviations of consumption over time. One can recall that $B-\delta$ is equal to $r-\delta$, which is the marginal product of capital. The relationship between effective depreciation and the time preference parameter implies the pattern of consumption over time.

In steady-state the rate of growth of consumption has to be equal to the rate of growth of physical capital, in order to hold constant the ratio $c(t)/k(t)$ in the equation for the growth rate of physical capital (3.16). Therefore, from equation (3.18) one concludes that the growth ratios of physical and human capital have to be equal each other. One assumes also that in the steady-state the growth rate for $u(t)$ is equal to zero. As a result, one obtains:

$$\gamma_c^* = \gamma_k^* = \gamma_h^* = \frac{1}{\theta}\big(B-(\delta+\rho)\big) \tag{3.33}$$

To calculate the steady-state growth rate of output per worker, one decomposes the function from equation (3.5) into growth rates:

$$\gamma_y^* = \gamma_A^* + \alpha\gamma_k^* + (1-\alpha)\{\gamma_u^* + \gamma_h^*\} \tag{3.34}$$

Recall that technology is constant over time, so after simplification, one gets:

$$\gamma_y^* = \gamma_A^* + \gamma_c^* = \frac{1}{\theta}\big(B-(\delta+\rho)\big) \tag{3.35}$$

The growth rate of output per worker in the steady-state is the function of two components: the rate of growth of technology and consumption in the steady-state.

Now one can discuss the behaviour of the economy in the proximity of the steady-state.

To derive the growth rates of variables $c(t)$, $k(t)/h(t)$, $c(t)/k(t)$, $u(t)$ in the proximity of the steady-state, one shall use equations (3.24), (3.18), (3.25), and (3.26).

$$\gamma_c = \frac{\alpha}{\theta}(z(t) - z^*) \tag{3.36}$$

$$\gamma_{k/h} = (z(t) - z^*) - \left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right) + B(u(t) - u^*) \tag{3.37}$$

$$\gamma_{c/k} = \left(\frac{\alpha - \theta}{\theta}\right)(z(t) - z^*) + \left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right) \tag{3.38}$$

$$\gamma_u = B(u(t) - u^*) - \left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right) \tag{3.39}$$

Recall that $z(t)$ (eq. 3.30) is a function of $k(t)/h(t)$ raised to a negative power. Then from equation (3.36), one can easily notice that the growth rate of consumption is inversely related to the ratio $k(t)/h(t)$. It means that the country which is initially rich in human capital relative to physical capital has $(k(t)^*/h(t)^* > k(t)/h(t))$, which implies that $z(t) > z^*$. As a result, the growth rate of consumption will be an increasing function of imbalances between $k(t)$ and $h(t)$. On the contrary, when a country is abundant in physical capital, the growth rate of consumption tends to decline.

Substituting the calculated values of γ_u, $\gamma_{k/h}$ from (3.39), (3.37), into (3.30) one obtains:

$$\gamma_z = -(1 - \alpha)(z(t) - z^*) \tag{3.40}$$

As a result one can obtain the equations of motion for $c(t)/k(t)$ and $u(t)$ from equations (3.38) and (3.49). The dynamics of those factors can be depicted by:

$$\frac{c(t)}{k(t)} = \frac{c^*}{k^*} + \left(\frac{\theta - \alpha}{\theta}\right)(z(t) - z^*) \tag{3.41}$$

$$u(t) = u^* + \frac{1}{B}\left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right) \tag{3.42}$$

The dynamics of $k(t)/(h(t)$ cannot be derived in the same way as equations (3.41), (3.42). One shall use the equation of motion for γ_c, where one substitutes for $z(t)$ from (3.30), for z^* from (3.31) and for $u(t)$ from (3.42):

$$\frac{k(t)}{h(t)} = \left(\frac{\alpha A(t)}{B}\right)^{1/(1-\alpha)} \left(u^* + \frac{1}{B}\left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right)\right) \tag{3.43}$$

The dynamics of all those variables depends on the expression $(\theta - \alpha)$ from equation (3.41), which in turn implies $u(t)$ and $k(t)/(h(t)$. Worth emphasising is the fact that the dynamics of the economy depend on both technology parameters (A(t), B). It would be meaningless to discuss both cases and focus on the dynamics of those factors, so the author proceeds to a presentation of the growth pattern.

Having calculated the steady-state values and growth rates of variables, one can proceed to determine the growth rate of the economy. The value of the growth rate *of* $k(t)$ can be derived as the difference between the growth rates of $c(t)$ and $c(t)/k(t)$ (equations 3.36, 3.38):

$$\gamma_k = \frac{1}{\theta}[B - \delta - \rho] + (z(t) - z^*) - \left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right) \tag{3.44}$$

The value of the growth rate of $h(t)$ can be derived as the difference between the growth rates of $k(t)$ and $k(t)/h(t)$ (equations 3.44, 3.37):

$$\mathrm{\gamma_h} = \frac{1}{\mathrm{\theta}}[\mathrm{B} - \mathrm{\delta} - \mathrm{\rho}] - \mathrm{B}(\mathrm{u(t)} - \mathrm{u}^*) \tag{3.45}$$

If one looks at equation (3.34) in terms of steady-state proximity instead of the steady-state itself, one can calculate the growth rate of $y(t)$. One substitutes in equation (3.34) for the growth rates of $k(t)$, $u(t)$, $h(t)$ from equations (3.44), (3.39) and (3.45), then one gets:

$$\gamma_y = \frac{\dot{A}(t)}{A(t)} + \alpha(z(t) - z^*) - \left(\frac{c(t)}{k(t)} - \frac{c^*}{k^*}\right) + \frac{1}{\theta}[B - \delta - \rho] \tag{3.46}$$

If one splits the volatile and constant variables, then one gets:

$$\gamma_y = \left\{\frac{\dot{A}(t)}{A(t)} + \alpha z(t) - \frac{c(t)}{k(t)}\right\} + \left\{-\alpha z^* + \frac{c^*}{k^*} + \frac{1}{\theta}[B - \delta - \rho]\right\} \tag{3.47}$$

Substituting in equation (3.44) for $z(t)$, z^*, c/k^* from equations (3.30), (3.31), (3.28), one gets:

$$\begin{aligned}\gamma_y = &\left\{\frac{\dot{A}(t)}{A(t)} + \alpha A(t) u(t)^{1-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} - \frac{c(t)}{k(t)}\right\} \\ &+ \left\{B\left(\frac{1-\alpha}{\alpha}\right) - \frac{\rho + \delta - \theta\big(\delta + \rho - \theta(n+\delta)\big)}{\theta}\right\}\end{aligned} \tag{3.48}$$

The derivatives with respect to the particular variables:

$$\frac{\partial \gamma_y}{\partial A(t)} = -\frac{\dot{A}(t)}{A(t)^2} + \alpha u(t)^{-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} \tag{3.49}$$

$$\frac{\partial \gamma_y}{\partial k(t)} = \frac{c(t)}{k(t)^2} - \alpha(1-\alpha)A(t)k(t)^{\alpha-2}\big(u(t)h(t)\big)^{1-\alpha} \tag{3.50}$$

$$\frac{\partial \gamma_y}{\partial h(t)} = \alpha(1-\alpha)A(t)k(t)^{\alpha-1}u(t)^{1-\alpha}h(t)^{-\alpha} \tag{3.51}$$

$$\frac{\partial \gamma_y}{\partial u(t)} = \alpha(1-\alpha)A(t)u(t)^{-\alpha}\left(\frac{k(t)}{h(t)}\right)^{\alpha-1} \tag{3.52}$$

$$\frac{\partial \gamma_y}{\partial B} = \left(\frac{1-\alpha}{\alpha}\right) > 0 \tag{3.53}$$

$$\frac{\partial \gamma_y}{\partial n} = -\theta < 0 \tag{3.54}$$

$$\frac{\partial \gamma_y}{\partial \delta} = -\frac{1-(1-\theta)\theta}{\theta} \tag{3.55}$$

$$\frac{\partial \gamma_y}{\partial \rho} = -\frac{1-\theta}{\theta} < 0 \tag{3.56}$$

$$\frac{\partial \gamma_y}{\partial \theta} = n + \frac{\delta - \theta^2 + \rho}{\theta^2} \tag{3.57}$$

From the above equation (3.48) and the first-order derivatives (equations 3.49 – 3.57), one can conclude that the growth rate of output per worker depends positively on the level of human capital, the fraction of human capital used in producing output, and the technology parameter B, and negatively upon the time discounting parameter and population growth.

The effects of technological progress, depreciation, physical capital and the parameter for preferences θ, are ambiguous.

From equation (3.48), one can depict the average rate of growth of output per capita over the interval 0 – T:

$$\frac{\log y_{i,T} - \log y_{i,0}}{T} = \frac{\dot{A}(t)}{A(t)} - \left(\frac{1 - e^{-\beta T}}{T}\right)\log y_{i,0} + \left(\frac{1 - e^{-\beta T}}{T}\right)\log y_i^* + u_{i,0-T} \qquad (3.58)$$

where i is a subscript of country, $u_{i,0-T}$ represents the error term between dates 0 and T, β is the convergence coeffiecient. The covergence ratio for the Uzawa-Lucas model is equal to $(1 - \alpha)[c(t)/k(t) + \delta + n]$.

3.3. Modification in Open Economy

Now one shall ask where institutions play a role. The author will modify the technological change variable, $(A^{\cdot}(t))/(A(t))$, understood as the invented ideas. Jones (1995b) proposed a version of a technological change function depicted by:

$$\dot{A}(t) = \varphi H_A(t)^{\nu} A(t)^{\mu} \qquad (3.59)$$

where $H_A(t) = \sum_{i=1}^{M} h_i(t)^{\eta} L_{A,i}(t)$. In the above equations $A(t)$ denotes a stock of ideas in period t; $H_A(t)$ is an effective world research effort; i is a country subscript; $L_{A,i}(t)$ is the number of researchers in economy i in period t; $h_i(t)$ is a weight that adjusts for human capital. The disadvantage of that equation is to look from the perspective of whole world – A here is understood as a cumulative stock of ideas, which is the same for all countries. This approach seems to be too unrealistic and one should modify that equation.

The author suggests to modify the equation (3.59) in the following way:

i. allows the parameter φ to differ across countries,
ii. restrict the world into bordered countries. The author splits the $A(t)$ form eq. (3.5) into two components: $A_N(t)$ – stock of ideas produced by country i's neighbours; $A_i(t)$ – stock of country i's own ideas,
iii. the inventor and imitator's potential depends only on the country i quality of human capital, $h_i(t)$, and the number of researchers in the economy $L_i(t)$.

As a result, one obtains:

$$\dot{A}(t) = \varphi_i[h_i(t)L_i(t)]^{\nu} A_N(t)^{\mu} A(t)^{1-\nu} \tag{3.60}$$

In equation (3.60), one can easily interpret the parameter φ as an institutional environment. As was mentioned in chapter 1, institutions can be incorporated into the growth pattern through technological progress, which is shown in that equation. What is more, technological progress depends on the quality of the education sector (parameter h), and the stock of the labour force (factor L) and the stock of foreign patents (factor A_N) Therefore, the author obtained two equations (3.48) and (3.60), which will be used for the econometric investigation presented in next chapter.

3.4. Summary of Chapter

The Uzawa-Lucas model provided a picture of an economy with two sectors: consumables and education. What is more, this model allows human capital to be produced (without physical capital), and not to be a result of savings. Consequently, the steady-state level of consumption, physical capital, human capital and output depend heavily on the parameter B, which follows the quality of the education sector. It was also shown that the steady-state level of the average product of physical capital, z, is equal B/α.

The dynamics of the model are far complicated, and depend on the expression $(\theta - \alpha)$. Undoubtedly, the consumption rate is inversely related to imbalances between $\mathrm{k(t)}$ and $\mathrm{h(t)}$. For a country abundant in physical capital, the rate of consumption is declining with the increasing imbalances. On the contrary when a country is well endowed with human capital the consumption growth rate is increasing. Similarly to the steady-state dependence, the dynamics of all inputs also depend on the technology parameters, $\mathrm{A(t)}$ and B.

If one takes into consideration the growth rate of output per worker, one obtains a positive influence of human capital, the fraction of human capital used in producing output andthe technology parameter B. A negative effects of popultion growth, depreciation and the time discounting parameter are also found. What was not expected is the ambiguous impact of technological progress, $\mathrm{A(t)}$. Also ambiguous relationships hold for physical capital and parameter of preferences, θ.

Finally, the model provided two equations which will serve as the foundation for the econometric investigation. In turn, the author showed that the average rate of output per capita growth is a negative function of the initial level of output per worker and depends also on technological progress and the level of output steady-state which can be interpreted as a constant. When the author modified the Jones (1995b) approach for the representation of technological progress, one obtains a dependence of technological progress on institutional quality, the quality of the education sector, the stock of the labour force and the stock of bordered patents.

Chapter IV. Empirical investigation

The aim of this chapter is to examine the quantitative role of ideas and institutions on economic growth of countries. As an econometric method the thesis uses 3SLS. The alternative is the Arellano, Bond GMM estimator. The first method is much simpler to implement, it allows regressing two or more simultaneous equations, the inclusion of time and country specific effects and there is no need to contain the instruments in regressions. The second method is more justified to be used in economic growth regressions; however the author decided not to follow that procedure. This is due to the fact that one cannot include two simultaneous equations, and one had to search for many instruments. The advantages of the GMM method are allowing for the endogeneity of the explanatory variables, time-invariant country specific effect and inclusion of lagged values of explained variable. Furthermore, the Arellano-Bond estimator is suggested to be used in the case of small-T large-N panels, where one has to deal with a correlation of the error term and country fixed effects.

The chapter starts with a short introduction, in which the author recalls the main hypotheses tested by the thesis and explains the analytical form of the model. Also discussed will be the expected relationships between the explanatory and explained variables. The next section will provide a data description and summary statistics, focussing on highlihting the most extreme cases. Afterwards, one proceeds to report preliminary results which are based on extreme cases, correlation coefficients and finally results from a Granger causality test. After those, one can discuss the results of the econometric estimation of the basic model specification. Then the author will extend the model with two additional variables (interaction of institutions and patents stock; and GDP per capita), for which is devoted the next section. The following part will present an answer to the question of which institutions matter the most in shaping ideas. The last part will be devoted to a presentation of the results of sensitivity analysis, where the author examines the impact of country and time specific effects, outliers, fluctuations of GDP per capita, educational attainment, a change in the patent variable, and the inclusion of depreciation of patents. A final section will conclude the chapter.

4.1. Introduction into Analysis

Before presenting the equations used in the regression analysis, it is worth recalling the hypotheses of this thesis:

- Hypothesis 1: *institutions, through technological progress, impact positively upon economic growth*;
- Hypothesis 2: *technological spillovers influence positively the technological progress of neighbouring countries and in turn their economic growth*.

These two hypotheses will be verified with the use of two simultaneous equation models for panel data. The sample will cover 95 countries over the period 1970 – 2009. The first equation will explain economic growth in terms of initial GDP per capita, the rate of investment, population growth, years of schooling attained (as a proxy for human capital), and changes in the patent stock (proxy for technological change). The second equation will examine technological progress understood as the change in the patent stock in terms of institutional quality, population size, years of schooling attained and the stock of patents in border countries (as a proxy for ideas spillovers).

The analytical form of the equation was derived for the first equation from equations (3.48) and (3.58), and for the second equation from (3.60)[13]. As a result the author will examine the following set of equations:

$$\begin{cases} growth_{i,t} = \beta_0 + \beta_1 gdp\_pc_{i,t-1} + \beta_3 \overline{inv}_{i,t} + \beta_4 \bar{n}_{i,t} + \beta_5 educ_{i,t-1} + \beta_6 \Delta ideas_{i,t} + \varepsilon_{i,t} + u_i & (4.1) \\ \Delta ideas_{i,t} = \varphi_0 + \varphi_1 institutions_{i,t-1} + \beta_3 pop_{i,t-1} + \beta_4 educ_{i,t-1} + \beta_5 bor\_cum\_pat_{i,t-1} + \eta_{i,t} + \lambda_i & (4.2) \end{cases}$$

where the author has adopted the following notations: ***growth*** – growth rate of economy, ***gdp_pc*** – GDP per capita, ***inv*** – investment rate, ***n*** – population growth, ***educ*** – years of schooling attained, ***ideas*** – the stock of patents (proxy for technological change), ***institutions*** – a measure of institutional quality, ***pop*** – size of the population, ***bor_cum_pat*** –

[13] Due to the lack of data the skipped variables are: share of human capital used to produce output, depreciation, parameters for time preference and consumption smoothness preferences.

stock of patents of bordering countries, $\boldsymbol{i}$ - subscript of country, $\boldsymbol{t}$ – subscript of time, $\boldsymbol{\varepsilon}$, $\boldsymbol{\eta}$ – idiosyncratic errors, $\boldsymbol{u}$, $\boldsymbol{\lambda}$ – individual effects.

It is expected that in the first equation the coefficient for initial GDP per capita will have a negative sign, consistent with the hypothesis of conditional convergence (the country with a higher level of GDP per capita should have a lower rate of economic growth). The investment rate should bring the positive sign – the more investment in an economy, the higher the stock of capital, and in turn higher output. Population growth is a variable that should impact upon growth negatively, consistent with the common theory – higher population growth implies the higher needs for physical capital substitution. The influence of education quality (measured as years spent on schooling) should show a positive relationship with growth: the better educated a society is, the higher the probability of effective use of other resources in economy. The coefficient on the technological change (ideas) variable should be positive – more ideas in a country leads to a higher stock of efficient high quality technologies, and therefore higher economic growth.

The second equation, which is simultaneously the determinant of economic growth will be explained by institutions, which should have a positive influence. Institutions, through lower costs, the promotion of effective activities and supporting the appropriate micro- and macro-environment will leads to the better use of human capital and therefore a faster process of ideas creation. As was mentioned in section 1.2.3 ideas are created by humans, which demands high skills and competencies. Therefore, the better educated a society is, the more ideas should be created. What is more, this creation will be more intensive if more people are devoted to invention, which implies that the coefficient on population size should be positive. Finally, the creation of ideas is much easier when a country has broad access to existing ideas, including ideas created abroad. This implies that the neighbouring countries stock would matter positively for the creation of ideas. Simultanoeusly, it would prove the existence of positive international knowledge spillovers.

4.2. Data Sources, Terminology and Summary Statistics

Economic growth – variable ***growth*** – is an annualized average growth rate of GDP per capita in 5-year periods[14] from the formula $\sqrt[5]{y_t/y_{t-5}}-1$, where y_t denotes GDP per capita at 2005 constant prices – variable ***gdp_pc***. As a source was used PWT 7.0 and the original name for the variable is ***rgpl***. The rate of growth was observed in the interval -21.4% to 13.9%. The lowest value belongs to Congo, which has a highly volatile growth rate. If one tries to overcome annual fluctuations, the author suggests using instead of GDP per capita in a particular year, the average from +/- 2 years around each year – variable ***gdp_pc2***. Then it turned out the lowest observed growth rate is -12.7% and the highest is 10.4%.

The observed GDP per capita has a mean equal 11,487.53 USD. The minimum is 117.59 USD for the Democratic Republic of Congo in 2000 and the maximum is found for Luxembourg in 2009 and is 84,571.54 USD. The smoothed data show that these two countries have a GDP per capita of 179.89 and 86,252.42 USD, respectively. However, the lowest value is observed in Zimbabwe in 2009 year and equals 144.98 USD.

Population growth – variable ***n*** – is a real change in population size[15], measured as the annual growth rates of population size averaged over 5-year periods, based on the population size – variable ***pop***. The source for these data was also PWT 7.0. The descriptive statistics reveals that the lowest population growth rate is -4.38% for Rwanda in 1995 and the highest 9.21% for the same country 5 years later. There are only 6 observation with a population growth rate lower than -1% and 7 countries with a rate higher than 5%. The standard deviation equals 1.24%. When one looks at population size, it turns out that the smallest countries are Iceland (204,104 people in 1970) and Bahrain (218,031 people in 1975). On the opposite end of the scale are India and China with 1,156,898,000 and 1,323,592,000 people in 2010, respectively.

The rate of investment – variable ***inv*** – is the investment share in real GDP at 2005 constant prices. Data were taken from the PWT 7.0 and derived from the variable ***ki***. Here, the author again took 5-year averages. The lowest and at the same time the only negative rate is observed for Sierra Leone in 2005 and equals -2.25%. The highest share of investment

[14] Technical note: the last period for computed growth rate of economy cover only 4 years instead of 5-years.
[15] Natural growth of population corrected by migration balance.

can be observed in Malawi in 2008 and equals 74.64%. The countries with investment shares exceeding 50% of GDP are Algeria, Jordan, Singapore, Tunisia, Malawi, and Ghana. The lowest values that do not exceed 5% are observed for Haiti, Uganda and Rwanda.

The education variable – variable ***educ***– depicts the average years of schooling attained for the population aged 25 and over. The author used data from the Barro and Lee (2011) database of Educational Attainment for Population Aged 25 and Over. The original name of the variable is ***yr_sch***, which was calculated as the product of the fraction of people that attained primary, secondary and tertiary education times the duration of each level. In the sensitivity analyses the variables ***yr_sch_sec*** and ***lsc*** will also be used. The first additional variable, ***yr_sch_sec,*** focuses on the people who attained secondary education and the variable ***lsc*** shows the fraction of the population who finished secondary education. An analysis of the data reveal that there are 15 observations with average years attained below 1 (for Nepal, Morocco, Sierra Leone, Burundi, Rwanda, DRC, Algeria, Haiti), where for most of these pertain to the years 1970 and 1975 (and one observation for 1980 – Nepal). An average of 10 years or more spent on education is observed among 95 observations, where the 5 countries with the highest levels are the United States, the Czech Republic, Norway, Canada, and Germany. When one focuses on secondary education as the highest level attained, then the worst 9 countries are Uganda, Burundi, Tanzania, Rwanda, the DRC, Zambia, Malawi, Nepal and Morocco (values of ***yr_sch_sec*** below 1). The top of the list is made up of 6 countries: Germany, the United States, Norway, Austria, Australia and Estonia, with average years of secondary schooling attained above 5. Interesting results are revealed when one pays attention to the fraction of people who finished secondary education – there are 11 countries with a fraction of population who finished secondary school below 1% and at the top are partially different countries from the group with the highest average years of schooling generally and at secondary level. Those top 5 countries are Czech Republic, Slovenia, Germany, Lithuania and Hungary (all above 50% of indicator ***lsc***).

The most crucial variable – ***institutions*** – is measured by the Economic Freedom of the World (EFW) indicator, provided by the Fraser Institute (2011). This indicator assesses 5 areas: the Size of Government (Expenditures, Taxes, and Enterprises); the Legal Structure and Security of Property Rights; Access to Sound Money; the Freedom to Trade Internationally; and the Regulation of Credit, Labour, and Business. In each area there are a few components and sub-components, that together give a measure based on 42 different indicators, scaled from 0 to 10. The author used the chain-linked index with 2000 as the base year. The lowest value of the indicator was observed for 4 observations (Nicaragua for 1985 and 1990, Uganda for 1990, and the DRC for 1980 – the value of EFW is below 3). The undisputed lead go to two countries known as the Asian Tigers (Hong Kong, Singapore), where Hong Kong is the only country which obtained a rate above 9. Besides those two countries there are 7 others for which the quality of institutions was assessed above 8: New Zealand, Switzerland, Ireland, the United States, the Netherlands, Canada and the United Kingdom.

The last factor – ***ideas*** – is derived from the World Bank (2012) as patent applications from residents and non-residents. The author of the thesis sums up both values and made the cumulative sum over time. In the basic version, the patent stock was calculated with an assumption that there is no depreciation rate. In the sensitivity analysis this will be extended to allow for a depreciation rate of 5% and 15%. Additionally, the author formulated the variable ***bor_cum_pat*** which depicts the cumulative sum of patents of border countries, which will indicate the effect of spillovers. The lowest cumulative sum of patents in 2010 are observed for Nepal, the DRC, Rwanda, Burundi, and Fiji (not exceed 250 patents). On the other hand are Japan, United States, Germany, South Korea, China, United Kingdom, Canada, and France, where the sum exceeds 1 million. In the case of Japan, it is 12,270 million patents in 2010[16]. Countries with the lowest cumulative sum of border country's patents are the Dominican Republic, Burundi, Haiti, and Kenya (lower than 3,000). On the top of the list are Mexico, Canada, Switzerland, Belgium Luxembourg and France (where the bordered cumulative stock of patents exceed 4 million patents for each country). The analysis of patents on borders can be misleading because island countries like Australia do not have any neighbours, so the value of this sum equals zero.

[16] It is well known that Japan tends to give patents to relatively minor inventions. This has led some to suggest that the value of a Japanese patent is around ¼ of an American one. For this reason, the number of Japanese patents is often divided by four.

4.3 Preliminary relationships

The presented descriptive statistics in the previous section, lead one to think about the pattern and relationships in the data. The author calculated the annualized changes in GDP per capita, the stock of patents, border patents and institutional quality over the period 1970–2009. Then were chosen the most extreme cases, which are reported in tables 11 – 13 (Appendix 1). Table 11 shows the 10 extreme countries (5-worst and 5-best performing) with regard to the largest and smallest changes in institutional quality. Table 12 shows the data with regards to changes in GDP per capita (in other words, economic growth). Table 13 shows the countries with regards to changes in the patent stock. The presented results lead to the conclusion that one cannot find any pattern and relations based on the most extreme cases. The only noticeable fact is the probable correlation of the change in the patent stock and the border patent stock. However, that is only a conjecture, and for that reason, one should look at the pair-wise correlations, which are presented in table 14 (Appendix 1).

The results from table 14 are consistent with the earlier presented theories and the conceptual framework. Particularly the growth rate of an economy is correlated positively with economic freedom, investment, education and negatively with population growth. The positive correlation of growth and GDP per capita is not counterfactual with the hypothesis about conditional convergence, because the correlation coefficient shows the relations of current growth and current GDP per capita, not the initial one. The cumulative stock of patents does not appear to be correlated with economic growth however. When one looks at the stock of patents they are correlated positively with education, population size (negatively with its growth), GDP per capita and Economic Freedom (especially Area 2). This component of EFW depicts the Legal Structure and Property Rights, which as was mentioned in section 1.2.3 helps the aim of institutions in creating ideas. Worth emphasising is the fact that one observes a negative correlation of Economic Freedom Area 1, which depicts Government Size, with a few variables. It seems that government policy is positively related to GDP per capita, education and border patents. That would imply that government interventions could sometimes bring positive results.

After presenting the correlation, it is justified to assess causality in the Granger sense, which is summarized in the appendix in table 15. The results of the test[17] show that most of the explanatory variables cause in the Granger sense growth or the patent stock or at least that the relationships from those variables towards growth and patents is stronger than the other way round. In turn, GDP per capita influences growth but with reverse causality, where the first relationship is stronger than the second. Also the connection between population growth and growth is reversible, where the stronger influence from population growth upon growth is noticed among Advanced Economies and Emerging and Developing Economies. In the case for the whole World however, the relationship is reversed. Investment is counterfactual to expectations – the test showed that the impact from investment to economic growth is stronger than the reverse case. In that case one can talk of the simultaneity of growth and investment. Schooling quality presents the strongest causality toward economic growth, especially for the Emerging and Developing Economies. The opposite relation is fully neglected. Similar causality is observed between growth and the patent stock, where the second determines the first factor. A stronger relationship is perceived among Advanced Economies. When one looks at the interactions of patents stock and the other variables, it seems that institutions are not the cause in a Granger sense for patents when taking for whole World. However, there exists reverse causality between those factors among Emerging and Developing Economies, where the influence from patents towards institutions is stronger than the opposite case. The patent stock seems to be affected by population size only in the group of Emerging and Developing Economies. For Advanced Economies and the whole World the relationship is not significant but stronger for the causality from population size to the patent stock. The relationship between the patent stock and bordered patents is completely reversible and one cannot indicate which direction is the stronger one.

[17] The author performed a Granger test "by hand". The procedure was as follows: make a regression using panel fixed estimator of economic growth/patents stock on every explanatory variable with 4 lags (t-5, t-10, t-15, t-20). In the model was also included the 4 lags of the explained variables (economic growth/patents stock). In the second step the author did the reverse regression (explanatory variables on the economic growth/patents stock with analogical right hand side variables). The p-values for the Granger causality test were obtained from the joint significance test of all lags of the explanatory variables in the growth/patent stock equations and of all lags of growth/patents stock in the equations from the second step.

4.4. Results of Basic Model Estimation

In all models consideration will be given to three samples: the whole World (85 countries), Emerging and Developing Economies (57) and Advanced Economies (28). From the original sample which covered respectively 95, 62 and 33 countries were excluded those which have less than 1 million people in 1970. The results of the main regression specification are reported in table 1 (models 1 – 3).

Undoubtedly, one observes convergence among countries. What's more, convergence is stronger among Emerging and Developing Economies (convergence rate equals 2.85%) than among Advanced Economies (convergence rate equals 2.38%). That is consistent with theoretical prediction that less developed economies grow faster towards the steady-state. The rest of the results depend upon the sample: evidently among Emerging and Developing Economies population growth matters, in a countrefactual way. One obtains a negative sign, inconsistent with theoretical predictions. Nevertheless, this coefficient ban be explained by the fact that lesser developed countries depend on the raw labour force more than highly developed one. Investment is positively related to growth in the World sample, as well as among Emerging and Developing Economies. Inconsistent with theory I obtain a negative sign on investment among Advanced Economies. Also among Advanced Economies there was observed another unpredicted relationship, namely the negative sign on the stock of patents in the growth regression. Educational attainment seems not to be related to economic growth.

When one looks at the patent stock equation it turns out that institutions matter in the case of Emerging and Developing Economies as well Advanced Economies. However, among the first group of countries the relationship is positive, while in the second it is negative. In the whole sample, one does not observe a significant impact of institutions. As in the growth regressions, population size also matters. Educational attainment has no significant impact on ideas. The border stock of patents – variables expressing the international knowledge spillovers – has a negative sign in the World sample and is statistically insignificant in the two other samples.

The observed differences among the 3 samples can be explained by the predominant conviction that economic growth models are better fitted to an explanation of growth patterns among Emerging and Developing Economies rather than in the whole World or in Advanced

Economies only. The author’s results confirm that and show that it is essentially justified to split the sample into subsamples based on the different features of the economies. The results of the main regressions can also be caused by omitted variables, which will be solved in the next part devoted to an extension of the model.

4.5. Extensions of Model

The main specification was extended by adding into patents stock equation an interaction between institutions and the patent stock and an additional variable GDP per capita. The author expects that the role of institutions diminish with a higher stock of patents. This expectation comes from two facts: (i) countries with high quality institutions cannot do much to improve them, and (ii) the countries with the highest stock of patents are more productive anyway, so they do not need any institutional improvements. GDP per capita was included, because it is expected that ideas (understood as patents) require investment outlays which are cost-intensive. For that reason, one expects a positive relationship between GDP per capita and the patent stock. The results of that extension are reported in table 2. In the left-hand side part of the table are presented results when including the interaction variable only. In the right-hand side part are results when including both variables (the interaction and GDP per capita).

The additional variable – the interaction of institutions and the patents stock – has a negative statistically significant sign. It means that as the level of the patent stock increases the effect of institutions diminishes. That influence is stronger for Advanced Economies than for Emerging and Developing Countries, which is consistent with the explanation provided in the previous paragraph. What is more, the inclusion of the interaction brings a significant positive relation betwen institutions and the patent stock. Additionally, one gets a positive impact of bordered patents on the patent stock. Also, the relationship between education and the patent stock which did not hold in the basic model specification, is significant and positive here. On the contrary to the first regression, population size matters only among Advanced Economies, and not among Emerging and Developing Countries.

Table 1. Regressions results of the main model specification with the country and time specific effects

	Countries with more than 1 mln people						All the countries					
	World		***Advanced Economies***		***Emerging and Developing Economies***		***World***		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*
model no.	1		2		3		4		5		6	
GDP per capita	-0.051***		-0.048***		-0.056***		-0.049***		-0.037***		-0.056***	
	(0.005)		(0.008)		(0.006)		(0.005)		(0.008)		(0.006)	
Population growth rate	0.124		-0.015		0.333**		0.133		0.059		0.333**	
	(0.126)		(0.277)		(0.149)		(0.126)		(0.288)		(0.149)	
Investment	0.085***		-0.056*		0.077***		0.087***		-0.037		0.077***	
	(0.018)		(0.032)		(0.021)		(0.018)		(0.034)		(0.021)	
Educational attainment	0.000	*0.022*	-0.000	*0.010*	-0.003	*0.032*	0.000	*0.021*	-0.001	*0.013*	-0.003	*0.032*
	(0.002)	*(0.016)*	(0.001)	*(0.022)*	(0.004)	*(0.023)*	(0.002)	*(0.016)*	(0.001)	*(0.021)*	(0.004)	*(0.023)*
Ideas	0.031		-0.048**		0.136**		0.027		-0.031*		0.136**	
	(0.041)		(0.019)		(0.058)		(0.040)		(0.018)		(0.058)	
Institutions		*0.016*		*-0.114****		*0.045****		*0.010*		*-0.100****		*0.045****
		(0.013)		*(0.031)*		*(0.010)*		*(0.013)*		*(0.030)*		*(0.010)*
Population size		*0.001****		*0.001*		*0.001****		*0.001****		*0.002*		*0.001****
		(0.000)		*(0.002)*		*(0.000)*		*(0.000)*		*(0.002)*		*(0.000)*
Bordered patents stock		*-0.038**		*0.005*		*-0.030*		*-0.042**		*0.014*		*-0.030*
		(0.022)		*(0.031)*		*(0.027)*		*(0.022)*		*(0.032)*		*(0.027)*
Constant	0.385***	*0.699****	0.540***	*1.073***	0.386***	*0.510***	0.373***	*0.758****	0.423***	*0.836**	0.386***	*0.510***
	(0.046)	*(0.212)*	(0.085)	*(0.489)*	(0.062)	*(0.241)*	(0.045)	*(0.210)*	(0.085)	*(0.498)*	(0.062)	*(0.241)*
Number of observations	511		177		334		519		185		334	
R2	0.5024	0.6338	0.6038	0.6821	-0.0360	0.6314	0.5089	0.6374	0.6333	0.6880	-0.0360	0.6314
aic	*-2,778.612*		*-1,189.987*		*-1,764.810*		*-2,824.858*		*-1,222.916*		*-1,764.810*	
bic	*-2,037.248*		*-958.128*		*-1,288.417*		*-2,072.271*		*-981.389*		*-1,288.417*	
chi	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Source: own calculations.

Table 2. Regressions results of extended model by interactions of institutions and patents, and additionally - GDP per capita

	*additional interaction institutions*stock of patents*						*additionally gdp pc in patents equation*					
	World		***Advanced Economies***		***Emerging and Developing Economies***		***World***		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*
model no.	25		26		27		28		29		30	
GDP per capita	-0.054***		-0.049***		-0.054***		-0.051***	*0.169****	-0.045***	*0.449****	-0.051***	*0.237****
	(0.005)		(0.007)		(0.006)		(0.005)	*(0.042)*	(0.008)	*(0.108)*	(0.006)	*(0.052)*
Population growth rate	0.123		0.025		0.282*		0.128		0.047		0.276*	
	(0.122)		(0.256)		(0.146)		(0.121)		(0.255)		(0.145)	
Investment	0.092***		-0.046		0.110***		0.092***		-0.043		0.110***	
	(0.017)		(0.029)		(0.021)		(0.017)		(0.029)		(0.021)	
Educational attainment	0.001	*0.052****	-0.000	*0.042***	0.002	*0.070****	0.001	*0.053****	-0.000	*0.032**	0.002	*0.072****
	(0.002)	*(0.013)*	(0.001)	*(0.017)*	(0.003)	*(0.018)*	(0.002)	*(0.013)*	(0.001)	*(0.017)*	(0.003)	*(0.017)*
Ideas	-0.013*		-0.027***		-0.006		-0.012*		-0.026***		-0.004	
	(0.007)		(0.006)		(0.009)		(0.007)		(0.006)		(0.009)	
Institutions		*0.064****		*0.052**		*0.075****		*0.056****		*0.040*		*0.061****
		(0.012)		*(0.029)*		*(0.013)*		*(0.012)*		*(0.028)*		*(0.013)*
Institutions x Ideas		*-0.359****		*-0.479****		*-0.341****		*-0.375****		*-0.539****		*-0.368****
		(0.020)		*(0.044)*		*(0.023)*		*(0.021)*		*(0.045)*		*(0.023)*
Population size		*-0.000*		*0.007****		*0.000*		*-0.000*		*0.007****		*0.000*
		(0.000)		*(0.002)*		*(0.000)*		*(0.000)*		*(0.001)*		*(0.000)*
Bordered patents stock		*0.211****		*0.376****		*0.165****		*0.186****		*0.361****		*0.117****
		(0.023)		*(0.043)*		*(0.028)*		*(0.023)*		*(0.041)*		*(0.029)*
Constant	0.427***	*1.683****	0.532***	*0.988***	0.416***	*1.820****	0.407***	*0.702***	0.500***	*-2.251****	0.397***	*0.575**
	(0.038)	*(0.173)*	(0.075)	*(0.406)*	(0.048)	*(0.215)*	(0.038)	*(0.300)*	(0.076)	*(0.868)*	(0.048)	*(0.344)*
Number of observations	511		177		334		511		177		334	
R2	0.5359	0.7735	0.6839	0.8103	0.5735	0.7858	0.5373	0.7789	0.686	0.8266	0.5748	0.7964
aic	*-3,018.681*		*-1,276.605*		*-1,905.387*		*-3,032.804*		*-1,291.391*		*-1,924.137*	
bic	*-2,273.080*		*-1,041.570*		*-1,425.184*		*-2,282.966*		*-1,053.180*		*-1,440.122*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: own calculations.

Table 3. Regressions results of sensitivity analysis subject to particular Areas of Freedom (Area 1 and 2)

	EFW 1						***EFW 2***					
	World		***Advanced Economies***		***Emerging and Developing Economies***		***World***		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*
model no.	46		47		48		49		50		51	
GDP per capita	-0.044***		-0.044***		-0.045***		-0.047***		-0.044***		-0.045***	
	(0.006)		(0.011)		(0.007)		(0.005)		(0.009)		(0.006)	
Population growth rate	0.085		-0.162		0.261*		-0.088		-0.014		0.176	
	(0.132)		(0.327)		(0.151)		(0.157)		(0.307)		(0.192)	
Investment	0.080***		-0.051		0.095***		0.083***		-0.045		0.102***	
	(0.019)		(0.044)		(0.021)		(0.019)		(0.037)		(0.024)	
Educational attainment	-0.001	*0.019*	-0.001	*0.017*	-0.001	*0.028*	-0.000	*0.013*	-0.001	*0.015*	0.000	*0.022*
	(0.003)	*(0.017)*	(0.002)	*(0.023)*	(0.004)	*(0.023)*	(0.002)	*(0.016)*	(0.001)	*(0.023)*	(0.003)	*(0.022)*
Ideas	0.145***		0.057*		0.144***		0.102**		-0.004		0.087**	
	(0.055)		(0.031)		(0.053)		(0.049)		(0.028)		(0.034)	
Institutions		*0.015****		*0.039****		*0.021****		*0.014***		*-0.014*		*0.027****
		(0.005)		*(0.014)*		*(0.007)*		*(0.006)*		*(0.016)*		*(0.009)*
Population size		*0.001****		*0.001*		*0.001****		*0.001****		*0.003*		*0.001****
		(0.000)		*(0.002)*		*(0.000)*		*(0.000)*		*(0.002)*		*(0.000)*
Bordered patents stock		*-0.018*		*-0.005*		*-0.039*		*-0.020*		*0.011*		*-0.061***
		(0.021)		*(0.026)*		*(0.029)*		*(0.019)*		*(0.034)*		*(0.027)*
Constant	0.268***	*0.621****	0.461***	*0.234*	0.268***	*0.772****	0.320***	*0.667****	0.479***	*0.307*	0.293***	*0.988****
	(0.038)	*(0.185)*	(0.118)	*(0.397)*	(0.048)	*(0.248)*	(0.051)	*(0.169)*	(0.098)	*(0.504)*	(0.055)	*(0.229)*
Number of observations	536		175		361		495		175		320	
R2	-0.5385	0.6112	0.0938	0.6611	-0.2537	0.6063	0.1077	0.6514	0.6674	0.6644	0.3831	0.6695
aic	*-2,859.080*		*-1,170.651*		*-1,844.776*		*-2,730.573*		*-1,158.525*		*-1,700.856*	
bic	*-2,109.356*				*-1,358.666*		*-1,994.776*		*-927.495*		*-1,229.816*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Note: Area 1 - Size of Government, Area 2 - Legal Structure and Security of Property Rights, Area 3 - Access to Sound Money, Area 4 - Freedom to Trade Internationally, Area 5 - Regulation of Credit, Labour, and Business.
Source: own calculations.

Table 4. Regressions results of sensitivity analysis subject to particular Areas of Freedom (Area 3 and 4)

	EFW 3						*EFW 4*					
	World		***Advanced Economies***		***Emerging and Developing Economies***		***World***		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*
model no.	52		53		54		55		56		57	
GDP per capita	-0.044***		-0.048***		-0.046***		-0.047***		-0.044***		-0.049***	
	(0.004)		(0.008)		(0.006)		(0.005)		(0.009)		(0.006)	
Population growth rate	0.102		-0.025		0.297**		-0.108		-0.025		0.217	
	(0.126)		(0.264)		(0.149)		(0.243)		(0.292)		(0.266)	
Investment	0.097***		-0.051*		0.106***		0.091***		-0.044		0.112***	
	(0.017)		(0.030)		(0.020)		(0.019)		(0.035)		(0.020)	
Educational attainment	0.002	*0.021*	-0.000	*0.016*	0.000	*0.031*	-0.000	*0.016*	-0.000	*0.012*	0.001	*0.026*
	(0.002)	*(0.016)*	(0.001)	*(0.021)*	(0.003)	*(0.022)*	(0.002)	*(0.016)*	(0.001)	*(0.023)*	(0.003)	*(0.022)*
Ideas	-0.011		-0.037***		0.080**		0.105*		-0.046*		0.096**	
	(0.030)		(0.013)		(0.040)		(0.058)		(0.024)		(0.045)	
Institutions		*-0.008*		*-0.055****		*0.009**		*0.022****		*-0.056***		*0.019***
		(0.005)		*(0.012)*		*(0.005)*		*(0.007)*		*(0.024)*		*(0.008)*
Population size		*0.001**		*0.001*		*0.001****		*0.001***		*0.002*		*0.001****
		(0.000)		*(0.002)*		*(0.000)*		*(0.000)*		*(0.002)*		*(0.000)*
Bordered patents stock		*-0.039**		*0.005*		*-0.060***		*-0.027*		*0.002*		*-0.065***
		(0.024)		*(0.031)*		*(0.031)*		*(0.021)*		*(0.032)*		*(0.029)*
Constant	0.352***	*0.926****	0.529***	*0.726*	0.308***	*0.988****	0.326***	*0.608****	0.497***	*0.702*	0.339***	*0.917****
	(0.036)	*(0.210)*	(0.079)	*(0.461)*	(0.047)	*(0.267)*	(0.057)	*(0.189)*	(0.093)	*(0.499)*	(0.057)	*(0.248)*
Number of observations	543		177		366		512		177		335	
R2	0.5053	0.6165	0.659	0.7011	0.3219	0.6067	0.0176	0.629	0.6168	0.6685	0.2697	0.6344
aic	*-2,864.429*		*-1,198.300*		*-1,852.571*		*-2,792.091*		*-1,180.917*		*-1,748.958*	
bic	*-2,112.435*		*-966.441*		*-1,364.741*		*-2,058.861*		*-949.058*		*-1,279.820*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Note: Area 1 - Size of Government, Area 2 - Legal Structure and Security of Property Rights, Area 3 - Access to Sound Money, Area 4 - Freedom to Trade Internationally, Area 5 - Regulation of Credit, Labour, and Business.
Source: own calculations.

Table 5. Regressions results of sensitivity analysis subject to particular Areas of Freedom (Area 5)

	EFW 5					
	World		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*
model no.	58		59		60	
GDP per capita	-0.056***		-0.044***		-0.057***	
	(0.005)		(0.008)		(0.007)	
Population growth rate	0.163		-0.014		0.414***	
	(0.121)		(0.276)		(0.144)	
Investment	0.108***		-0.046		0.120***	
	(0.017)		(0.032)		(0.021)	
Educational attainment	0.001	*0.033***	-0.000	*0.013*	-0.002	*0.059***
	(0.002)	*(0.016)*	(0.001)	*(0.022)*	(0.004)	*(0.023)*
Ideas	-0.001		-0.025		0.079**	
	(0.029)		(0.018)		(0.040)	
Institutions		*-0.034***		*-0.098****		*0.021*
		(0.016)		*(0.035)*		*(0.015)*
Population size		*0.001***		*0.003*		*0.001****
		(0.000)		*(0.002)*		*(0.000)*
Bordered patents stock		*-0.053***		*-0.006*		*-0.078****
		(0.023)		*(0.034)*		*(0.028)*
Constant	0.434***	*0.978****	0.492***	*1.006**	0.400***	*0.988****
	(0.047)	*(0.214)*	(0.085)	*(0.558)*	(0.063)	*(0.253)*
Number of observations	495		177		318	
R2	0.5757	0.6438	0.6871	0.679	0.4007	0.6425
aic	*-2,746.718*		*-1,183.405*		*-1,713.115*	
bic	*-2,010.920*		*-951.546*		*-1,242.858*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Note: Area 1 - Size of Government, Area 2 - Legal Structure and Security of Property Rights, Area 3 - Access to Sound Money, Area 4 - Freedom to Trade Internationally, Area 5 - Regulation of Credit, Labour, and Business.
Source: own calculations.

4.6. Which Institutions Matter the Most?

Within the framework of the experiment, the author examined the role of different institutional areas and tried to address which institutional freedom matters the most in the invention of ideas. Results of that test are reported in tables 3, 4 and 5. Recall that in the basic model specification institutions (covering 5 areas) have a positive impact on Emerging and Developing Economies, a negative effect on Advanced Economies and no significant impact for the World. Now, one looks at each area of institutions separately:

Area 1. Size of Government
Area 2. Legal Structure and Security of Property Rights
Area 3. Access to Sound Money
Area 4. Freedom to Trade Internationally
Area 5. Regulation of Credit, Labour, and Business.

It turns out that the Size of Government Freedom has a significant impact at the 1% level among all examined samples (World, Advanced Economies, Emerging and Developing Economies). Legal Structure and Security of Property Rights is related to ideas mostly among Emerging and Developing Economies, less significantly in the World and has no impact on Advanced Economies. The third freedom, Access to Sound Money, has a positive influence in Emerging and Developing Economies, and a negative impact in Advanced Economies. Freedom to Trade has a similar impact, though it influences also the World positively. Regulation on Credit, Labour and Business has a negative impact on the World and Advanced Economies and no impact on Emerging and Developing Countries. Shortly, in most cases the relation of particular areas of Freedom has a negative impact on Advanced Economies (only the Size of Government is positively related). In the case of Emerging and Developing Economies all freedoms except the last (Regulation on Credit, Labour and Business) has a positive impact on ideas.

4.7. Sensitivity Analysis

This section will present results from sensitivity analysis (see Appendix 1: tables 6-10) with respect to country and time specific effects, outliers, fluctuations of GDP per capita, educational attainment, a change in the patent variable and including a depreciation rate for patents.

In the main model specification country and time specific effects were included (fixed effects, see table 1). When one compares these with the model without those effects (Appendix 1: table 6), it turns out that the lack of country and time specific effect leads to a lack of convergence in the examined samples. What is more, one gets a change in the impact of population growth, with it found to have an effect in the World and Advanced Economies only. One observes a significant effect of the patent stock in the growth equation in all samples and the significance of education in the growth equation (World, Emerging and Developing Economies). These results show that one observes high heterogeneity of countries and it is important to include fixed effects in order to have the appropriate form of the model. The lack of convergence can be explained by the fact that the model without country specific effects does not cover the unobserved characteristics of the steady-state of an economy, which is crucial in examining conditional convergence.

Typically in growth regression one excludes very small countries (with less than 1 million populations). One explains this by the fact that these countries (which are usually island countries or small enclaves) have economy dynamics that cannot be explained by the model (Qatar and its monoculture economy). Mankiw et al (1992) further argue that countries with less than 1 million inhabitants are biased with a higher probability of wrong data measurement. When the author followed this rule, it is justified to examine the impact of these countries on the results. The model with all countries no matter of size of population (Table 1, models 4-6) does not differ from the model without these countries (Table 1, models 1-3). The inclusion of all countries does not impact on the quantitative results of the model. It means that those countries have a minor impact on the regression results. However, exclusion of them does not improve the quality of model in the sense of AIC / BIC criterion which was not expected.

In the main model specification, the growth rate of an economy was calculated on the basis of smoothed GDP per capita (through the use of a moving average procedure).

A question that arises is what happen if GDP per capita growth is derived by using initial and end period values of per capita GDP only. The second approach is widely used in economic growth regression and here the author showed (Appendix 1: table 7) that the results do not differ. In particular, one obtains the same signs on the coefficients, the same significance levels and similar coefficient values.

In much research, authors obtained no significant relation between economic growth and educational attainment. It was argued that this may be due to the lack of adequate variables as proxies for human capital. Here, the authors uses two alternative variables (the average years of secondary schooling attained for population aged 25 and over – ***yr_sch_sec*** and the fraction of the population who finished secondary education – ***lsc***) instead of that used in the main specification (the average years of schooling attained for population in aged 25 and over). In the main specification (Table 1, models 1 – 3) one did not observe any significant relationship, in both regression equations. When one changes the variable which depicts the educational attainment to average years of secondary schooling, it turns out that it is negatively related to economic growth and ideas production among Advanced Economies. And still there is no impact on the World and Emerging and Developing Economies. If one used the share of population who finished secondary education, one gets a positive relation to patents stock in the case of Emerging and Developing Economies. In the rest of the samples and equations, there are no observed significant relations.

The next proposed change by the author is to use the patent flow (Appendix 1: table 9) instead of the stock (Table 1). Since in the main model, the author used the change in the stock in the regression model, one considers the impact of new patents on economic growth (because of an assumption of a zero percent depreciation rate). When, one changes the stock of patents into new patents, the change in that variable would capture the additional number of patents a country as in comparison to the previous period. Inclusion of this variable in the model does not generate different results.

The last issue considered is to relax the assumption of a zero percent depreciation rate. The inclusion of a deprecation rate (Appendix 1: table 10), leads to a significant coefficient on the patent stock in the growth regression for the World. It also impacts on the significance of the patent stock among Emerging and Developing Economies, making it more influential. While in the main model, patents have a negative impact on growth in Advanced Economies, this impact diminishes when depreciation is allowed for. What is more, the negative impact of bordered patents in the patent stock equation among all countries disappears.

4.8. Summary of Chapter

The main hypotheses of this thesis were examined using a simultaneous equation model and 3SLS. The author considered 95 countries over the period 1970–2009. The first hypothesis concerning the positive impact of institutions on economic growth was confirmed only for Emerging and Developing Economies. The relationship in Advanced Economies is negative, while for the World there is no significant coefficient. The second hypothesis emphasised the importance of knowledge spillovers and was not confirmed, with the coefficient being negative even among Advanced Economies. Besides the main hypotheses, the model tested several other issues. Undoubtedly, one observes conditional convergence among countries, where evidently Emerging and Developing Economies grew faster than Advanced Economies, which is consistent with a convergence phenomenon. The author obtained the positive impact of both the population grow rate and population size on performance for Emerging and Developing Markets. The first relationship is not consistent with theoretical predictions and is not confirmed in other papers. However, it can be partially justified by the fact that poorer countries depend more on the raw labour force. Besides, it seems that patents (a proxy for technological change) are not best suited to the explanation of the growth pattern – a positive and significant sign is obtained only for Emerging and Developing Economies. Investment matters also in the case of Emerging and Developing Economies. There is no significant impact of education (both on economic growth and technological progress).

The main model extended by new variables (an interaction of institutions and patents stock; GDP per capita) brought more satisfactory results. Inclusion in the model of both variables seem to be a reasonable idea. Here one obtained a significant impact of institutions on all 3 samples which diminishes with a higher stock of patents (negative sign on the interaction). What is more, in those models, one observes international spillovers of knowledge in all 3 samples, which confirms the second main hypothesis of this thesis. Additionally, it turned out that educational attainment is positively related to patents creation. The sign of GDP per capita (variables showing the cost-intensive character of innovation) is positive and significant in all 3 samples.

The assessment of the significance of particular freedoms showed that the Size of Government Freedom is mostly positively related to ideas creation (significant in all

3 samples). Besides that the Legal Structure and Security of Property Rights (for Emerging and Developing Economies, World), Freedom to Trade (for Emerging and Developing Economies, World). Regulations of Credit, Labour and Business Market seemed to have either a negative impact (on World, Advanced Economies) or no significant relationship (Emerging and Developing Economies). In the case of Advanced Economies unexpected coefficients were found on Access to Sound Money, and Freedom to Trade.

Sensitivity analysis showed that most of the results do not depend on the variables included. In particular, the removal of potential outliers, unsmoothed GDP per capita, and the use of the volume of new patents instead of stocks do not affect the results. Partially, the results are sensitive to the educational attainment variable, where the share of population who finished secondary level is the most significant. Undoubtedly, the lack of country and time specific effects has a negative impact on the results and leads to the bias. Also the incorporation of depreciation rate seems to be rational and should be applied in further research.

Conclusions

The aim of this thesis was to examine the relationship between institutions, international knowledge spillovers and economic growth. The author raised two hypotheses: the first concerned the positive impact of institutions upon economic growth and the second the positive impact of knowledge spillovers on technological progress of neighbouring countries. A model was estimated by 3SLS for two simultaneous equations. The examined sample of 95 countries (World) over the period 1970-2009 was split into two subsamples: Advanced Economies and Emerging and Developing Markets.

The first hypothesis was confirmed only for Emerging and Developing Economies in the basic model. However, in the extended model (when including the interaction of institutions and the patent stock, and the variable GDP per capita) it was valid in all three samples. The second hypothesis was fully rejected in the main model specification. Nevertheless, in the extended model the relationship between technological spillover and technological progress did hold. This showed that the extended model seems to be justified and better suited to an explanation of growth patterns. The author obtained a negative sign on the interaction, which implies a diminishing effect of institutions with a higher patent stock. GDP per capita is highly significant in all samples.

Besides investigating the main hypotheses, the author considered other issues and variables. It turned out that in the examined samples one observes conditional convergence. This phenomenon is stronger among Emerging Developing Economies than Advanced Economies, where the convergence coefficients equal 2.85% and 2.38%, respectively. One unsatisfactory result concerns the lack of an impact of the patent stock (or its negative sign) on economic growth. Only in basic model, did one observe the positive sign for Emerging and Developing Economies.

Additionally, in the case of the World sample the significant variables were investment in the growth equation and population size in the patent equation. Bordered patents have a negative sign, which is inconsistent with expectations. In the extended model one finds in thepatent stock equation that there are significant impacts of educational attainment and technological spillovers. Among Advanced Economies one obtained results inconsistent with expectations, most notably the negative impact of investment on economic growth, and the negative impact of institutions on the patent stock. In the extended model, the negative sign on investment disappeared, and the impact of institutions is positive. Furthermore, one observed a significant impact of population size and technological spillovers. In the basic model for Emerging and Developing Economies, one observed a positive impact of population growth and investment on economic growth. In the extended model, one also found a positive impact of educational attainment and technological spillovers on the patent stock.

Despite the limited possibilities of model quality assessment and the lack of impact of the used measure of technological progress, the author tries to bring some direction for policy makers. Undoubtedly, institutions matter in shaping a good environment for ideas inventions. Of particular importance is the Legal Structure and Security of Property Rights. That means, the mentioned conceptual framework of institutions supporting markets, inventors and imitators is valid and should be taken seriously by people in power. What is more, it turned out that two other freedoms matter – Size of Government and Freedom to Trade – which are both in the scope of the authorities. Those results suggested that good quality institutions support the effective rules of game and lead to efficient utilization of human capital in creating ideas.

The quantitative investigation showed that it is justified to split the sample into subsamples, and the best fitting model is for Emerging and Developing Economies. That is consistent with the general belief that economic growth models are better suited to an explanation of growth patterns for poor and emerging markets. Results showed the weak impact of technological progress on economic growth. That can be caused by the used measure (patent stock change) and should bring caution with conclusions. Surely, the extended model partially filled the gap in the existing literature and pointed out future directions for research – it is reasonable to examine the scope of the impact of variables in the guise of diminishing/increasing returns. Also, the impact of population growth is the issue to which researchers should pay more attention. In that model one obtained the unpredicted positive sign. However, a broader look at the result allows one to conclude that poor countries rely more on the raw labour force, and that in these circumstances the relationship would be supported.

Concisely speaking, for future work it is recommended to pay attention to the used proxy for technological change and to include the depreciation of patents if it is one of the used variables. Surely, researchers should stress the role of the marginal impact of variables. It is also important to re-examine the role of population size. Still one should search for the particular recipe for policy makers and try to answer which institutions matters, maybe in the guise of a particular solution rather than using the aggregate measures of institutional quality. It is also appreciated to use other econometric approaches like GMM estimators.

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AIC	–	Akaike Information Criterion
BIC	–	Bayes Information Criterion
CIA	–	Central Intelligence Agency
DRC	–	Democratic Republic of Congo
EFW	–	Economic Freedom of the World
GDP	–	Gross Domestic Product
IMF	–	International Monetary Fund
MRW	–	Mankiw-Romer-Weil
NGT’s	–	New Growth Theories
PWT	–	Penn World Table
R&D	–	Research and Development
SLS	–	Stage Least Squares
TFP	–	Total Factor Productivity
WDI	–	World Development Indicators
WGI	–	Worldwide Governance Indicators

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Abstract

This master's dissertation concerns the issue of economic growth with particular attention to institutions and technological spillovers. The impact of those variables upon economic growth is investigated through the intermediate channel of technological progress. The empirical model is estimated using 3SLS on a sample covering 95 countries over the period 1970-2009, which are further divided into two sub-samples: Advanced Economies and Emerging and Developing Economies.

Zusammenfassung

Die Arbeit greift die Thematik des Wirtschaftsaufschwunges mit der besonderen Aufmerksamkeit auf Institutionen und technologische Außeneffekte auf. Der Einfluss der beiden Variablen ist durch den indirekten Kanal des technologischen Fortschrites untersucht. Die empirische 3SLS Verifikation fasst die Gruppe von 95 Länder in dem Zeitraum von 1970 bis 2009 um.

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Appendix with Tables

Table 6. Regressions results of the main model specification WITHOUT the country and time specific effects

	Countries with more than 1 mln people						**All the countries**					
	World		***Advanced Economies***		***Emerging and Developing Economies***		***World***		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*
model no.	7		8		9		10		11		12	
GDP per capita	-0.002		-0.008		-0.002		-0.002		-0.005		-0.002	
	(0.001)		(0.011)		(0.002)		(0.001)		(0.010)		(0.002)	
Population growth rate	-0.383***		-0.491***		-0.220		-0.368***		-0.353**		-0.220	
	(0.112)		(0.177)		(0.157)		(0.112)		(0.178)		(0.157)	
Investment	0.050***		0.031		0.039*		0.051***		0.053		0.039*	
	(0.019)		(0.039)		(0.020)		(0.019)		(0.040)		(0.020)	
Educational attainment	0.001**	*-0.003*	0.001	*-0.009*	0.003***	*-0.010*	0.001**	*-0.003*	0.001	*-0.006*	0.003***	*-0.010*
	(0.001)	*(0.006)*	(0.001)	*(0.009)*	(0.001)	*(0.007)*	(0.001)	*(0.006)*	(0.001)	*(0.009)*	(0.001)	*(0.007)*
Ideas	0.050***		0.081***		0.065***		0.046***		0.055**		0.065***	
	(0.017)		(0.025)		(0.022)		(0.016)		(0.025)		(0.022)	
Institutions		*0.025** *		*0.028*		*0.033** *		*0.023** *		*0.020*		*0.033** *
		(0.011)		*(0.019)*		*(0.014)*		*(0.011)*		*(0.019)*		*(0.014)*
Population size		*0.0005*** *		*-0.000*		*0.0005*** *		*0.0005*** *		*-0.000*		*0.0005*** *
		(0.000)		*(0.000)*		*(0.000)*		*(0.000)*		*(0.000)*		*(0.000)*
Bordered patents stock		*-0.015** *		*-0.044*** *		*-0.000*		*-0.016*** *		*-0.053*** *		*-0.000*
		(0.006)		*(0.010)*		*(0.007)*		*(0.006)*		*(0.010)*		*(0.007)*
Constant	0.011	*0.253*** *	0.071	*0.710*** *	-0.002	*0.078*	0.008	*0.268*** *	0.046	*0.849*** *	-0.002	*0.078*
	(0.010)	*(0.074)*	(0.101)	*(0.160)*	(0.014)	*(0.098)*	(0.010)	*(0.073)*	(0.092)	*(0.165)*	(0.014)	*(0.098)*
Number of observations	511		177		334		519		185		334	
R2	0.047	0.061	-0.915	0.141	-0.036	0.081	0.064	0.064	-0.235	0.160	-0.036	0.081
aic	*-2,318.623*		*-1,000.720*		*-1,432.084*		*-2,358.245*		*-1,028.780*		*-1,432.084*	
bic	*-2,272.023*		*-965.783*		*-1,390.162*		*-2,311.474*		*-993.356*		*-1,390.162*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: own calculations.

Table 7. Regressions results of sensitivity analysis: instead of 5-year average GDP per capita, there are used annualized data

	World		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*
model no.	13		14		15	
GDP per capita	-0.062***		-0.060***		-0.068***	
	(0.005)		(0.009)		(0.007)	
Population growth rate	0.025		0.156		0.193	
	(0.143)		(0.313)		(0.170)	
Investment	0.090***		-0.055		0.085***	
	(0.020)		(0.037)		(0.024)	
Educational attainment	0.000	*0.023*	0.001	*0.010*	-0.003	*0.033*
	(0.002)	*(0.016)*	(0.002)	*(0.022)*	(0.004)	*(0.023)*
Ideas	0.029		-0.051**		0.123**	
	(0.045)		(0.021)		(0.057)	
Institutions		*0.006*		*-0.113****		*0.040****
		(0.013)		*(0.031)*		*(0.012)*
Population size		*0.001****		*0.001*		*0.001****
		(0.000)		*(0.002)*		*(0.000)*
Bordered patents stock		*-0.039**		*0.001*		*-0.032*
		(0.023)		*(0.031)*		*(0.028)*
Constant	0.474***	*0.751****	0.646***	*1.112***	0.489***	*0.550***
	(0.049)	*(0.213)*	(0.091)	*(0.491)*	(0.063)	*(0.250)*
Number of observations	511		177		334	
R2	0.4858	0.6357	0.5832	0.6822	0.1388	0.6325
aic	*-2,642.077*		*-1,137.579*		*-1,664.053*	
bic	*-1,900.712*		*-905.720*		*-1,187.661*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: own calculations.

Table 8. Regressions results of sensitivity analysis subject to educational attainment indicator

	lsc **as an educational attainment variable**						***yr_sch_sec*** **as an educational attainment variable**					
	World		***Advanced Economies***		***Emerging and Developing Economies***		***World***		***Advanced Economies***		***Emerging and Developing Economies***	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*	growth	*patents*
model no.	16		17		18		19		20		21	
GDP per capita	-0.051***		-0.052***		-0.058***		-0.052***		-0.050***		-0.055***	
	(0.005)		(0.008)		(0.007)		(0.005)		(0.008)		(0.007)	
Population growth rate	0.129		0.025		0.339**		0.143		0.007		0.331**	
	(0.125)		(0.288)		(0.144)		(0.124)		(0.276)		(0.150)	
Investment	0.083***		-0.066*		0.075***		0.073***		-0.061*		0.079***	
	(0.018)		(0.035)		(0.022)		(0.018)		(0.033)		(0.021)	
Educational attainment	0.032	*-0.220*	-0.041*	*-0.511***	0.051	*-0.021*	-0.004	*0.036**	-0.002	*-0.010*	-0.008	*0.105***
	(0.023)	*(0.190)*	(0.021)	*(0.259)*	(0.052)	*(0.284)*	(0.003)	*(0.022)*	(0.002)	*(0.027)*	(0.008)	*(0.041)*
Ideas	0.041		-0.059***		0.153**		0.066		-0.050***		0.121**	
	(0.045)		(0.022)		(0.063)		(0.048)		(0.019)		(0.048)	
Institutions		*0.025**		*-0.113****		*0.045****		*0.038****		*-0.114****		*0.044****
		(0.013)		*(0.031)*		*(0.010)*		*(0.011)*		*(0.031)*		*(0.011)*
Population size		*0.001****		*0.000*		*0.001****		*0.001****		*0.001*		*0.001****
		(0.000)		*(0.002)*		*(0.000)*		*(0.000)*		*(0.002)*		*(0.000)*
Bordered patents stock		*-0.033*		*-0.003*		*-0.025*		*-0.025*		*0.006*		*-0.045*
		(0.022)		*(0.029)*		*(0.027)*		*(0.021)*		*(0.031)*		*(0.028)*
Constant	0.383***	*0.680****	0.591***	*1.369****	0.381***	*0.536***	0.381***	*0.531****	0.561***	*1.140***	0.383***	*0.632****
	(0.048)	*(0.211)*	(0.093)	*(0.480)*	(0.065)	*(0.236)*	(0.053)	*(0.201)*	(0.086)	*(0.498)*	(0.064)	*(0.245)*
Number of observations	510		177		333		511		177		334	
R2	0.470	0.631	0.543	0.688	-0.211	0.629	0.347	0.628	0.597	0.682	0.105	0.638
aic	*-2,775.040*		*-1,196.246*		*-1,759.860*		*-2,793.631*		*-1,191.855*		*-1,767.239*	
bic	*-2,034.018*		*-964.387*		*-1,283.843*		*-2,052.266*		*-959.996*		*-1,290.846*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*

Source: own calculations.

Table 9. Regressions results of sensitivity analysis: instead of stock of patents, use the volume of new patents

	World		*Advanced Economies*		*Emerging and Developing Economies*	
dependent variable	growth	*patents*	growth	*patents*	growth	*patents*
model no.	22		23		24	
GDP per capita	-0.060***		-0.061***		-0.075***	
	(0.012)		(0.013)		(0.012)	
Population growth rate	-0.211		0.164		0.371	
	(0.293)		(0.553)		(0.507)	
Investment	0.042		-0.006		0.020	
	(0.031)		(0.051)		(0.033)	
Educational attainment	-0.003	*0.076*	-0.002	*-0.043*	-0.029***	*0.381****
	(0.003)	*(0.058)*	(0.002)	*(0.072)*	(0.010)	*(0.108)*
Ideas	0.032		-0.046**		0.079***	
	(0.023)		(0.021)		(0.023)	
Institutions		*0.154****		*-0.160**		*0.144****
		(0.043)		*(0.083)*		*(0.046)*
Population size		*0.003***		*0.001*		*0.002*
		(0.002)		*(0.004)*		*(0.001)*
Bordered patents stock		*-0.067**		*-0.028*		*-0.066**
		(0.039)		*(0.082)*		*(0.036)*
Constant	0.495***	*-0.213*	0.630***	*1.524*	0.672***	*-0.864***
	(0.092)	*(0.440)*	(0.123)	*(0.997)*	(0.097)	*(0.433)*
Number of observations	344		163		181	
R2	0.2841	0.2807	-1.2266	0.2692	-0.2376	0.3905
aic	*-1,186.567*		*-718.703*		*-591.580*	
bic	*-545.180*		*-492.859*		*-217.356*	
chi	*0.0000*	*0.0000*	*0.0000*	*0.001*	*0.0000*	*0.0000*

Source: own calculations.

Table 10. Regressions results of sensitivity analysis: include a depreciation of the patents stock at 5% and 15%

	depreciation = 0.05						depreciation = 0.15					
	World		Advanced Economies		Emerging and Developing Economies		World		Advanced Economies		Emerging and Developing Economies	
dependent variable	growth	patents	growth	patents	growth	patents	growth	patents	growth	patents	growth	patents
model no.	37		38		39		43		44		45	
GDP per capita	-0.060***		-0.045***		-0.062***		-0.063***		-0.045***		-0.065***	
	(0.005)		(0.008)		(0.007)		(0.007)		(0.008)		(0.007)	
Population growth rate	0.217*		-0.028		0.334**		0.237*		0.018		0.345**	
	(0.123)		(0.274)		(0.141)		(0.141)		(0.306)		(0.137)	
Investment	0.055***		-0.049		0.070***		0.048**		-0.046		0.067***	
	(0.018)		(0.031)		(0.021)		(0.021)		(0.031)		(0.024)	
Educational attainment	-0.004	0.033	-0.000	0.024	-0.006	0.046	-0.008	0.054	0.000	0.034	-0.009	0.079
	(0.004)	(0.021)	(0.001)	(0.027)	(0.006)	(0.030)	(0.007)	(0.035)	(0.001)	(0.041)	(0.007)	(0.053)
Ideas	0.142**		-0.029**		0.158***		0.166**		-0.020*		0.126***	
	(0.060)		(0.013)		(0.054)		(0.082)		(0.011)		(0.043)	
Institutions		0.059***		-0.124***		0.057***		0.064***		-0.158***		0.081***
		(0.009)		(0.039)		(0.013)		(0.013)		(0.058)		(0.028)
Population size		0.001**		0.003		0.001**		0.001		0.003		0.001**
		(0.000)		(0.002)		(0.000)		(0.001)		(0.003)		(0.001)
Bordered patents stock		0.007		0.034		-0.005		0.010		0.030		0.006
		(0.015)		(0.034)		(0.022)		(0.009)		(0.041)		(0.016)
Constant	0.433***	0.009	0.489***	0.519	0.447***	0.092	0.491***	-0.231	0.488***	0.532	0.517***	-0.321
	(0.046)	(0.161)	(0.079)	(0.554)	(0.056)	(0.201)	(0.055)	(0.194)	(0.082)	(0.724)	(0.059)	(0.250)
Number of observations	511		177		334		511		177		334	
R2	-0.984	0.5582	0.6598	0.6306	-0.8752	0.5596	-5.4841	0.4023	0.6427	0.4534	-2.3167	0.4197
aic	-2,574.846		-1,111.539		-1,593.517		-2,047.275		-967.548		-1,215.172	
bic	-1,833.481		-879.680		-1,117.124		-1,305.910		-735.689		-738.780	
chi	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: own calculations.

Table 11. Breakdown of 5 the worst and best performing countries with regards to change in institutional quality over 1970 – 2009

country	*GDP per capita*	*Ideas*	*bordered patents*	*EFW*	*EFW area 1*	*EFW area 2*	*EFW area 3*	*EFW area 4*	*EFW area 5*
Venezuela	-0.50%	3.88%	6.39%	-1.25%	-1.67%	-0.14%	-1.14%	-3.45%	0.52%
United States	2.49%	7.65%	5.11%	-0.13%	0.98%	-0.96%	0.15%	-0.41%	-0.21%
Luxembourg	5.02%	1.47%	3.82%	-0.11%		-0.44%	0.21%	-0.21%	-0.11%
Sierra Leone	-0.44%	0.67%		0.01%	-0.81%		1.09%	1.41%	0.09%
Belgium	2.51%	1.66%	3.73%	0.02%	0.07%	-0.84%	0.27%	-0.44%	1.19%
...	...	...	...	...	...	...	...	...	...
Ghana	1.44%	1.44%		2.25%	1.06%		2.94%	3.58%	2.01%
Argentina	1.53%	3.61%	6.65%	2.30%	0.41%	3.92%	4.22%	4.38%	0.74%
Peru	0.87%	10.40%	6.44%	2.40%	0.74%	6.25%	2.59%	3.40%	
Bangladesh	2.91%	13.62%	5.68%	2.67%	3.06%		5.07%	3.39%	1.82%
Chile	4.71%	7.07%	4.20%	2.79%	2.68%	2.03%	19.71%	1.09%	1.04%

Note: table shows the annualized growth rate.

Source: own calculations.

Table 12. Breakdown of 5 the worst and best performing countries with regards to growth rate of GDP per capita over 1970 – 2009

country	*GDP per capita*	*Ideas*	*bordered patents*	*EFW*	*EFW area 1*	*EFW area 2*	*EFW area 3*	*EFW area 4*	*EFW area 5*
DRC	-5.56%	4.66%		0.69%	0.69%		0.72%	2.46%	0.89%
Zimbabwe	-2.44%	1.93%	5.16%		-0.77%		-3.60%		
Nicaragua	-2.43%	4.81%	4.47%		0.03%		0.09%	1.08%	
Malawi	-1.06%	3.10%	2.72%	0.44%	1.03%		0.53%	-0.36%	1.24%
Haiti	-0.82%	7.02%	3.29%		-0.51%		0.69%		
...	...	...	...	...	...	...	...	...	...
Hong Kong	5.82%			0.06%	0.09%	0.27%	0.05%	-0.08%	-0.02%
Thailand	5.85%		17.32%	0.56%	0.06%	0.57%	0.47%	1.01%	0.75%
Singapore	6.34%	18.71%	17.32%	0.57%	0.71%	0.30%	1.27%	0.04%	0.46%
South Korea	7.56%	19.79%		1.27%	0.14%	0.92%	2.97%	0.46%	2.01%
China	8.44%		10.74%				0.86%		2.20%

Note: table shows the annualized growth rate.

Source: own calculations.

Table 13. Breakdown of 5 the worse and best performing countries with regards to the change in the stock of patents over 1970 – 2009

country	*GDP per capita*	*Ideas*	*bordered patents*	*EFW*	*EFW area 1*	*EFW area 2*	*EFW area 3*	*EFW area 4*	*EFW area 5*
Sierra Leone	-0.44%	0.67%		0.01%	-0.81%		1.09%	1.41%	0.09%
Italy	2.20%	1.26%	2.77%	0.90%	0.09%	1.16%	2.11%	0.03%	1.04%
Ghana	1.44%	1.44%		2.25%	1.06%		2.94%	3.58%	2.01%
Luxembourg	5.02%	1.47%	3.82%	-0.11%		-0.44%	0.21%	-0.21%	-0.11%
Belgium	2.51%	1.66%	3.73%	0.02%	0.07%	-0.84%	0.27%	-0.44%	1.19%
...	...	...	...	...	...	...	...	...	...
Indonesia	4.88%	12.96%	17.32%	0.77%	0.63%	0.91%	0.64%	0.54%	1.47%
Bangladesh	2.91%	13.62%	5.68%	2.67%	3.06%		5.07%	3.39%	1.82%
Malaysia	5.32%	17.32%	17.79%	0.16%	0.19%	0.92%	-0.47%	-0.39%	0.75%
Singapore	6.34%	18.71%	17.32%	0.57%	0.71%	0.30%	1.27%	0.04%	0.46%
South Korea	7.56%	19.79%		1.27%	0.14%	0.92%	2.97%	0.46%	2.01%

Note: table shows the annualized growth rate.

Source: own calculations.

Table 14. Pairwise correlation matrix of all the used variables

	growth	***growth2***	***gdp pc***	***gdp pc 2***	***n***	***pop***	***inv***	***lsc***	***yr sch***	***yr sch sec***	***ideas***	***bor cum pat***	***EFW***	***EFW area 1***	***EFW area 2***	***EFW area 3***	***EFW area 4***	***EFW area 5***
growth	1 .00																	
growth2	0.95*	1 .00																
gdp pc	0.11*	0.08*	1 .00															
gdp pc 2	0.11*	0.08*	1*	1 .00														
n	-0.18*	-0.14*	-0.43*	-0.43*	1 .00													
pop	0.14*	0.12*	-0.1*	-0.1*		1 .00												
inv	0.26*	0.24*			0.08*	0.12*	1 .00											
lsc	0.13*	0.1*	0.59*	0.59*	-0.5*			1 .00										
yr sch	0.16*	0.13*	0.7*	0.7*	-0.61*	-0.09*		0.83*	1 .00									
yr sch sec	0.12*	0.1*	0.74*	0.74*	-0.5*			0.87*	0.86*	1 .00								
ideas			0.35*	0.35*	-0.19*	0.17*		0.25*	0.3*	0.37*	1 .00							
bor cum pat			0.61*	0.61*	-0.35*			0.46*	0.48*	0.54*	0.3*	1 .00						
EFW	0.36*	0.31*	0.64*	0.65*	-0.35*		0.11*	0.49*	0.6*	0.6*	0.25*	0.4*	1 .00					
EFW area 1	0.1*	0.09*	-0.18*	-0.18*	0.16*	-0.06		-0.11*	-0.14*	-0.09*		-0.12*	0.3*	1 .00				
EFW area 2	0.25*	0.22*	0.73*	0.73*	-0.47*		0.08*	0.46*	0.64*	0.6*	0.25*	0.43*	0.73*	-0.22*	1 .00			
EFW area 3	0.33*	0.29*	0.51*	0.51*	-0.18*		0.13*	0.34*	0.35*	0.39*	0.22*	0.33*	0.81*	0.11*	0.46*	1 .00		
EFW area 4	0.26*	0.22*	0.57*	0.57*	-0.4*		0.09*	0.52*	0.62*	0.6*	0.13*	0.35*	0.82*	0.09*	0.62*	0.54*	1 .00	
EFW area 5	0.26*	0.21*	0.55*	0.55*	-0.29*	-0.1*		0.37*	0.52*	0.48*	0.23*	0.33*	0.84*	0.3*	0.58*	0.57*	0.65*	1 .00

Note: Star (*) denotes the pairwise correlation at 5% level of significance. Missed correlation coefficients are for pairs of variables without significant correlation at 10%. ***growth*** – growth rate of GDP per capita measured as 5-year average; ***growth_2*** – growth rate of GDP per capita; ***gdp_ pc*** – GDP per capita; ***gdp_pc_2*** – five-year average GDP per capita, ***n*** – population growth; ***pop*** – population size; ***inv*** – investment rate; ***lsc*** – share of people who finished secondary education, ***yr_sch*** – average years of schooling attained; ***yr_sch_sec*** – average years of secondary schooling attained; ***ideas*** – cumulative stock of patents with no depreciation; ***bor_cum_pat*** – cumulative sum border patents with no depreciation; ***EFW*** – summary index of Economic Freedom of the World; ***EFW area X*** – Economic Freedom of the World at area X: **1** – Size of Government (Expenditures, Taxes, and Enterprises); **2**- Legal Structure and Security of Property Rights; **3** – Access to Sound Money; **4** – Freedom to Trade Internationally; **5** – Regulation of Credit, Labour, and Business.

Source: own calculations.

Table 15. Breakdown of p-values for Granger-causality test

null hypothesis			*World*	*Advanced Economic*	*Emerging and Developing Economies*
growth	does not Granger-cause	GDP per capita	0.0000	0.0000	0.0125
GDP per capita	does not Granger-cause	growth	0.0072	0.0128	0.0252
growth	does not Granger-cause	population growth	0.0059	0.0160	0.0119
population growth	does not Granger-cause	growth	0.0025	0.2432	0.0413
growth	does not Granger-cause	investment	0.0018	0.0277	0.0139
investment	does not Granger-cause	growth	0.0000	0.0001	0.0000
growth	does not Granger-cause	educational attainment	0.2366	0.0000	0.0026
educational attainment	does not Granger-cause	growth	0.9252	0.1731	0.9599
growth	does not Granger-cause	patents stock	0.0058	0.0000	0.0161
patents stock	does not Granger-cause	growth	0.5373	0.6782	0.4050
patents stock	does not Granger-cause	institutions	0.2513	0.5934	0.0690
institutions	does not Granger-cause	patents stock	0.0081	0.1112	0.0019
patents stock	does not Granger-cause	population size	0.2732	0.4537	0.0935
population size	does not Granger-cause	patents stock	0.3843	0.4983	0.5590
patents stock	does not Granger-cause	educational attainment	0.0245	0.0083	0.0429
educational attainment	does not Granger-cause	patents stock	0.0914	0.5560	0.0469
patents stock	does not Granger-cause	border patents stock	0.0000	0.0000	0.0000
border patents stock	does not Granger-cause	patents stock	0.0000	0.0000	0.0001

Source: own calculations.