
**Cracow University of Economics**

Field of science: Social Sciences

Discipline of science: Economics and Finance

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# Investigating economic convergence: application of the SURE model to Latin American and Central and Eastern European countries

PhD Thesis

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Cracow, 2021

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# Introduction

Existing differences in the standard of living between specific regions of the world, or rather countries, are a commonly known problem. This issue is not only the subject of political debate but it is also present in the academic research of sociology, public policy, psychology and economics. It seems natural that cross-country differences are not a problem that has just emerged recently. National living conditions and economic situation have varied for centuries, but their measurement was and still is a problem for the scientific community. One may find research articles investigating some cross-country differences published from the 1800s (Smith, 1776; Malthus, 1798; Ricardo, 1815; Easterlin, 2000; Maddison, 1994). There are multiple measures used to compare wealth between the countries (Fleurbaey, 2009), but the most frequently used and probably easiest indicator is the Gross Domestic Product per capita (GDP p.c.). The problem when analysing cross-country differences is therefore not measure-related. It lies deeper in the economic growth theory and requires answers to the reasons for such income differences and some patterns.

Taking the economic perspective into account, a substantial breakthrough happened thanks to Solow publishing in 1956 his article, which presented a model of economic growth. It didn't take long for the model to be analysed by other researchers and for conclusions to emerge. One such conclusion regarded income convergence, which is a catching up process between countries to a particular steady point. This is a clear implication from one of the model's assumptions, namely the concept of diminishing returns to capital. In the neoclassical school of economic growth, decreasing returns to capital imply its movement between countries. Once returns in country *A* do not provide the expected and satisfactory rates, companies are expected to invest in country *B* with a lower initial capital to achieve better targets. As a result, country *B* grows faster and can potentially catch up country *A* in the long run. The reason why this effect happens is still an open question (Islam, 2003; Ganong and Shoag, 2017; Johnson and Papageoriou, 2020).

Income convergence was questioned by the endogenous growth theory. The supporters of this school do not necessarily see a limit in returns to capital, rather the returns can be even increasing when considering the knowledge or human capital in general (Romer, 1986; Lucas 1988).

The theoretical problem described above led to substantial arguments in the academic community. In order to see which theory is valid, empirical analyses on the existence of the

convergence effect were performed. The convergence debate emerged and multiple studies and econometric analyses testing the convergence hypothesis were published.

Bernard and Durlauf (1996) explained the framework used for convergence testing and divided it into cross-section and time series approaches. The cross-section tests take into account only the initial GDP per capita levels of a specific country group and compare it with the growth for further years. If the countries with lower initial income grow faster, then the convergence hypothesis appears to be confirmed. This type is described as unconditional beta convergence (absolute convergence). If some other variables covering the structural conditions of economies (e.g. human capital level, government spending, investment or technological progress) are taken into account in the growth analysis, then one has to do with the so-called conditional beta convergence (Sala-i-Martin, 1996; Barro, 1991; Islam, 2003). On the other hand, the time series approach verifies whether the differences between countries are getting lower over time. Contrary to beta convergence, which assumes the higher growth rates of poorer countries, the sigma convergence occurs also if richer countries do not grow at all, or even shrink. Thus the gap between a poorer country and a richer is simply lower, not necessary purely driven by the growth of poorer country. A stronger implication of this method is the lack of unit roots in income differences and a weaker cointegration of the output in two analysed regions. This type of convergence may also be checked utilising standard deviation represented by the letter sigma, hence the name (Egger and Pfaffermayr, 2009; Simionescu 2014).

Many authors have analysed beta convergence, but there is still no leading conclusion. Barro and Sala-i-Martin (1990) used regression in order to examine income data for 48 US states since 1840. The authors found evidence for beta convergence and therefore confirmed – although with a high capita-share coefficient of 0.8 – the neoclassical growth model. Two later publications Barro, Sala-i-Martin, Blanchard and Hall (1991) and Barro and Sala-i-Martin (1992) delivered similar results in favour of the convergence hypothesis for another set of data. The speed of the convergence was equal to approximately 2% per year, resulting in a long period required for poorer countries to catch up.

Based on the Barro and Sala-i-Martin's (1991) methodology, many authors researched other datasets. Thomas (1995) checked 12 EU member states through 1975-1991 and 166 EU regions for the same period. The author confirmed the beta convergence hypothesis with a speed of 1.61% and 0.35% respectively. The conditional beta, holding constant the industry employment, had an even higher speed with 2.73% for the EU countries and about 1% for the regions. Martin and Sanz Villarroya (2001) also confirmed both the unconditional and conditional beta convergence for 15 EU countries. Kaitila (2005) analysed 15 EU regions and

8 CEE countries and confirmed conditional beta convergence. Today, there are still many authors dealing with this topic. Próchniak (2011) confirmed the beta convergence for 10 CEE countries. Głodowska (2015) analysed EU27 countries and 276 NUTS2 regions with a regression and found a speed of 3.7% and 2.5%. Chapsa, Tsanana and Katrakilidis (2015) found evidence for conditional beta convergence among 14 EU countries.

On the other hand, using similar regression methodology, beta convergence hypothesis was rejected. Mankiw, Romer and Weil (1992) analysed whether the Solow model's theory can be confirmed via empirical analysis. In the second part of their analysis, the authors tested the convergence speed. They did not confirm the unconditional beta convergence hypothesis with only the conditional one being positively verified on 3 samples of different countries. Dowrick and DeLong (2003) analysed 109 countries from Penn World Tables in order to find absolute beta convergence and failed to do so. Holmes (2005) did not find evidence for unconditional beta convergence among 16 Latin American countries with a standard regression, using a different method, largest principal component analysis (LPC), and he found evidence for two samples. Rapacki and Próchniak (2009) verified 27 transition countries between 1995 and 2005, using a regression and found mixed results - some samples confirmed the unconditional beta convergence, some did not.

The research outlined above confirms the disproportion among results for beta convergence using regression, but additional methodologies can also be applied. Among the most popular are panel data approach, unit root tests and standard deviations in order to verify the sigma convergence. These methods also do not deliver homogenous results.

Based on the analysed literature, it should be stated that, although the convergence topic is a classical one in economic debate, even today there is no clear answer, whether convergence exists. It remains unclear whether convergence patterns in selected group of countries are similar. There is also a mixture of methodologies, but they do not appear to achieve a common line, which results in an open debate and in many open questions, where a research gap is clearly visible.

The substantial differences among the research results and various convergence tests lead in a natural way to the following main hypothesis:

**H0: Economic convergence is a country-specific phenomenon, which exhibits substantial heterogeneity among countries of comparable level of economic growth or geopolitical situation.**

Detailed hypotheses:

H1: The Seemingly Unrelated Regression Equations (SURE) model is an empirically important generalisation of the panel regression in the case of analyses of the convergence effect.

H2: The magnitude of the parameters describing the speed of convergence shows statistically significant differences across the analysed CEE and LA countries.

H3: The exclusion of some selected structural variables in convergence testing leads to different results and is an example of convergence heterogeneity across the analysed CEE and LA countries.

H4: The human capital regressor used for conditional convergence verification has an important impact on the model's explanatory power.

With the arguments and hypotheses listed above, the main objective of the doctoral dissertation was defined:

**O0: Empirical verification of the income convergence hypothesis and cross-country heterogeneity with Seemingly Unrelated Regression Equation System based on Latin American and Central and Eastern European Countries.**

Within the main objective, the following detailed objectives are established:

O1: Introduction of a new methodological approach in convergence testing, which is based on the model of Seemingly Unrelated Regression Equations (SURE).

O2: Verification of the convergence hypothesis and its heterogeneity for the analysed CEE and LA countries.

O3: Statistical verification of human capital impact on convergence testing.

O4: Comparison of results obtained on the basis of the SURE model with the mainstream literature.

Based on the literature analysed in the first part, the following main research question was formulated:

**RQ0: What are the dominant convergence trends in the selected developing countries and can they be analysed with a non-standard econometric framework?**

Detailed research questions:

RQ1: How can the SURE model be applied for the convergence tests?

RQ2: Are the cross-country parameters heterogeneous?

RQ3: What are the magnitudes of the convergence with the SURE model for the selected countries?

RQ4: Do the results obtained by the SURE method differ from the commonly used regressions?

According to the established research hypotheses and objectives, the Seemingly Unrelated Regression Equations (SURE) serve as the core econometric environment in which to perform the analyses presented in this dissertation. The most important advantage of the SURE model (and the Zellner (1962) estimator) utilised in testing the convergence, is the variability of parameters across analysed objects in the system (such as countries being analysed jointly as a catching-up region). The panel regression techniques performed by many authors cited above, are built on the basis of the restrictive assumption that parameters are constant across objects. Consequently, it forces researchers to treat the convergence effect as a homogenous phenomenon without any chances of country specificity. Contrary to the panel regression strategy, the SURE model allows to account for those cross-country differences. In addition, within this framework the formal comparison of various hypotheses can be obtained, while the hypothesis of common speed of catching-up processes being of primary importance. Obtaining multiple results based on the model set-up clearly supports the heterogeneity of convergence hypothesis. In the case of this thesis, four scenarios were analysed: the novel approach, treating the country group as one entity and allowing for correlation of the error term (M1, Zellner estimator) and the rather classical approach where countries are treated separately (M0, OLS estimator). Despite the standard analysis that included all six explanatory variables, the models were also analysed without the human capital variable (Meh1 and Meh0). Exclusion of the human capital variable can be as a good choice as any other for heterogeneity analysis, but among the convergence research papers there seems to be no particular pattern for its inclusion or exclusion.

At this place it is important to note why the countries of Central & Eastern Europe (CEE) and Latin America (LA) can serve as a suitable example for testing the convergence and the above-mentioned hypotheses together with the SURE model. Both regions, CEE and LA, include countries that can be categorised as emerging. In general, emerging countries - defined as low-income ones with rapid economic growth (Hoskisson et al. 2000) - are particularly interesting for growth analyses. Further, despite some economic similarities like the GDP growth rates, both country groups have a completely different scope of culture, history, geography and even political situation. This argument is important when one wants to analyse the heterogeneity of convergence, which is a crucial objective of this thesis. Despite those arguments, there is also one related to the research gap. While Central & Eastern European countries were and still are broadly analysed with respect to the convergence effect, among the Latin America ones only several high-quality research articles investigating such an effect may be found. There is visibly a lack of literature.

The dissertation has a theoretical-empirical nature and its structure is set in four chapters.

Chapter 1 deals with the theoretical aspects of economic growth that derived the convergence concept. It describes the respective models from the neoclassical and endogenous growth theory schools. Further, the reopening of the convergence debate after the financial crisis is introduced.

Chapter 2 presents the empirical model used for convergence testing. It deals with the assumptions of Seemingly Unrelated Regression Equations (SURE) and methods of its estimation. Later, it shows how the convergence hypothesis can be verified with this approach.

Chapter 3 deals with some of the chosen economic performance indicators for the CEE region. Later, the SURE model results with the discussion are presented.

Chapter 4 describes how LA countries performed from the economic perspective. The second part of chapter 4 presents the SURE model results.

The summary of the thesis is last and concludes with final remarks.

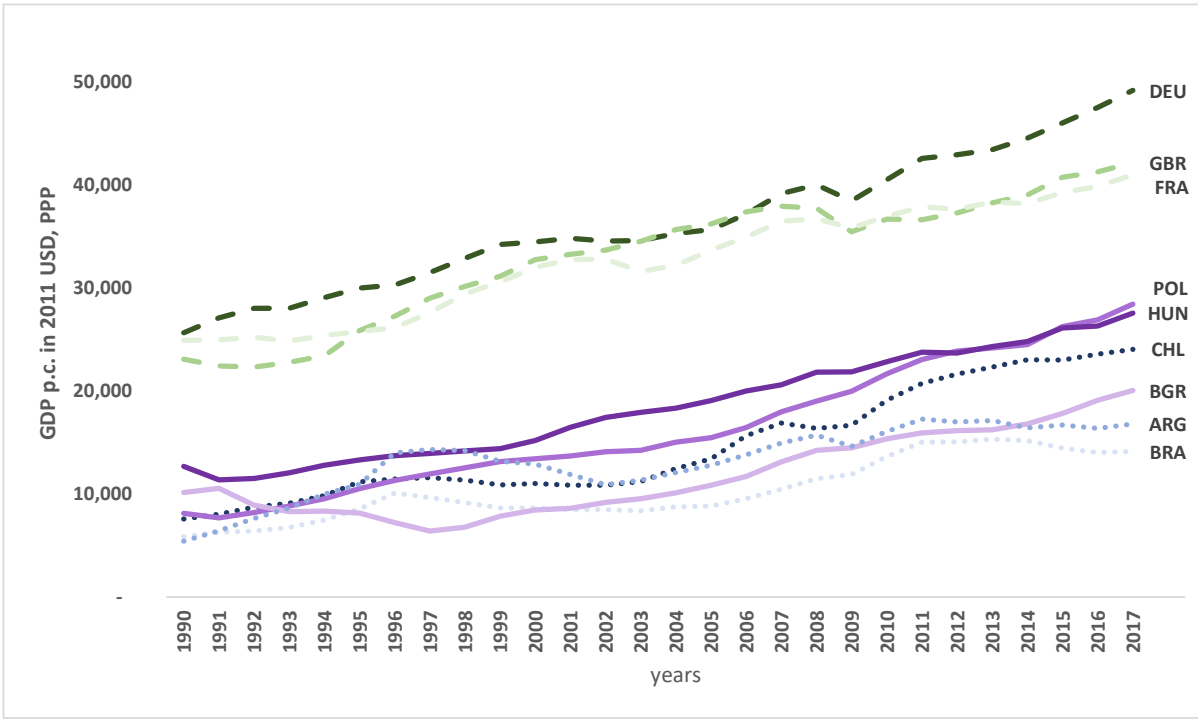
# Chapter 1: The nature of economic convergence: review of the mainstream development and methodology

## 1.1 The importance of economic convergence and a review of first fundamental schools of economic thought.

### 1.1.1 The importance of the convergence issue

Whether less wealthy countries will ever catch up the richer ones is nowadays a very important topic in political debates and among the public. The differences between regions i.e. the EU western and eastern countries are stressed by many leading European politicians. Looking at empirical data, one may have reasons for identifying enormous differences. In order to highlight the importance of the convergence analysis in general, Fig.1 below should provide a good point of departure. The most interesting countries from three regions were purposely selected to demonstrate the differences.

Figure 1: GDP per capita development in selected European Countries in 1990 - 2017. Constant prices in 2011 USD PPP.




Source: Own elaboration based on Penn World Tables 9.0.

Figure 1 above presents the GDP per capita levels of three selected Eastern European (full-line), Western European (dash-line) and Latin American (dotted-line) countries.

All three western European countries started in 1990 with a GDP level of approximately 24 000 USD and in 2017 achieved a magnitude of approx. 40 000 USD, with the exception of Germany, which speedily recovered after the 2008 global financial crisis and achieved 49 000 USD. On the other hand, there are the Central & Eastern European and Latin American countries, which had a much worse start. Their GDP per capita level oscillated around 12 000 USD in 1990. After 28 years Hungary and Bulgaria doubled and Poland more than tripled their 1990 GDP level. Similar to CEE, LA countries started at the same level in 1990. Both Argentina and Chile managed to triple their initial GDP p.c. levels (and fastest recovered after the financial crisis), whereas Brazil increased it 2.5 times. When considering the fastest grower among the analysed western European countries, Germany reached in 2017 192% of the 1990 level. In general, the catching up process can be clearly visible. Last but not least the observations of transition and emerging countries, which are not able to jump into the high-income level, are more and more common. All the above mentioned facts provide arguments especially for journalists, politicians and policy makers. For the purpose of this thesis, the most important conclusion of the Figure 1 above is that initial GDP p.c. matters.

The early presentation of these empirical facts has two reasons. First, it shows the importance of the topic in public debate, and second, it describes what economic growth theory is dealing with. In fact, the convergence process defined as the speed of catching up of a poorer country towards a richer one, is a sub-discipline of economic growth theory. Therefore, while analysing the income levels for potential phenomena like convergence, it is helpful to be aware of what the economic growth theory discipline is offering since the 18$^{th}$ century. Nowadays, the mainstream may be divided into the classical, which yielded to neoclassical by the end of 19$^{th}$ century, and into the endogenous growth theory. A brief historical review of most popular publications will deliver a solid starting point for discussions and understanding of the convergence hypothesis.

### 1.1.2 Classical economics

Among the most famous classical economist one may find Adam Smith, Thomas Malthus, David Ricardo and John Stuart Mill. Starting with the most popular, and considered as the first economist, one finds Adam Smith with his work The Wealth of Nations (1776). Some researchers argue whether Smith was a moral philosopher (Winch, 1992), or even a behavioural economist (Ashraf, Camerer and Loewenstein, 2005). Regardless of the opinion,

he is considered as the father of economy and his work has set some foundations in the classical growth theory. Already in the first three chapters of The Wealth of Nations (1776), the reader will notice the attention, which Smith paid to labour and its division, or rather specialisation. It is worth noting, that labour (and its utilisation) is also receiving huge attention in contemporary models of economic growth, not only in the well-known Solow Model, but for instance in endogenous growth models based on innovation. Going further, most of the current models consider human capital to some extent and Adam Smith was the first one describing all the relations of labour and educational training in a scientific way (Kyklos, 1969). The idea was set therefore already in 18$^{th}$ century.

Another very popular and worth-mentioning concept introduced by the author was the so-called "absolute advantage principle". This concept describes the free trade benefits for countries that specialise in their more productive good compared with the foreign country's production (not to be confused with comparative advantage). Here the problem of richer and poorer countries was not only presented, but also received the simple, above-mentioned solution.

Last but not least, the author is famous for the so-called "invisible hand of the market", which is intended to present how the interest of individuals is contributing to the well-being of the whole country.

Despite the above-mentioned ideas, which set foundations for the economic growth theory, Smith described also aspects of the price theory, how the wages work and criticised the mercantilism system, which was considered to be the mainstream model during those times.

A few decades after Smith's Wealth of Nations (1776) was published, the industrial revolution took its roots in Europe. Through this revolution and the dynamic growth phase, inequality became a popular topic. This was because more common people took over positions, which previously were held only by the aristocracy. Further, although a strong growth phase was observed, the political situation was not very favourable to the economic development in Europe during that period (i.e. continental blockade of Napoleon). These events were visible in David Ricardo's (1772-1823) work. Ricardo may be considered as the pure economic theoretician, who derived some common logical laws, rather than going into empirical theory (Coleman, 1996). Among the most popular papers one may find The High Price of Bullion, proof of the depreciation of bank notes (Ricardo, 1810), Essay on the influence of a Low Price of Corn on the Profits of Stock (Ricardo, 1815) and the book On The Principles of Political Economy (Ricardo, 1821).

The first paper offered huge theoretical implications to monetary policy and the value of money. Ricardo noted among others, that the value of bullion like gold is determined by the capital involved in its production, labour and its scarcity. But there is another interesting point, which is still valid today, in economic growth theory:

> If, therefore, we could be fully assured that the effects of the abundance, and the consequent depreciation of the currency, would diminish the powers of consumption in the idle and unproductive class, whilst it increased the number of the industrious and productive class, the effect would undoubtedly be to augment the national wealth, as it would realize into capital that which was before expended as revenue. (Ricardo, 1810, p. 41)

Although this citation is not the point of interest in this specific Ricardo's work, it shows that he agreed with the concept of investment to boost economic growth more, than when it is done by consumption. In fact, he was aware of the investment being a growth determinant, but mentioned that one cannot be sure whether the income distribution would secure it. His later work (Ricardo, 1815) is more about an open economy and whether tariffs are beneficial, or not. Generally, Ricardo saw a free market advantage and did not support the hypothesis to restrict imports. Last but not least the author wrote a similar work to Smith (1776) with respect to size and the breadth of topics. Ricardo (1821) concentrated on standard demand and supply topics, but also many chapters were focused on taxes and trade. Through his comparative advantage principle (enhanced Smith's absolute advantage), Ricardo made the specialisation of a country's labour profitable, even if they needed more hours for producing a specific good, than another, more competitive country. The important conclusion from Ricardo's work towards the economic growth theory, maybe the diminishing returns of labour. The concept maybe seen for instance in the neoclassical models of economic growth, where implications of diminishing returns to capital explain the investment done in another, poorer country, resulting in the convergence process. Ricardo didn't go that far, because he saw lower returns with increase of personnel not as a law. The following citation may summarise his concept of capital and labour accumulation and the introduced rent theory:

> If the fund for the maintenance of labour were doubled, trebled, or quadrupled, there would not long be any difficulty in procuring the requisite number of hands, to be employed by those funds; but owing to the increasing difficulty of making constant additions to the food of the country, funds of the same value would probably not maintain the same quantity of labour. (Ricardo, 1821, Chapter 21, p. 209).

In the same time to Ricardo, Thomas R. Malthus (1776-1834) investigated the nature of population growth. His most popular work, An Essay on the Principle of Population as it Affects

the Future Improvement of Society (Malthus, 1798), presented geometrical population growth that was stopped by food shortages and natural disasters. This concept may be seen right in the first chapter, with his two basic assumptions, later visible in his overall model. First, food is necessary for existence of humankind and secondly, the passion between sexes is necessary and will remain. Although it may appear pessimistic, this view was fitting into the times prior to the Industrial Revolution. Food shortages were common and the per capita consumption didn't change much during that period (Dutta et al., 2018). Therefore Malthus (1798) proposed a model of economic growth, which was characterised by some restrictions. One and probably biggest restriction was the fixed supply of production factor, such as land, and the second being the population's income. The implication of setting the production supply fix is straightforward and takes the form of decreasing returns of scale for other factors. This was already visible in the previously discussed Ricardo concept. For instance, whenever one would increase the personnel (labour) with the fixed supply of capital (land), the returns will be smaller and smaller over time with every increase. Further, the restriction set on population's income indicates, that any increases in capital would lead to the parallel increases in population. Frankly speaking if it would be possible to increase the capital stock through some kind of technological progress, it would not increase the per capita income since the population would grow accordingly and find some kind of equilibrium.

Galor and Weil (1999) see this Malthusian concept as a good indication during those times:

> This Malthusian framework accurately characterized the evolution of population and output per capita for most of human history. For thousands of years, the standard of living was roughly constant, and it did not differ greatly across countries. (Galor and Weil, 1999, p. 1).

Further, Maddison's (1977) research on historical GDP development led to a similar conclusion, that in fact the per capita GDP growth rate in the world was zero. Both population and income rose about 0.04% per year in two millenniums before the industrial revolution. This is explained exactly by the mechanism introduced by Malthus (1798).

John Stuart Mill is considered as the last of the major classical economists (Winch, 1963). With his work Principles of Political Economy (Mill, 1871) the author presented the broad range of economic science. Discussed issues cover production optimisation, fiscal/monetary policy, international trade and theory of firm. Further, Mill's view on government is also worth noting with respect to current debates of market intervention. It was

much more complex, than from his predecessors discussed before. This is also due to the fact, that since Smith's publication in 1776 already a hundred years had passed and the situation in Western economies was different. Mill argued, that a proper government system is one that fits best to the community. His ideas and concepts in a more microeconomic manner were utilitarian, suggesting that decisions should be made based on the choices maximising happiness.

What may be important to the growth theory are the defined production factors, namely capital, labour and natural agents, whereas capital is defended as product of labour and natural agents provide the rest. With this respect, the problem of food shortage is discussed in the book's Chapter VII as well. Mill refers to the Malthusian concept, in which the population increases geometrically, and the food production cannot keep up due to land, which is restricted geographically. A very interesting remark affecting the economic growth models is made on the labour class:

> Among the middle classes, in many individual instances, there is an additional restraint exercised from the desire of doing more than maintaining their circumstances—of improving them; but such a desire is rarely found, or rarely has that effect, in the labouring-classes. If they can bring up a family as they were themselves brought up, even the prudent among them are usually satisfied. Too often they do not think even of that, but rely on fortune, or on the resources to be found in legal or voluntary charity. (Mill, 1871, Chapter VII (3) p. 134).

This may show how the population, or rather innovation, was considered during that time. The human capital concept although it existed, was not similar understandable as currently. Nowadays it is considered as something, that enhances the productivity (or technological progress) and thus the economic growth. The endogenous growth theory or even National Innovation Systems are far away from seeing the middle class as being passive for improvement (Jimenez, 2019). This may be driven by comparable low education of the population in the 19$^{th}$ century than today. For instance, Tabellini (2010) analysed the cultural and education effects on economic development from 1850, when the literacy rate was much lower than currently. This means, that Mill's concept could be understandable and valid in those times.

The classical economists described above were different than current typical researchers in economics. This is also because other sub-disciplines of economics, as we know them today were not yet established (econometrics, statistics, and other). The 18/19$^{th}$ century economists focused rather more on philosophical and political economy with general macroeconomic

aspects. To sum up their common view, they looked towards the freedom of every individual and the finding of material income. This rent-seeking was not selfish as a whole, but led to more value added in the entire economic system. Further, it was psychologically and morally correct (Grampp, 1948). The classical economists were therefore more akin to philosophers, who dealt, or rather specialised, in the field of economics. But exactly these philosophers set foundations to the current growth theory and convergence debate. Some of their concepts about population growth, production factors or even the diminishing returns principle are well known and used today. It may be especially visible when considering the neoclassical school, which will be the next focus.

### 1.1.3 Neoclassical economics

By continuing, improving and finally enhancing classical economics, the neoclassical school of thought emerged. This school has its roots in the end of 19$^{th}$ and beginning of the 20$^{th}$ century. Famous researchers who set the foundations of this school include W. S. Jevons, L. Walras, A. Marshall, V. Pareto, F. Y. Edgeworth, and L. Robbins. Compared with classical economics, which concentrated more on empirical aspects of supply and demand, the neoclassical one tries to explain how the equilibrium state works. It may be the steady state of supply and demand on the goods market, but also the steady state when considering the macroeconomic perspective. One may also find there models of economic growth, which are optimised in the equilibrium state (e.g. the Solow or Ramsey models). Some of the most important authors in this school contributed to modern macroeconomic dynamics and further, to the convergence theory. A review of key publications will deliver suitable information.

The Coal Question (Jevons, 1866) is an interesting work concerning the neoclassical economic growth theory, or rather its limits. Jevons presented in his first chapter the importance of coal as a production factor, something that enhanced the productivity of the whole country. The author was however aware, that resources have a limit. Although he was speaking generally about coal, the reader may note that the idea behind extensive and intensive growth was already there. Extensive growth is characterised mainly by increases in output achieved with proportional production factors increases (input). Interestingly, the extensive growth patterns were still visible in the first half of the 20$^{th}$ century (Sargent, 2013), and for some countries, especially the post-communist states, even later. In the long run, this may lead to problems, or even extinction of natural resources. A much more sustainable way of enhancing the growth is the intensive form characterised for instance by productivity increases – nowadays this

statement is straightforward. It was not like that in the 19th century, but exactly this kind of a problem was presented by Jevons (1866). Going further, the author argued about the price of this natural resource, especially with respect to the workload needed for its production; in his times, the prices were too low. But, regardless of the mining facilities, Jevons made a huge remark in Chapter VI towards economic growth theory, and even convergence: he highlighted the importance of innovation, and not only the innovation coming from one scientist, but from the entire nation. This, characterised by examples of machinery inventions in the industry, can be seen as a proxy for intensive growth. Further, the author indicated that innovation might be transferred from one country to another. This is exactly what convergence theory is about, especially with respect to Total Factor Productivity (TFP) convergence, a topic broadly discussed today (Levenko, Oja and Staehr, 2019; Huang et al., 2019; Feder, 2018).

Another recognised neoclassical author, Leon Walras (1834-1910), set the foundations of current macroeconomic models with his most recognized work "Elements of Pure Economics" (Walras, 1899; translated by Jeffe, 1954) and introduced general equilibrium theory, which was later reviewed and derived formally by Abraham Wald (1936). The theory revolutionised the ways of thinking, and it allowed to analyse broadly the effects of any changes in economic systems. The output, factor prices, market prices, income and similar variables could be affecting the whole market, going beyond the borders. For theory classification purposes it is however important to mention, that technological change is not considered to be a variable (exogenous) in most of the general equilibrium models. Last but not least, the most important question in his theorem was related to the existence of general equilibrium. To sum up the general equilibrium theory, or rather its problems, the following classification may help:

1. Problem of the existence of a solution to the general equilibrium model.
2. Problem of uniqueness of the general equilibrium solution. Should a solution to (1) exist, is it unique with only one set of prices and quantities or rather multivariate?
3. Problem of stability of the general equilibrium solution. Should a solution to (1) exists, would it be a stable or and unstable equilibrium?

All the answers to the above mentioned problems depend on the assumptions made. Therefore, to review the set of these problems, many papers later were published (Wald, 1936; Arrow and Debreu, 1954; John, 1999). Despite the fact, that the general equilibrium theory is a subject of microeconomics, some foundations towards the economic growth theory, or rather convergence theory, may be found in Walras' work as well.

In Part I of his most famous work Elements of Pure Economics (Walras, 1899) the author presents economics as a broad science, but not as broad as Smith (1776) did. He differentiates between the political and social economy, taking the classical theory into account and makes contributions towards political economy as well (for instance communism vs. individualism). Walras views on that matter may be classified as Marxian, but with a tension towards a free market. He saw in many matters the intervention of the state as beneficial, for instance with respect to the landlords, who were requesting huge rents. Part II and Part III deal with the already described market equilibrium and utility functions (in some editions of the book Part II and Part III are analysed as one chapter). Part IV deals with more with the determinants of economic growth, which are still slightly different then the once used currently. Walras defines three factors, namely land, labour and capital, while in modern economics capital includes the land. This is not a problem however, since the different meaning of these factors is clearly visible. Capital is the social wealth, that can be used more than once, contrary to income, which may be used only once. Both capital and income can be material or immaterial, however the income is a result of services from capital. Land is a separate factor, because Walras views it as something original, which is constant in quantity. Labour is self-explanatory; persons contribute into it and are not an industrial product like capital. Finally one may find a visible starting point towards the convergence hypothesis while the author describes the equilibrium in production. To achieve it, three conditions need to be set:

1. Exchange equilibrium in service and products markets.
2. Equality between selling price and cost of production.
3. Absence of profit or loss to entrepreneurs.

Of course to achieve such conditions globally, or rather across countries, convergence needs to take place. Taking into account the exchange in service and products, one should know, that one country may be specialised in the first one, while the other in the second. The division of specialisations was already described by Ricardo (1821) and well-known to Walras. To achieve therefore an equilibrium there, firms will seek profits and use the opportunities in poorer (in a manner of service or products) market. The second point requires a transfer of production plants into other countries, due to differences between the production costs across countries (i.e. labour, natural resources). The absence of profit or loss to entrepreneurs in an equilibrium state is a more complex hypothesis (for instance considering the working capital), but if it takes place globally, then convergence would need to exist, when not profitable companies go bankrupt and the profitable ones take their place in the respective country. Part V delivers more ideas about capital formation, and an equality between selling prices and the

production costs. Part VI describes the money circulation and analyses three phases of that process. In Part VII the author investigates the economic progress (economic growth), which takes places after the increase in capital is higher than the increase in population. Some concepts here were also referred to Malthus (1798), although the technological progress was already mentioned, the author saw as an essential characteristic for the growth the rise in price of land services. Last but not least, Part VIII describes the firm theory with respect to the monopoly and price fixing. A solid review of Walras work was performed by Friedman (1955).

Generally, if we consider the equilibrium hypothesis of Walras globally, then the income convergence hypothesis is not much different. The equilibrium on the markets would require a catching up process occurring in a more or less complex way.

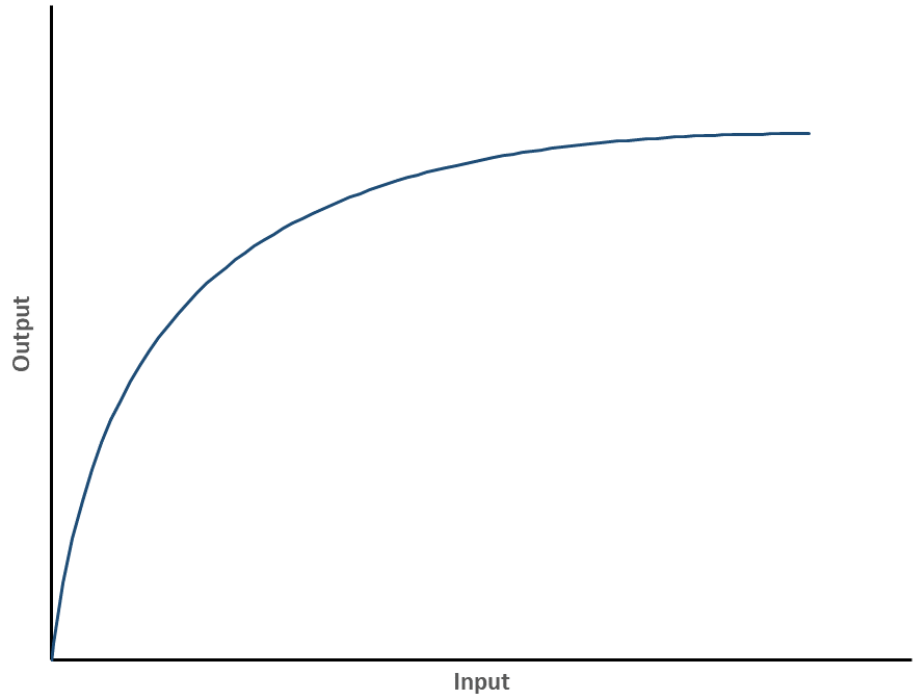
Alfred Marshall (1842-1924), Vilfredo Pareto (1848-1923) and Francis Ysidro Edgeworth (1845-1926) were similar to the previously described influential neoclassical economic theorists. However, they dealt more with microeconomic optimisation problems than economic growth theory, but their contribution was visible as well, also when we consider the pareto-optimum. The description of their works would be however beyond the scope of this thesis. Some more recent reviews of economic growth theories in a historical perspective may be found in papers by Sharipov (2015) or Piętak (2014).

First neoclassical growth theories as we know them today emerged in 1950-1960; in that time the problems moved from dynamic equilibrium to how to achieve the potential growth with new technology or increased productivity (Sharipov, 2015). The connection with the classical economy comes when one considers the factors of production. The neoclassicists use here similar capital and labour. The land is nowadays already considered in capital and thus not treated as a separate variable. The fundamental and special assumption in the neoclassical models of economic growth theory is the diminishing returns concept. Whenever a production factor increases, the output increases but with a lower rate. Formally when we consider the input variable as X and the output as Y, the Y gets increased with bigger X, but these increases are smaller and smaller. As an example one may consider a shoe-production plant with 10 workers and a daily production of 80 shoes. When we double the amount of workers (production factor: labour) and keep other factors constant we will not be able to achieve 160 shoes production, but a lower rate. The reason for this may be for instance the production site capacity or the equipment needed. Of course their production will be higher than the initial rate, because the new workers contribute somehow to the facility, but if we increase even further the number of people and keep other factors constant, let us assume to 100 workers, then further production

increases will be hardly visible. This is how the diminishing returns concept works and interestingly enough, its description may already be found in Smith (1776) or Malthus (1798).

Figure 2*Figure 2: Diminishing returns to capital concept* presented below visualises the phenomenon as a function. One may observe that the slope is increasing, but the increases get lower (they diminish). This is because the first derivative is positive and the second derivative is negative, meaning that the function is concave downward. This diminishing returns to capital concept is a very important implication for the whole growth and convergence debate. The endogenous growth models, using sometimes knowledge or human capital as a base for a production factor, can work in an opposite way: the factors may lead to increasing returns.

Figure 2: Diminishing returns to capital concept




Source: Own elaboration based on the neoclassical production function.

## 1.2 The origins of the convergence debate within neoclassical and endogenous growth models

### 1.2.1 The neoclassical Solow growth model and concept of unconditional convergence

One of the most important and recognised models of economic growth was presented in the article by Solow (1956) entitled “A Contribution to the Theory of Economic Growth”. It was in fact a huge contribution in those times taking into account the current utilisation and

simplicity of the model. The assumptions of the model are straightforward: there is a single good Y(t), which is going to be produced by two production factors namely the labour L(t) and capital K(t). Every individual consumes a part of his income and the second part is saved for investment, the constant s is added so one may get the saving sY(t). The increases of capital consist of investment and therefore as the above mentioned sY(t). Further, the model is based on the neoclassical production function and therefore there are diminishing returns to capital and constant returns to scale. The population grows in an exogenous manner, hence the variable of its growth, n, is not explained by the model. The model has also the assumption that aggregate demand and supply need to match, so the economic system equilibrium can take place. With these pre-requirements one may investigate the interactions between the variables in a mathematical and theoretical sense, but the environment has also some more complex insights. In fact, also in his first paper which presented the model (Solow, 1956) the author offered some extensions of it, with the exogenous technological progress.

It is also important to know, how the model may be presented from the mathematical point of view, therefore the modern scheme will be presented below.

Two of the most important assumptions in the model, which will be described throughout this dissertation, are the constant returns to scale and diminishing returns to capital and labour. Further, it should be possible to derive the function and the model is set in continuous time.

Let K, L, A be Capital, Labour and technology respectively.

F: $\mathbb{R}_+^3 \rightarrow \mathbb{R}_+$

$$F_K(K,L,A) = \frac{\partial F(K,L,A)}{\partial K} > 0 \quad F_L(K,L,A) = \frac{\partial F(K,L,A)}{\partial L} > 0 \tag{1}$$

$$F_{KK}(K,L,A) = \frac{\partial^2 F(K,L,A)}{\partial K^2} < 0 \quad F_{LL}(K,L,A) = \frac{\partial^2 F(K,L,A)}{\partial L^2} < 0 \tag{2}$$

The idea behind this set of equations is straightforward. Both labour and capital cannot be a negative number, which seems like a common-sense assumption. The continuous time assumption allows to use the methods of differential calculus, which will be a huge help and simplification for future calculations.

The first partial derivatives with respect to both K and L need to be positive. This means that when the unit of capital or labour will be increased, the function increases as well. Further, the second partial derivatives with respect to K and L must be lower than zero, which represents the diminishing returns to capital and labour respectively. In other words, every additional increase of K or L will lead to lower increases in the production.

When considering the whole economy, a different equilibrium needs to be taken into account, namely the one between the households and the firms. This equilibrium is described by the following equation:

$$\max \; F\left(K, L, A_{(t)}\right) - r_{(t)}K - w_{(t)}L \qquad (3)$$

Where rK denotes the cost of capital, that is provided by the households for the firms and wL stands for the labour costs rate. One should note, that the above equation requires an equilibrium between labour supply/demand and capital. With the returns on scale assumptions companies would like to maximise the production factors, K and L, infinitely, but both of them are scarce. Hence the respective prices for labour and capital have the following form:

$$w_{(t)} = F_L(K_{(t)}, L_{(t)}, A_{(t)}) \qquad (4)$$

$$r_{(t)} = F_K(K_{(t)}, L_{(t)}, A_{(t)}) \qquad (5)$$

Finally, some additional, or rather optional, assumptions of the model exist. An example of such reasonable assumptions, which guarantee a stable growth path, are the so-called Inada conditions, named after the Japanese researcher (Inada, 1963). The equations 6 and 7 describe respectively the capital and labour behaviour in the production function. When K or L is 0, then its growth is infinitely, and once K or L approach infinity, the derivative, meaning the growth, is approaching zero.

$$\lim_{K\to 0} F_K(K, L, A) = \infty \quad and \quad \lim_{K\to \infty} F_K(K, L, A) = 0 \; for \; L > 0 \; and \; A. \qquad (6)$$

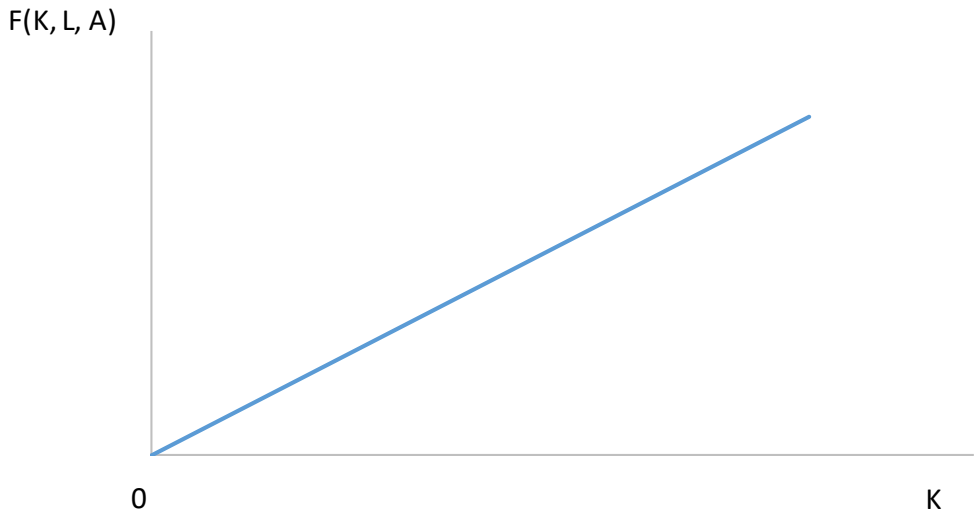
$$\lim_{L\to 0} F_L(K, L, A) = \infty \quad and \quad \lim_{L\to \infty} F_L(K, L, A) = 0 \; for \; K > 0 \; and \; A. \qquad (7)$$

In an example of a Robinson Crusoe economy, one may think about an abandoned island, where no production took place. Robinson (L) decides to collect the coconut from the tree, so the increase of production, which was 0, is approaching infinity for this first coconut after starting using labour. And vice versa, if Robinson found some helpers who will help him in collecting the coconuts, every additional helper (L) will be less productive, if the number of helpers approaches infinity, the increases in production become 0.

To visualise this example, Figure *3* shows a production function not supporting the Inada conditions and the diminishing returns to capital concept. It increases in a linear manner. Every increase in one of the production factors will lead to the proportional increase in the production, which is not supported by the neoclassical, or even the classical theory.

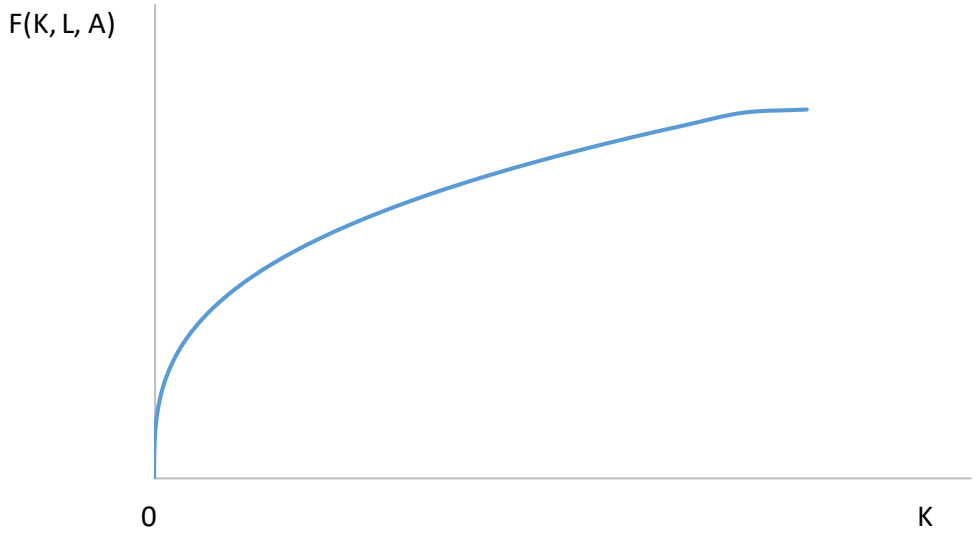
Figure *4* on the other hand presents the production function with all the assumptions met. One may see, that the increases of K or L lead to less and less increases of production. It looks similar to Figure *2* which presented the diminishing returns to capital concept, but differs because of the equations discussed above. When looking carefully, right at the 0 the line meets the axis (equation 6 and 7) and the end of the line is without any slope (equation 2).

Figure 3: Production function not supporting the diminishing returns to capital and the Inada conditions.




Source: Own elaboration based on the neoclassical production function.

Figure 4: Production function supporting the diminishing returns and Inada conditions.




Source: Own elaboration based on the neoclassical production function.

Having all the assumptions for the Solow Model and its advanced version described, the next step would be the procedure of reaching the steady state, a state of equilibrium, where the economy cannot get any more productive through additional capital increases; a state, where the per capita income is constant. The following steps will help reaching such a stable state.

To define capital growth, we use equation 8, where $\delta$ stands for the depreciation rate of capital and $I$ the investment. Hence the capital grows on the difference between investment and the depreciation.

$$K_{(t+1)} = K_{(t)} \times (1 - \delta) + I_{(t)} \qquad (8)$$

Equation 9 shows the pre-requirement for equilibrium in a closed economy. Knowing that C is consumption, the total production needs to be on the same level as the consumption with the investment.

$$Y_{(t)} = C_{(t)} + I_{(t)} \qquad (9)$$

Bearing in mind the formulas discussed previously, the following equation 10 requires a solution in order to visualise the allocation and capital increases in an economy:

$$K_{(t+1)} \leq F\left(K_{(t)}, L_{(t)}, A_{(t)}\right) + K_{(t)} \times (1 - \delta) - C_{(t)} \quad (10)$$

To obtain Equation 10 it was enough to insert the production function into 9 and solve it by I. And exactly this was inserted into 8, where K(t) was replaced with the production function as well. This means, that the capital in future period must be equal or lower than the increase of capital (function) plus the capital from previous period lowered by the depreciation rate; then one must deduct the consumption.

In the Solow model, the saving rate is exogenous (between 0-1) and further, the savings are equal to investment because we analyse the long run. So, the savings are equal to the production deducted by the consumption as in equation 11, which can be rewritten as 12 and the consumption as 13:

$$S_{(t)} = I_{(t)} = Y_{(t)} - C_{(t)} \quad (11)$$

$$S_{(t)} = sY_{(t)} \quad (12)$$

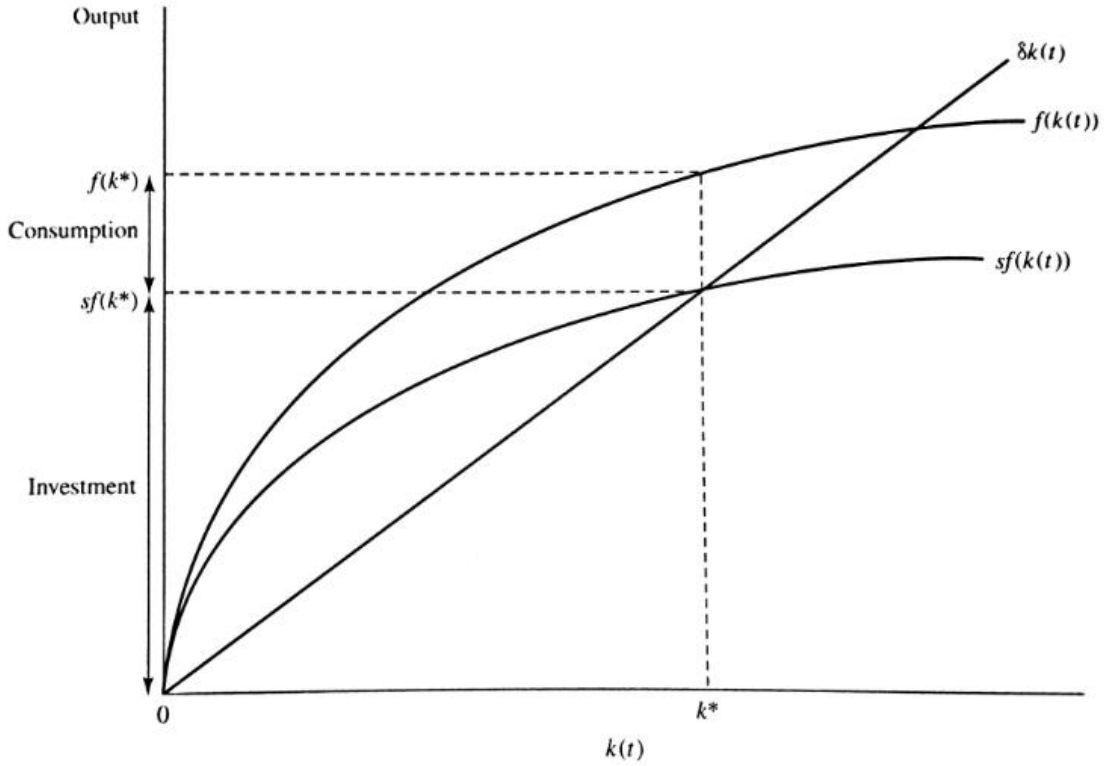
$$C_{(t)} = Y_{(t)} \times (1 - s) \quad (13)$$

After considering all the relevant relationships and equations the next step is the Solow-Model equilibrium, which has the following form:

$$K_{(t+1)} = sF\left(K_{(t)}, L_{(t)}, A_{(t)}\right) + K_{(t)}(1 - \delta) \quad (14)$$

In the steady state of the Solow Model, the economy grows at 0 growth rate, the higher growth is only achieved by the technological progress. The changes in the saving rate or the population growth affect the output respectively positive and negative. Furthermore, and most important for this thesis, countries tend to converge with each other. Figure 5 below, shows the Solow Model as derived previously, however lowercase letters stand for the units of effective labour (one may think about it like the units per capita).

Figure 5: Steady state of the Solow Model




Source: Acemoglu, D. (2010*). Introduction to modern economic growth*. Princeton University Press, p. 38.

When putting together the formulas, figure's and assumptions of the Solow model, the convergence implication is clearly visible. If two countries have similar parameters, i.e. saving rate, population growth and technological progress, their per capita income will tend to converge into a steady state due to diminishing returns to capital. This will occur irrespectively of the initial income level. Thus, to sum up the Solow model implies convergence, because of two assumptions already mentioned before:

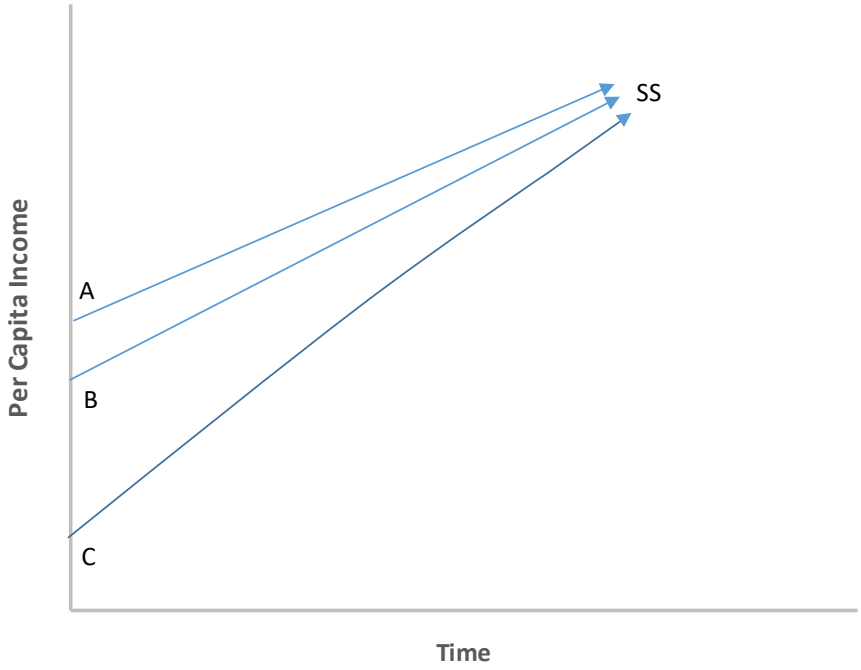
1. Diminishing returns to capital.
2. Same parameters across countries.

Specifically, this implies so-called unconditional or absolute convergence, because the parameters are assumed to be the same across countries. A contrary outcome will occur if the parameters are allowed to vary depending on the region; in such a situation conditional convergence is expected to take place.

Going back to the above two points, the first assumption was already explained and comes from classical theory, or rather neoclassical production function. The second assumption is derived from the long run perspective. In the long run, it is assumed that the exogenous parameters are equal. To visualise the absolute convergence process, *Figure 6* below will help.

The vertical axis represents per capita income and the horizontal axis represents time. There are three countries on the chart, A, B and C. Country A had the highest initial per capita income across them, while country C the lowest and B the middle one. One may observe that after a period of time, in the long run, the countries achieved one steady state marked as SS. This is because of different growth rates, which may change during time. Line B has a greater slope than line A, thus it grew faster, while line C has the biggest slope and the fastest growth rate. At the end all countries reach the same steady state in the long run. This phenomenon explained below presents the so-called beta convergence, where poorer countries are subject to a faster growth rate. There is however another solution to reach the same steady state as well. The so-called sigma convergence takes place, when richer countries are subject to a decline, and the gap is decreasing with time.

Figure 6: Unconditional convergence process presented on 3 countries with different initial income




Source: Own elaboration based on the unconditional beta-convergence hypothesis.

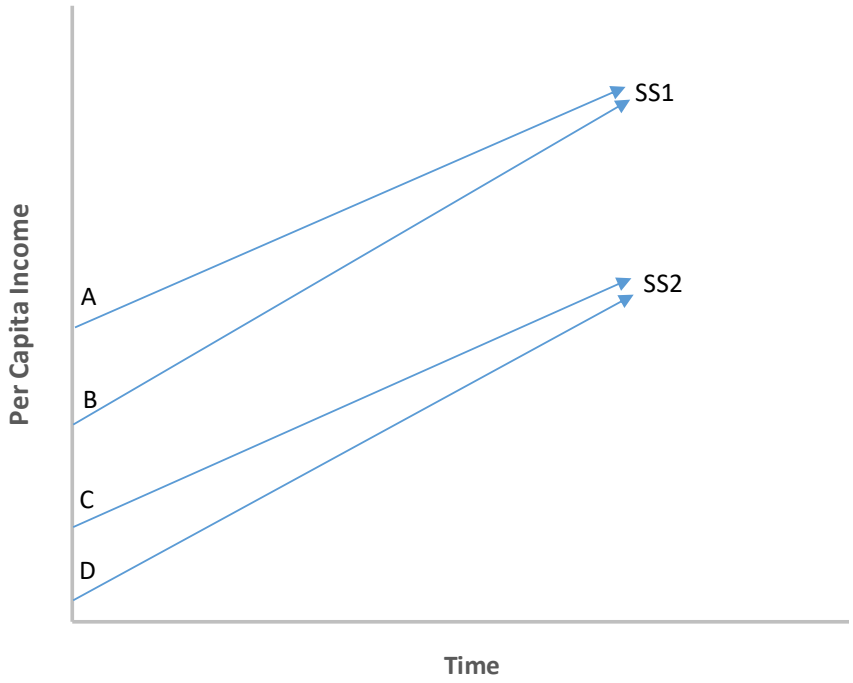
### 1.2.2 The neoclassical Mankiw-Romer-Weil model and the concept of conditional convergence

Another neoclassical model, which contributed largely to the convergence debate is the Mankiw-Romer-Weil model (MRW). Their paper, entitled "A Contribution to the Empirics Of Economic Growth" (Mankiw, Romer and Weil, 1992), enhances the previously described Solow Model by allowing human and physical capital accumulation in order to account for cross-country differences. To sum it up for the purposes of this research, the conditional beta

convergence is presented, which means that exogenous parameters like the saving rate, are not assumed to be equal in all countries. Moreover, according to the evidence provided by the authors, such a model accounts for 80% of the cross-country income variation. But also, another statement with respect to the Solow model was made: not all countries are assumed to converge towards one specific steady state, in fact there are more steady states and countries may reach their own one. Figure 7 below presents the different way of thinking from the standard Solow Model represented by *Figure 6*. For this example, four countries were considered with different initial incomes but also with different parameters in the regression. Countries A and B have similar parameters, so they are likely to converge towards one specific steady state, the SS1. Country B is therefore converging towards country A. On the other hand, there are other countries, C and D with even lower initial income then A and B. C and D have however different parameters than A and B, but they are similar with each other (for instance political situation). Therefore, they have a different steady state SS2 and country D converges towards the richer one country C.

From the empirical perspective one may think about similar groups of countries, like OECD or the EU.

*Figure 7*: Conditional convergence process presented on 4 countries with different initial income

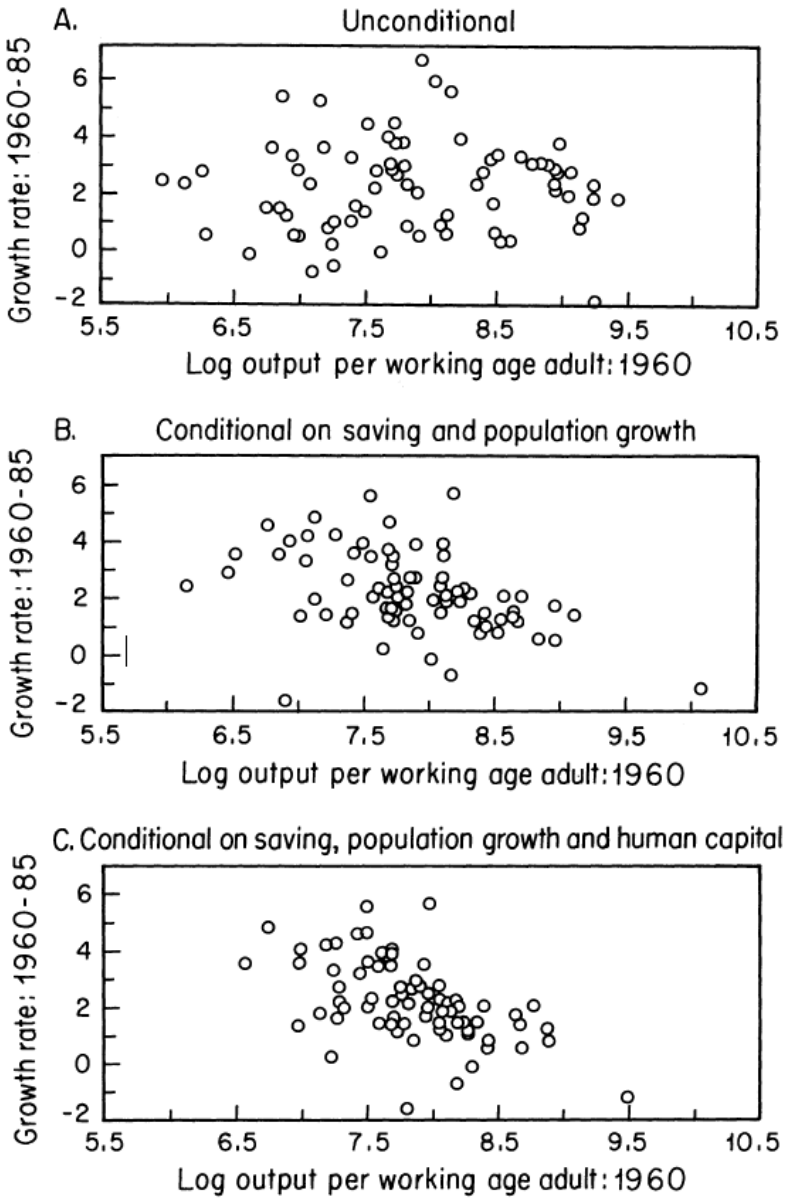



Source: Own elaboration based on the conditional beta-convergence hypothesis.

Looking at the model itself there is no need to derive it explicitly like the Solow Model explained before. One should only consider that in the first step the authors included a proxy for human capital into the basic Solow Model equation. In the second step, the authors allowed the parameters to vary across countries, i.e. they considered different investment, population growth, technology growth, depreciation rates, and furthermore the years of schooling were considered for the countries differently as a proxy for human capital. It turned out that the conditional convergence was more likely to describe the reality of the model (better statistical significance) and were subject to higher convergence parameters than the basic Solow Model. The Figure 8 below presents how important the parameters are for the whole convergence debate.

All the charts present the average growth rates on the vertical axes and the initial income on the horizontal ones. The points inside represent the countries. A perfect description of the convergence would be a straight line from the left top corner to the right bottom corner, and this would mean that countries with a lower initial income were growing much faster than the richer ones in 1960. Chart A shown in Figure 8 does not specifically support this hypothesis, but one may consider the group of countries on the right sight (between 8 and 9.5 log income), there somehow may be a line visible. Such a separation of countries (by similarities in parameters) could be called club-convergence. Charts B and C have exactly the same structure but position the countries in a perspective that is more in favour of the convergence hypothesis. This is how the conditional convergence with (Picture C) and without human capital (Picture B) represents the empirical evidence.

*Figure 8*: Unconditional vs. conditional convergence in the MRW Model




Source: Mankiw, Romer and Weil (1992). A contribution to the empirics of economic growth. The Quarterly Journal of Economics, 107(2), page 427.

There are much more neoclassical models of economic growth. Most of them are based on the Solow Model described above and some are slightly more advanced. There are also many authors and papers dealing with such kind of models, for example:

- Nonneman and Vanhoudt (1996): Enhanced the Solow model even further than Mankiw, Romer and Weil (1992) by adding the accumulation of accumulation of technological know-how (in an endogenous way, so although it is based on the Solow-Model categorising it as a neoclassical one is questionable).

- Durlauf, Kourtellos and Minkin (2010): Analysed the empirical data based on a Solow Model which allowed for differences in production function across countries.
- Ramsey (1928): Introduced a model in his original paper for countries to maximise the utility through a specific saving rate. Although it was written in 1928, the model was recognised and described in more detail much later. Cass (1965) and Koopmans (1963) made remarkable suggestions, therefore the Ramsey model is also known under the name "Ramsey-Cass-Koopmans Model".
- Arrow and Kurz (1970): The authors made later a version of the Ramsey model without restrictions in investment.
- To get the literature review on some neoclassical economic growth models, although rare, one may refer to Piętak (2014) or Abreu (2019) and of course to textbooks, for instance Romer (1996) or Acemoglu (2008).

### 1.2.3 Endogenous Growth Theory and the convergence controversy debate

In opposition to the neoclassical models and their respective theories, the endogenous, or sometimes called "new" growth theory developed. In the 1980s, the theory emerged as a more or less critical reply to the neoclassical school. As the name "endogenous" underscores, one may think intuitively about some models, which take some specific variables into account and explain them as well. This is exactly the case. Technological progress is in most of the cases explained by the model, which doesn't occur in the neoclassical one. Furthermore, the most important difference to the previously described neoclassical theory is that such models do not use the concept of diminishing returns to capital. Rather, the returns to capital may even get bigger and bigger when considering human capital, or to be more specific, human knowledge. These conditions imply that the convergence does not need to take place at all, since companies in richer countries may still be able to get higher profits through additional capital inputs and do not need to invest in a poorer one. Thus, one steady state for all countries when considering the unconditional convergence and for similar when considering the conditional one, is not a straightforward implication of the theory.

Some of the main authors dealing with the endogenous school of economic growth include Romer (1986, 1994), Lucas (1988) or Rebelo (1991).

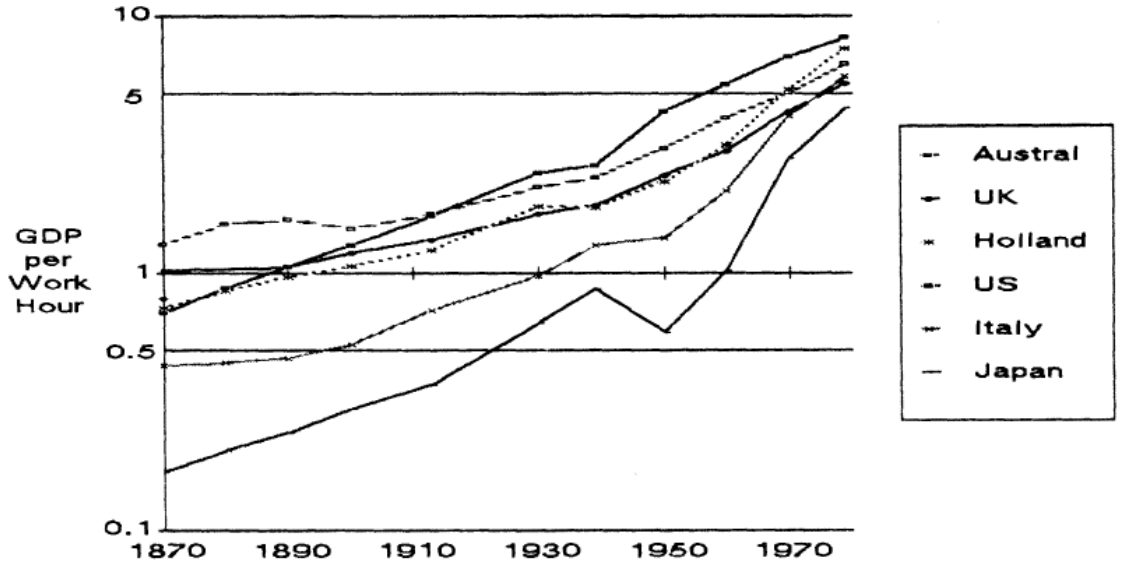
Romer (1994), who did a solid review of that topic, was of the opinion that the development of endogenous growth theory occurred because of two reasons: first, the convergence controversy and second, the passing of perfect competition. The second point relates to the small amount of developed economic growth models and their weak effectiveness

throughout the 1950s, 1960s and 1970s. The endogenous growth theory tried to develop a different point of view in that matter. This topic is certainly worth further investigation, but out of scope of this thesis. Therefore, the concentration is put on the convergence debate.

The convergence controversy emerged because of long-term empirical data sets that became available during that time, for instance the ones presented by Maddison (1977). This made the verification of some long-run models possible. The outcome of this kind of research was not straightforward. Some authors found evidence for convergence, some not at all. Hence the debate about the reality of the convergence hypothesis, and even the neoclassical theory, emerged.

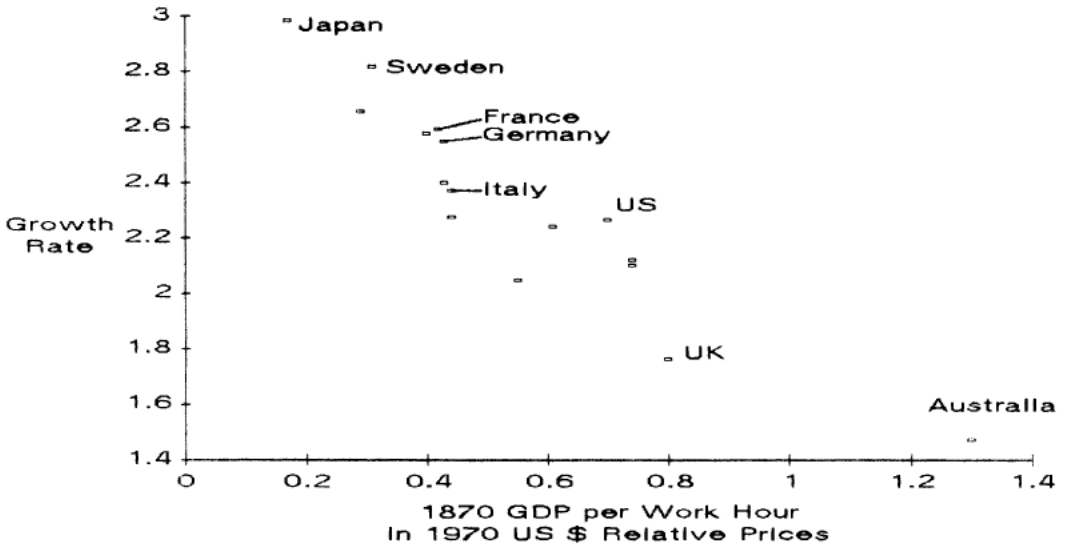
One of the first empirical findings that observed the convergence effect was conducted by Baumol (1986) with the use of the Maddison's (1977) data. In the first part of his paper Baumol discussed his observations from Maddison. The author later presented the convergence as a classical topic in economics, as an example the papers from Gerschonkron (1952) and even Veblen (1915) are taken: the authors observed the backwardness in productivity of industrialised countries in comparison to poorer ones. Further, some interesting findings about the income convergence are found in the paper as well. Figure 9 is an example of such a finding. Baumol took 6 countries from the Maddison data, namely Australia, United Kingdom, Holland, US, Italy and Japan. As one may see, the GDP per hour worked ratio was completely different in the starting period of 1870. But after 100 years it converged and the magnitudes became more common to all of the countries in 1970s. In fact, not only the unconditional beta (income) convergence is observable, but also the sigma, when considering Australia's decreasing income. It is also interesting to see, that Japan and Italy grew much faster than the remaining countries, especially after the Second World War, at which Japan's economy suffered mostly. A very similar trend is confirmed when analysing the growth rates in Figure 10, where we see some additional countries as well. The main finding here is straightforward: countries with lower initial income have a higher average growth rate – convergence takes place.

*Figure 9*: Convergence and productivity development of 6 chosen countries.




Source: Baumol (1986). Productivity growth, convergence, and welfare: what the long-run data show. *The American Economic Review*, page 1075.

*Figure 10*: Correlation of the initial income level and the average growth rate




Source: Baumol (1986), Productivity growth, convergence, and welfare: what the long-run data show. *The American Economic Review*, page 1076.

Furthermore, Baumol also highlights the unconditional convergence topic:

> Rather, what is striking is the apparent implication that only one variable, a country's 1870 GDP per work-hour, or its relation to that of the productivity leader, matters to any substantial degree, and that other variables have only a peripheral in-fluence. (Baumol, 1986, p. 1077).

The above-mentioned statement assigns all the significance towards one variable, namely the initial income. This however is questionable, especially when considering all countries of the world. De Long (1988) suggested that the countries chosen by Maddison are not random ones. These are indeed countries, which were able to track the history and are nowadays industrialised, so the convergence is self-explanatory in that case. As an example one may think about Ethiopia, one of the countries with the currently lowest GDP per capita income in the world. There is no data for this country going so far back – and probably for other poor countries as well. And having exactly this type of countries in the dataset would allow somebody to investigate the unconditional convergence in a world-trend, but once again, in the 1980s the data availability was much more problematic than today. But on the other hand Baumol (1986) mentioned the following:

> If country A's extraordinary investment level and superior record of innovation enhances its own productivity, it will almost automatically do the same in the long run for industrialized country B, though perhaps to a somewhat more limited extent. (Baumol, 1986, p. 1077).

It is clear that Baumol was completely aware of the problem and indicated the club convergence phenomenon in a more or less specific way - not the unconditional convergence across the whole world. Even more on that topic can be read in Chapter IV of his paper together with an explanation why the less-developed countries catching-up process is small. Baumol offered two specific reasons: the product mix and the education. The first one is straightforward. As an example one may think about technological progress made in Germany with respect to computer chipset production. Countries that are not very industrialised, e.g. Ethiopia or Zimbabwe, do not benefit from this innovation, as industrialised countries, because they do not produce neither computers nor chipsets. The second point relates to the education of the people in a country. Not having educated inhabitants leads to less innovation and less productiveness, although the convergence process may also be interrupted or not present at all. Baumol also verified whether the data supports the hypothesis of higher unemployment when productivity increases (robots will take our jobs), and it didn't. Quite the contrary: countries with higher productivity levels were in some cases subject to lower unemployment rates. Last but not least

the author concluded that the long run matters for policy makers. The economists/politicians focusing only on short run problems, like recessions, may forget about some powerful tools in the long-run policy toolbox, ones that were already analysed by the classicists.

As a response, or rather complementary to Baumol's paper, Abramovitz (1986) did an in-depth analysis of the rate of convergence using Maddison's dataset as well and checked 16 countries between 1870 and 1979. First of all, Abramovitz introduced the catching-up hypothesis and explained it as an implication of technological progress's transfers and allocations. The capital stock of richer countries is more advanced than that of the poorer ones. When a richer country replaces, let's say, the old machines with the new ones, the gap is not so high, as when a poor country replaces their obsolete technology. The higher the gap, the more productivity increases come with replacement of the capital stock. Furthermore, knowledge plays a potential role in the whole process as well. In fact, Abramovitz summarised the main idea behind the convergence into four points, as follows:

- Technological progress achieved by modernisation enhances growth because of both the returns from the modernisation done and the price reduction of capital goods in comparison with the labour price.
- Productivity growth enhances the aggregate output.
- Poorer countries have an opportunity from disembodied and embodied technology.
- Poorer countries may benefit from the improved labour allocation using redundant workers who were active for instance in the primary economic sector.

An important addition from the author, or rather an explanation for the catching up capability, was social development. The weak initial technological stage is not an adequate condition for the less developed countries to catch up; they need to be somehow socially advanced and capable of implementing the new technology. Abramovitz was of the opinion, that this social stage may be calculated as years of schooling, experience, management capabilities and openness of the country. Hence, although not defined by the author, a specific human capital level and proper economic institutions are what was meant with such a pre-requirement for the adoption of technological progress. Going further, Abramovitz calculated the relative productivity variance and correlation between initial income levels of productivity and its growth rates. After checking 15 countries with comparison to the US, the variance declined strongly from 0.5 in 1870 to 0.15 in 1979; this is clear evidence for the convergence. The inverse rank correlation between the initial productivity level and the growth rates was stronger over time as well. The only period not affected by the trend was World War II. After 109 years, the productivity level across the countries became similar. Hence the productivity

convergence took place. The author however highlighted the bias of the sample, previously mentioned: the countries were not selected randomly, but all of them are technologically advanced today. The results and conclusions were similar to the ones from Baumol (1986), but Abramovitz also analysed the time periods and splits the convergence of the 15 countries to US and the convergence of the 15 countries between each other. It was straightforward to split the time period between the two World Wars and what happened after. The highest convergence occurred after World War II due to all the effects responsible for enhancing the convergence effect: technological gap, higher social competence and general favourable conditions towards reforms. During the World War II period the convergence was not observable, in fact divergence occurred. Abramovitz concludes, that the convergence is not a specific phenomenon that may be applied to the initial income, as opposed to Baumol, there are some pre-requirements for a country like social capability and other determinants like natural resources or political wealth. The following quote from the conclusion should make Abramovitz's view on the convergence hypothesis clear:

> A reasonably complete view of the catch-up process, therefore, does not lend itself to simple formulation. Its implications ramify and are hard to separate from the more general process of growth at large. (Abramovitz, 1986, p. 406).

When considering productivity convergence one should bear in mind, that increases in the productivity were and are associated with increases in per capita GDP. This is why earlier studies were concentrated on this variable. The productivity enhancements were somehow treated as a synonym to the ones of GDP, especially when compared in the long-run. Although the GDP per capita analyses of the convergence (income convergence) are nowadays dominant, the research on productivity convergence is performed as well (e.g. Poudel, Paudel and Zilberman, 2011; Turganbayev, 2017).

One strong argument against the observed convergence was the already mentioned Maddison (1976) dataset that included a specific group of industrialised countries, which of course converged (DeLong, 1987). But Romer (1986) went much deeper and provided a knowledge-based growth model without the neoclassical diminishing returns to capital concept, with opposing results - in his model, the marginal productivity was increasing. In Romer's model the countries do not need to converge, in fact the poorer countries may even grow lower than the richer ones. This is because according to the author the knowledge as a special case of capital creates benefits that may be accumulated and used even further. Hence the long-run growth is knowledge driven by agents, who maximise their profits and look forward. In

addition, the technological progress is determined within the model, so the reader may find the departure from the Solow based models with exogenously defined technology. Furthermore, and what is important for this thesis as well, the author reviewed some papers about the convergence hypothesis. As a general result he found that similar countries tend to converge towards each other and that there is no evidence indicating the unconditional convergence when considering both the poor and rich countries.

Like Romer, Lucas (1988) observed a failure of countries to converge. Contrary to the previously described authors, Lucas used the World Bank Dataset (1983) and right at the beginning presented the enormously high differences in income per capita. For example, the industrial market economies had the GDP per capita on a 10,000 USD level in 1980, whereas Haiti and India 270 USD and 240 USD respectively. What is an more important observations is that the poorer countries did not manage to have higher growth rates, than the richer ones. One should mention however, that the author didn't use a specific methodology and didn't calculate any correlations - he simply compared some countries with each other. This comparison may be therefore biased because of the same argument, like the Madison dataset did. The empirical facts and the lack of a proper methodology only highlight the importance of the convergence research. Partly because of these reasons, Lucas (1988) presented in his work three specific models of economic growth: one considering physical capital accumulation and technological progress, second with human capital measured by years of learning and third, a model with human capital benefits from learning-by-doing. To conclude the research on convergence, the authors proposed a model, where poor countries remain poor and richer ones will stay rich because of the marginal product of physical capital, that tends to a constant. The convergence exists but is limited to some initial conditions. But when human capital is introduced and the model is considered as an open one, the convergence effect may depend exactly on such capital. One example would be the increasing wages in a rich country for qualified personnel, due to these increases employees from poorer ones would move to the richer country and thus even a divergence would be possible. The author also highlighted, that the model is fitting the evidence when analysing the US economy, but no special calculations on convergence were provided.

In the same period as Romer's and Lucas' research, Kormendi and Meguire (1985) found evidence for conditional convergence, although it was neither called that, nor was the aim of the article. The authors departed from growth accounting used during that time, which was based more or less on the factor inputs like labour or capital. Contrary, or rather complementary to such kind of research, they investigated 47 countries from the International

Monetary Fund database between 1950 and 1977. Eight hypotheses with the respective variables were chosen to obtain the growth determinants and its patterns. The initial conditions and population growth (neoclassical theory), the monetary variance (Barro's hypothesis from 1976, 1980) and money supply, the trade-off in technology (Black's hypothesis from 1979), the government spending (supply side hypothesis), inflation effect on capital stock (Tobin-Mundell hypothesis) and the trade openness of a country. The following equation (15) was used by the authors:

$$MDY_{(j)} = \alpha + X_{(j)}\beta + \varepsilon_{(j)} \tag{15}$$

Where $MDY_{(j)}$ represents the mean growth rate of aggregate output for country j, $X_{(j)}$ is a vector of the variables described before, $\beta$ is the coefficient vector and $\varepsilon_{(j)}$ the error term. The authors described the measures utilised for the variables set in $X_{(j)}$ together with their importance, to sum them up the situation looks as follow:

1. The first variable, initial per capita income (YPC), represents the neoclassical hypothesis that was already observed by previous researchers who dealt with the convergence effect. It is expected that the lower initial income will result in higher growth rates and vice versa. The authors used the 1975 per capita income in USD international prices.
2. The second hypothesis about the population growth (MDPOP) is not well-known in today's conditional convergence research. In a state, the country's growth rate should equal the exogenous technological growth and the growth of the labour force. Hence in the steady state the population growth rate equals the output growth rate. But if there is no steady state and the countries are in transition, then it is likely that the labour force or capital accumulation do not grow accordingly to population growth. If population grows faster, then the output growth is affected negatively.
3. Another variable, namely the standard deviation of monetary shocks (SRM) is derived from Barro's (1976, 1980) hypothesis about the monetary variance impact on investment. To be specific, if a country's monetary policy is difficult to predict, the investors are not very likely to foresee the potential earnings either. As a result investment may decline.
4. The risk of the aggregate technology measured by the standard deviation of the output growth (SDY). The hypothesis was introduced by Black (1979); countries are subject to positive risk-return trade off when choosing the aggregate technology. Riskier

technologies would be preferred and chosen, only if they would generate greater return and finally higher economic growth. The MDY should be therefore positively correlated with SDY.

5. The mean of money supply growth (MDM) is a variable that represents another hypothesis with respect to the monetary policy. Following Lucas (1972, 1973) and Barro (1976, 1980) the authors introduced the possibility of rejecting the monetary policy neutrality as another MDY determinant. According to the hypothesis the output growth should be unrelated to the money supply growth rate.
6. The mean growth of the government spending to output ratio (MDGX). The assumption during the period when the article was published was that the higher ratio of government spending is subject to lower output growth because of worse resource allocation. Thus, this variable was expected to show a negative correlation with the mean growth rate.
7. To verify the trade openness of a country, the mean growth of the exports to output ratio was utilised (MDEXX). The argument is straightforward: trade restrictions may affect the efficiency of an economy when looking at the comparative advantage and reducing the aggregate output which is part of the GDP anyway. Countries with a higher export to output ration should be therefore subject to higher average growth.
8. Last but not least the mean growth of inflation rate was considered (MDINF). According to the Tobin-Mundell effect in case of a high expected inflation rate, the money demand, or rather its balance, shifts towards real capital. This means that if a higher inflation takes place or is expected, people will tend to invest more in capital goods and therefore have a positive impact on economic growth. It is also worth mentioning, that Stockman (1981) was completely on the opposite side, suggesting a negative effect of inflation on GDP growth.

Furthermore, the regressions were run in two different versions, one including the Investment to GDP ratio, and the other without it. The reason for such a variation was to exclude the potential effects of other variables (1-8) on investment. The results of the regressions are presented below in Table *1* and *Table 2*, which include the investment variable:

Table 1: Summary of the conditional convergence regression results.

| | **Coefficient** | **Standard Error** | **T-statistics** |
|---|---|---|---|
| **YPC** | -0.006 | 0.0019 | -3.1 |
| **MDPOP** | 0.58 | 0.17 | 3.5 |
| **SDY** | 0.53 | 0.17 | 3.0 |

| | | | |
|---|---|---|---|
| **SRM** | -0.27 | 0.05 | -5.5 |
| **MDM** | 0.061 | 0.025 | 2.4 |
| **MDGX** | 0.024 | 0.14 | 0.2 |
| **MDEXX** | 0.075 | 0.061 | 1.2 |
| **MDINF** | -0.85 | 0.28 | -3.1 |

**Other Regression variables**

| | | |
|---|---|---|
| $R^2$=0.70 | $\overline{R^2}$=0.63 | SDR = 0.0095 |

Source: Own elaboration based on Kormendi and Meguire (1985). Macroeconomic determinants of growth: cross-country evidence. Journal of Monetary economics, 16(2), page 147.

*Table 2*: Summary of the conditional convergence regression results with the investment to income ratio variable (MIX).

| | **Coefficient** | **Standard Error** | **T-statistics** |
|---|---|---|---|
| **MIX** | 0.12 | 0.04 | 3.3 |
| **YPC** | -0.0086 | 0.0018 | -4.9 |
| **MDPOP** | 0.60 | 0.15 | 4.0 |
| **SDY** | 0.35 | 0.16 | 2.7 |
| **SRM** | -0.14 | 0.04 | -3.7 |
| **MDEXX** | 0.11 | 0.05 | 2.2 |
| **MDINF** | -0.31 | 0.25 | -1.2 |

**Other Regression variables**

| | | |
|---|---|---|
| $R^2$=0.72 | $\overline{R^2}$=0.67 | SDR = 0.0090 |

Source: Own elaboration based on Kormendi and Meguire (1985). Macroeconomic determinants of growth: cross-country evidence. Journal of Monetary economics, 16(2), page 152.

Looking at the regression excluding MIX from Table *1*, 63% of the variation in measured economic growth was explained, which is a solid result. The initial income turned out to have an effect on the economic growth – the neoclassical convergence hypothesis may therefore be confirmed. The population coefficient also confirms the neoclassical hypothesis but having a value of 0.60 it is below 1, which means that the population effect on growth doesn't go one for one. Although SDY may not be a prefect measurement for the aggregate technology, it has a positive effect on economic growth; for every 2% increase in SDY, there

is a 1% greater economic growth. The money supply shocks, SRM, have indeed a negative effect on the economic growth. MDM, MDGX and MDEXX have a little support of the respective hypotheses when considering the standard error. In fact, the government spending are even presenting the contrary result and would, although very little, enhance economic growth. The last variable, inflation, turned out to support the Stockman (1981) hypothesis: the higher it is, the worse GDP growth may be expected. The coefficient is also three times its standard error, and suggests a very strong effect.

The next part of the regression included the investment variable, which should lower the effect of the remaining variables that may directly or indirectly influence the GDP growth exactly through such an investment. First of all, the MIX has a positive effect on economic growth, which was expected. The coefficient also bears huge power looking at the size of standard error (1/3 of the coefficient). The initial capital again confirms the convergence hypothesis, with a slightly higher coefficient then previously. Other variables didn't change so much as well, when compared with Table *1*.

The paper from Kormendi and Meguire (1985) may be considered as the leading one when looking at the methodology and the conditional convergence verification. Grier and Tullock (1989) also analysed conditional convergence as well. The authors used data from Sumer and Heston's database (1984) and analysed 113 countries with 7 variables to see whether they have an impact on GDP growth or not. The variables include initial GDP per capita (IGDP), growth rate of government spending's to GDP ratio (GOV), standard deviation of GDP growth (SDGDP), population growth (POP), inflation (INF), the change of inflation (CINF) and the standard deviation of inflation (SDINF). It is important to note that the authors performed some adjustments in the dataset in order to, for instance, net out cyclical fluctuations. One example of such an adjustment would be the averaged variables through 5 year intervals. Having once more a look into the variables, they are not much different than the ones utilised by Kormendi and Meguire (1985). Some of them are different and not as straight forward as it may seem, therefore additional explanation may be useful:

- Standard deviation of inflation: the hypothesis comes from Hayek (1944) and Friedman (1977), where the authors suggest, that higher inflation leads to uncertainty, which again influences the market activity. People who do not feel secure about the future value of money are of course more likely not to be certain about the market prises. The high variability of the inflation should affect GDP growth negatively.
- Standard deviation of income growth: should the income streams be subject to variability the uncertainty will lead to higher saving rates. Higher saving rates again are

considered as having a positive effect on growth and on aggregate risk-return trade-off in technology.

- Government consumption growth: the authors separated here the hypothesis of the government's intervention effect on the economy in two aspects. The first one, investment on basic public goods like roads, property rights, is considered to be growth-enhancing whereas any government regulations on economic activities were considered as lowering the growth. The variable used in the paper net out the government investment and transfers, further it is important to highlight that the variable a growth of the government's share in GDP; this should therefore be considered as having a negative effect on growth, since it involves more government activity.

Looking at the results it is worth mentioning, that the authors separated the regressions by the 24 OECD countries, the 89 Rest of the World Countries (ROW) and further, some geographical patterns, for instance, Africa, Americas and Asia. This is because the statistic inference strongly suggested not pulling all the data at once. Table 3 provides the summarised conclusions:

Table *3*: Summary of the conditional convergence regression based on the regions.

| | **OECD** (1951-1980) | **ROW** (1961-1980) | | **Africa** (1961-1980) | **Americas** (1961-1980) | **Asia** (1961-1980) |
|---|---|---|---|---|---|---|
| **IGDP** | -0.00083 | 0.00057 | | 0.00099 | -0.00019 | 0.00098 |
| **GOV** | -0.320 | -0.064 | | -0.207 | -0.126 | 0.113 |
| **SDGDP** | 0.170 | 0.097 | | 0.152 | -0.051 | -0.133 |
| **POP** | 0.870 | 0.669 | | 0.502 | 0.849 | 0.252 |
| **INF** | 0.014 | -0.159 | | -0.276 | 0.135 | -0.107 |
| **CINF** | -0.042 | 0.041 | | 0.087 | -0.095 | -0.006 |
| **SDINF** | -0.114 | -0.081 | | 0.016 | -0.095 | -0.148 |

Source: Own elaboration based on Grier and Tullock (1989). An empirical analysis of cross-national economic growth, 1951–1980. Journal of monetary economics, 24(2), pages 265, 270.

To visualise the differences in results better, the negative coefficients were highlighted. The convergence was visible only across the OECD and American countries, with a much higher rate for the OECD ones. Other countries didn't show the catch up process, even the opposite - they were subject to divergence. In Africa and Asia, the richer countries with higher initial income tended to growth faster than the poorer ones. POP, GOV and SDINF were the only variables that were everywhere with the same coefficient (despite Asia for GOV and Africa

for SDINF). Surprisingly, POP confirms the Malthusian hypothesis from the 18th century, described at the beginning of this thesis, where higher population led to lower income. The negative GOV variable means that higher government involvement is subject to lower GDP growth. The negative SDINF supports the hypothesis from Hayek (1944) and Friedman (1977) and confirms that uncertainty in market prices is not beneficial for the country's GDP.

Right from the outset, it may be seen that the results were mixed. It would also be correct to say, that the results indicated some heterogeneity. The authors themselves concluded that different countries and even different country groups were subject to specific growth patterns and no general model is applicable. Rather in contrary, a set of multiple models could fit the economic reality more likely.

After that time the researches started to verify the convergence effects more frequently, among other papers one may find Dowrick and Nguyen (1989) who confirmed post-war GDP and TFP convergence among the OECD countries, King and Rebelo (1989) with their conclusion, that neoclassical transitional dynamics cannot account for cross-country differences or Peacock, Hoover and Killian (1988) who departure from the standard hypothesis and tend towards the convergence heterogeneity based on the world-system theory that classifies nations into three zones. One obvious finding is, that there was no conclusion at all. Finally, Sala-i-Martin (1994) reached somehow a consensus and closed the debate with the proposal of a common rate of convergence of approx. 2% (Caselli, Esquivel and Lefort, 1996). The road to what would be seen as a consensus involved a lot of papers. Among the most important ones the reader may consider Barro and Sala-i-Martin (1990), Barro et al. (1991), Barro and Sala-i-Martin (1991), Barro (1991), Barro and Sala-i-Martin (1992) and, last but not least, Sala-i-Martin (1994).

The working paper from Barro and Sala-i-Martin (1990) did a so far original research on convergence effect, because it verified the US states, and not a set of countries, which was common among the previous articles. The interesting thing about this special set is, that the US states may be considered as completely open economies, hence the transitional dynamics and the catching up process should theoretically be more visible. The sample itself is pretty remarkably counting 48 states, personal income since 1840 and gross state product since 1963 until 1985. Further, the authors compare the results with a regression for 98 countries from 1960 to 1985. Both unconditional and conditional convergence with some extra variables like school-enrolment rates or government consumption were verified, the sigma convergence was checked as well in addition to the main analysis.

The methodology involved a regression which was based on a neoclassical and a endogenous growth model. The authors derived and described every single variable in a detailed way, further, the parameter representing the convergence speed is defined as β – that's where the term "beta convergence" comes from.

Conditional beta convergence turned out to be present clearly among the US states across many timeframes of the 1840-1988 period and, when considering the long period, the unconditional convergence was visible as well. First remark towards the previously described 2% consensus may be seen here: the rates of the conditional beta convergence ranged mostly between 2.0-2.5%. Looking at 98 countries from 1960 to 1985 only conditional convergence was present when holding constant the school-enrolment rates and the government consumption. The speed ranged about 2% per year as well. Another worth mentioning conclusion, or rather remark, is that the capital-share coefficient α was set as 0.8. If the parameter would have been lower the convergence speed would increase even more because of the enhanced process of diminishing returns to capital. This parameter is therefore crucial when analysing the convergence speed of any kind. So when analysing some endogenous growth models, which do not allow for diminishing returns to capital, the α parameter should become 1; but in that case the convergence would be much lower or not take place at all for the analysed sample. Some additional results are presented in Table 4, below.

Table 4: Summary of the convergence results based on the specific sample.

| | **Unconditional β** | **Conditional β** |
|---|---|---|
| **98 countries (1960-1985)** | -0.0037 | 0.184 |
| **20 OECD (1960-1985)** | 0.0095 | 0.0203 |
| **48 US States (1963-1986)** | 0.0218 | 0.0236 |
| **48 States, personal income (1930-1988)** | | 0.0207 |
| **29 States, personal income (1840-1880)** | | 0.0254 |
| **48 States, GSP (1963-1986)** | | 0.0222 |

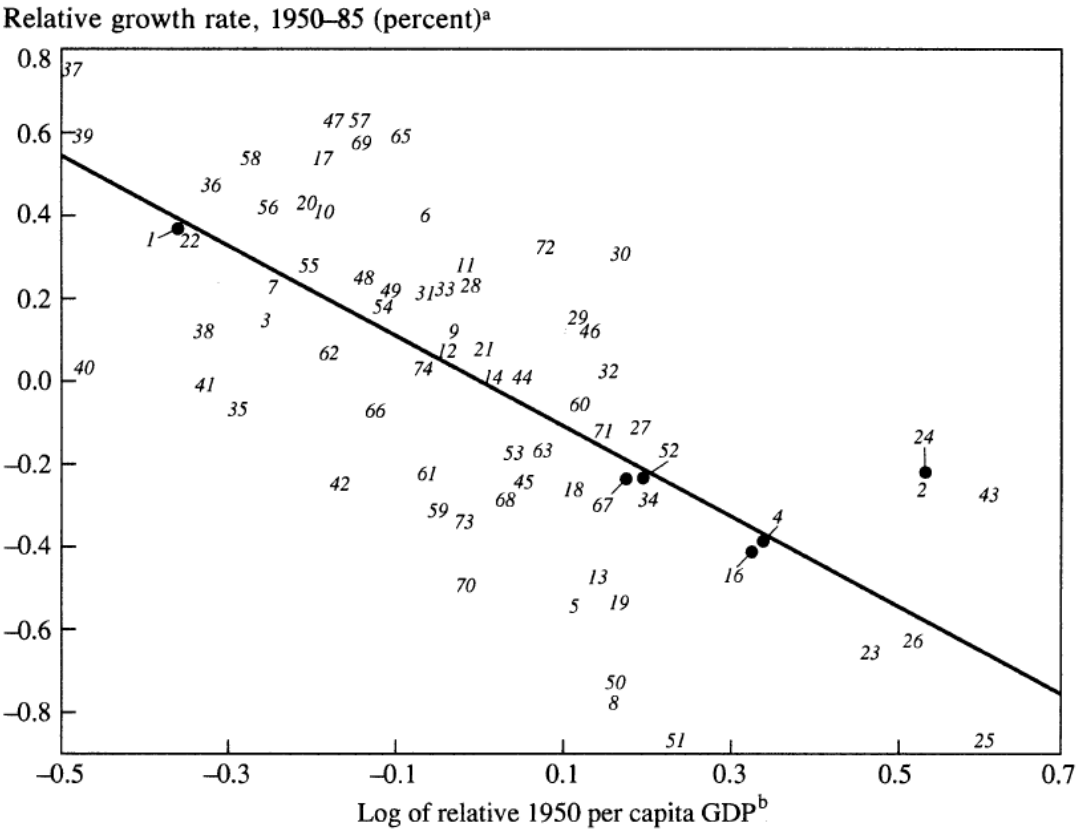
Source: Own elaboration based on Barro and Sala-i-Martin (1990). *Economic growth and convergence across the United States* (No. w3419). National Bureau of Economic Research, pages 42-47.

The next article from Barro et al. (1991) is complementary to the previously described Barro and Sala-i-Martin (1990); the methodology did not change. It is an extension of the empirical convergence analysis based on a bigger set of countries, namely 73 regions of Western Europe during the post war period after 1950. First, the authors performed a very similar analysis to the earlier one. They investigated the convergence effect across US states from 1880 to 1988, however with some additional variables for conditional convergence. Those additional variables included, despite some regional dummies, the share of income originating from agriculture at the start of the period and a structural composition variable. All the periods combined resulted in an unconditional β convergence of 1.75% and a conditional convergence of 2.24%, which is consistent with the previous paper. Further, the discussion about other relevant variables like migration or specific shocks was performed.

The second part of the paper concentrated on the European regions. It was not only Western European countries, but parts of them. So for Germany 11 regional GDP magnitudes were defined, for Italy 20, United Kingdom 11, France 21, Netherlands 4, Belgium 3 and last but not least 3 regions in Denmark which resulted in 73 regions overall. Such an approach, original so far, highlighted the differences across the countries itself. It is a fact, that Eastern Germany suffered more economically after the World War 2, than the Western part. For convergence purposes such a split is clearly understandable. The authors plotted the 1950s initial GDP value with the average growth rate in the period 1950-1985 of the European regions into a chart, which presented the convergence patterns very clear. *Figure* 11 was taken from the article, since it described well the transitional situation. Many of the regions with a lower initial GDP were subject to higher average growth and vice versa, the regions with a higher initial GDP did not manage to achieve the average growth level; this is especially visible on data points 37, 39 on the top left and 25, 23, 26 on the bottom right.

The regression results were slightly lower for the conditional beta convergence when compared with the US and slightly higher for the unconditional beta convergence; 1.78% and 1.83% respectively. This result fits into the commonly used 2% rate. Further, the authors performed a second analysis, where they allowed the β parameter to vary across countries (but not throughout the period). Table 5 presents these results. One may see, that the Netherlands were subject to the highest convergence rate of 4,96%, however with a huge standard error of 2.02. Netherlands were followed by UK (3.37%), Belgium (2.37%) and Germany (2.30%).
Last but not least the authors presented the sigma convergence across the European Regions, which is in *Figure* 12. As the reader may see the GDP difference nearly halved from 0.29 in 1950 to 0.18 in 1985. This is a clear evidence for sigma convergence.

Figure 11*:* Convergence of GDP across European Regions: 1950-1985.



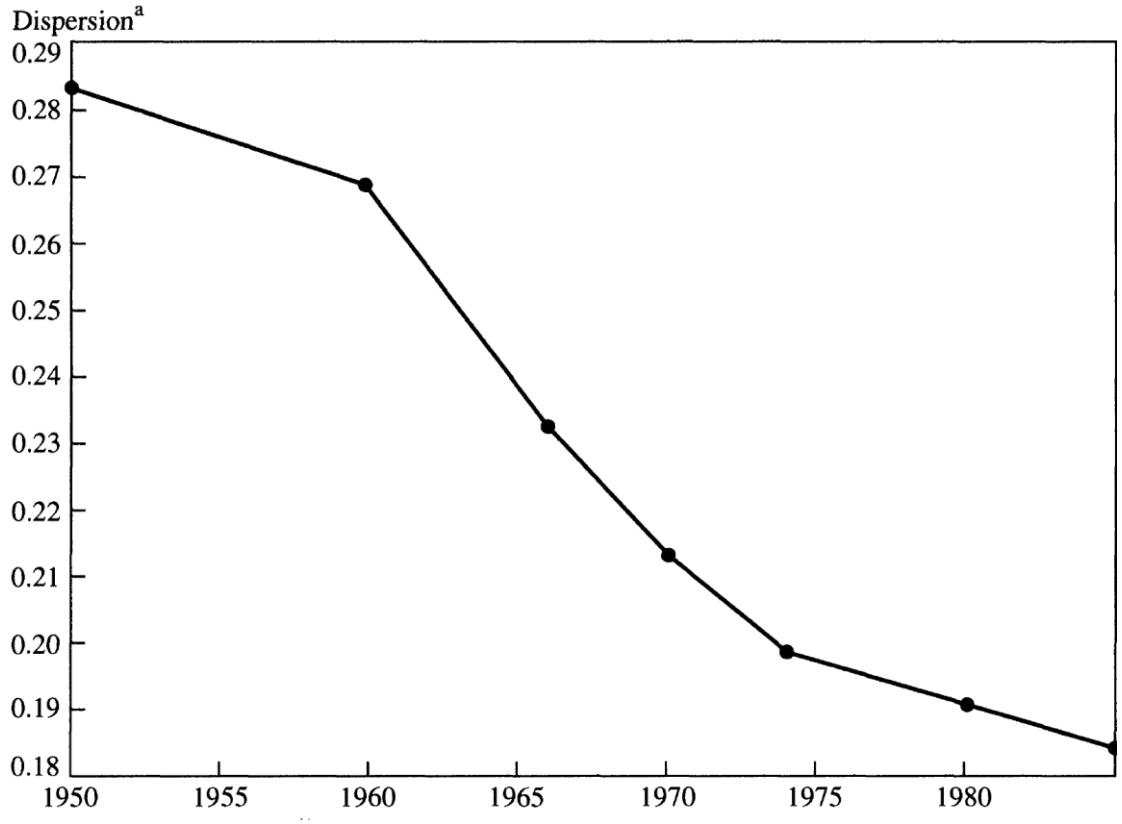

Source: Barro et al. (1991), Convergence across states and regions. *Brookings papers on economic activity*, page 144.

*Table 5:* Summary of the conditional convergence regression based on European Countries.

| | **Conditional β** (1950-1985) | **Standard Error** |
|---|---|---|
| **Germany (11 regions)** | 0.0230 | 0.0061 |
| **United Kingdom (11 regions)** | 0.0337 | 0.0093 |
| **Italy (20 regions)** | 0.0118 | 0.0036 |
| **France (21 regions)** | 0.0097 | 0.0059 |
| **Netherlands (4 regions)** | 0.0496 | 0.0202 |
| **Belgium (3 regions)** | 0.0237 | 0.0164 |
| **Denmark (3 regions)** | 0.0018 | 0.0211 |

Source: Barro et al. (1991), Convergence across states and regions. *Brookings papers on economic activity*, page 147.

Figure 12*:* Sigma convergence across European Regions: 1950-1985.




Source: Barro et al. (1991), Convergence across states and regions. *Brookings papers on economic activity*, page 149.

Barro (1991) published another paper which revealed more empirical facts with respect to economic growth. Not only was the convergence hypothesis verified, but also some patterns about human capital, investment, government consumption or political stability. The sample from Summers and Heston (1988), UN, World Bank, some local Banks and various other sources included 98 countries throughout the period from 1960-1985.

It turned out that the initial GDP is not negatively related to the average growth rate throughout the years – which is contrary to the unconditional convergence hypothesis – but if one includes the human capital variable, then convergence takes place. Barro looked at the school enrolment rates and included them in the regression to have a proxy for human capital, which, even according to Barro himself, is not a perfect indicator. The reason for it is because the initial school enrolment rate explains rather the investment into human capital than its initial level. Looking at the results, the conditional beta convergence for the whole sample is equal to 0.75% with a small standard error of 0.0012. One should also mention the huge variation of the sample, i.e. the GDP ranged from 208 USD to 7,380 USD. The results are therefore in contrary

to the ones performed by different authors or endogenous growth followers who claimed that the convergence across world countries does not take place. Of course, the sample is different, but the true reason behind this difference is the human capital proxy that was included by Barro, which has a real and significant impact on the results.

Other variables and results are worth mentioning as well. The GDP growth was negatively related to the government consumption to GDP ratio. The private investment to GDP was subject to negative correlation with the government consumption to GDP ratio as well, and this observation may suggest the crowding out effect. Furthermore, public investment did not highly correlate with growth. The physical investment seemed to increase with higher human capital, and further, human capital decreased the fertility rate. The political instability indicator (including revolutions, coups, and political assassinations) caused less growth, which is straightforward. Similar to research described previously, price distortions didn't increase the GDP growth here as well. Those observations may be interesting not only for growth and convergence analyses, but also for policy makers.

Last but not least Barro and Sala-i-Martin (1992) republished their NBER working paper (Barro and Sala-i-Martin, 1990) in the Journal of Political Economy with the same content as in 1990. This allowed for a much higher reader spectrum and assured greater awareness of economic growth. Later, Sala-i-Martin (1994) reviewed the convergence debate.

To summarise the research about convergence throughout the end of 20$^{th}$ century, there was no conclusion whether convergence exists or not. There was also no clear terminology before Barro and Sala-i-Martin (1990) when analysing its different types. Also, the methodology was not defined and convergence analysis was subject to simple comparisons between the initial income and the average growth rate. Once the initially richer country had a lower average growth rate than the poorer one, the convergence was assumed to take place. The advanced methodology was introduced by Kormendi and Meguire (1985), who published a leading paper with respect to the conditional convergence verification and later by Barro and Sala-i-Martin (1990). They introduced a common regression framework that was utilised by other researchers. From this point, many papers have adopted it and continued the research using different countries and different time frames. The "natural" rate of convergence seemed to be around 2% and varied only little from sample to sample. This seemed to be a commonly accepted result known as the convergence consensus. The reason for it was not the small rate itself, but a redefinition of the neoclassical growth models prediction. Sala-i-Martin (1994)

wrote a review paper about the progress and the debate between the endogenous and neoclassical growth. The following citation should provide insight:

> The model's [neoclassical] prediction was, instead, that the growth rate of an economy would be inversely related to the distance from its steady state. Only if all economies were to converge to the same terminal point would poor countries grow faster than rich ones. But if one accepts that countries differ in their levels of technology, attitudes towards saving, tax rates, etc., then one must also accept that these countries will approach different steady states. The growth rate of an economy is then predicted to be inversely related to the distance from its steady state. The concept of convergence conditional on the steady state is known as 'conditional convergence'. (Sala-i-Martin, 1994, p. 743).

The impression was that since economists accepted this hypothesis and explanation, the convergence topic did not seem interesting anymore (with some outliers such as Caselli, Esquivel and Lefort, 1996). This changed when the 2008 global financial crisis emerged. After this phenomenon, the researchers started to ask themselves not only about the nature of the financial crisis, but later, whether it had a positive or negative effect on the convergence hypothesis. A lot of convergence related papers started to be published again and the convergence debate was reopened and is ongoing today. The next part of the thesis deals with this subject specifically. Also, as the reader may have noted at this point, the pre-crisis literature review above did not include many CEE or LA analyses. The reason for this is simple: during the 1990s the convergence literature did not focus on those regions, partly because of the historical data availability and partly, because the convergence topic was questioned in general, not only for a specific geographical area. Some literature for CEE started to appear in the very late 1990s (Brzeski and Colombatto, 1999) and more and more during the early 2000 when the data availability improved. To be more specific, the real high-quality papers were found after 2008 when the convergence debate was reintroduced (Jarco, 2018). The LA convergence-literature is more limited, especially when considering high quality papers with remarkable citations. Several are worth mentioning (i.e. Karras, 1997; Dobson and Ramlogan, 2002; Dobson and Ramlogan, 2006). Convergence in LA is rather checked on country basis, than on the whole region (Jarco and Pipień, 2020). The next sections will deal with the literature review for CEE and the limited for LA in more detail.

This chapter presented the many theories and origins of the convergence debate. To sum up the various points of view of the previously described papers and economic schools, Table *6* is provided below.

Table 6: Breakdown of the schools and theories important for the convergence debate.

| | **Authors** | **Mainstream idea** | **Convergence** |
|---|---|---|---|
| Classical | Smith, Ricardo, Malthus, Mill | Markets regulate themselves. Wealth comes from trade (not gold). Not successful companies fail. Growth factors defined (land, labour, capital). Investment and improved productivity enhance growth as a determinant. | Not defined, but exists; division of labour and technical progress leads to growth. |
| Neoclassical | Jevons, Walras, Marshall, Pareto, Ramsey, Solow, Barro, Sala-i-Martin | Dynamic equilibrium concepts introduced and analysed. Steady states. Pareto-efficiency. Diminishing returns to capital as a basic assumption in economic growth models. | Growth models introduced; convergence exists as an implication of diminishing returns to capital. |
| Endogenous | Romer Paul, DeLong, Lucas, Stokey, | New way for long run economic-estimates necessary. Technological progress and human capital included in the models of economic growth as endogenous variables. Convergence debate; sceptical point of view. | Growth models without diminishing returns to capital; convergence is not an automatic implication in the long run. |

Source: Own elaboration based on the analysed literature.

## 1.3 Reintroducing the convergence debate after the global financial crisis

### 1.3.1 The impact of the 2008 Global Financial Crisis – some selected issues

The Global Financial Crisis was undoubtedly a catastrophic event, when considering the massive GDP contraction that occurred globally in 2008 and later. It is estimated that financial crises downgrade the potential output by 1.5%-2.4% (Furceri and Mourougane, 2012). One of the most popular explanations for the origins of the financial crisis lays in toxic financial instruments within the subprime lending sector, some authors however see a direct fault in the banking structure in general (Kumm, 2018). Various researchers also tried to find the causes in moral hazard issues i.e. the accumulation of more and more wealth or dehumanization (Szulczewski, 2019; Sainz et al., 2019). Others see the importance of regulations imposed on financial institutions to control the market in avoiding the slowdowns caused by today's and future crises' (Dabrowski, 2010).

Although the reasons for the crisis are still a topic of debate, some new established systems and ideas are a visible part of the recent financial crisis' consequences. One may find the following frequently researched terms, or rather topics:

1. Liability Guarantee Schemes.
2. Liquidity Support Programs.
3. Macroprudential Policy.

**Liability Guarantees**

It is well-known that after the financial crisis many governments acted in order to intervene and counteract the slowdown. A crucial part of it related to trust i.e. the certainty of some banks' funds especially after Lehman Brothers default. Uncertainty clearly accompanied financial sector activities and lead, through natural ways or rather causal relationships, to a GDP slowdown generally. People with no trust to the banks will not feel likely to take a mortgage/loan or generally take risk averse decisions. As an example of such a decision one could take the investment in stocks or even placing a huge amount of money on their bank account. The second issue sounds very unrealistic in the 21$^{st}$ century but one just needs to think about the uncertainty and panic that may result in a domino effect. Another example to justify this risk-averse decision would be situation in Greece, where banks were closed for 20 days and limits to cash withdrawals were set.

In order to avoid such situations in general and enhance public trust towards the banking sector, some countries introduced liability guarantees. In that case countries extended the already existing liability coverages, while others cut the limits of such coverage even completely.

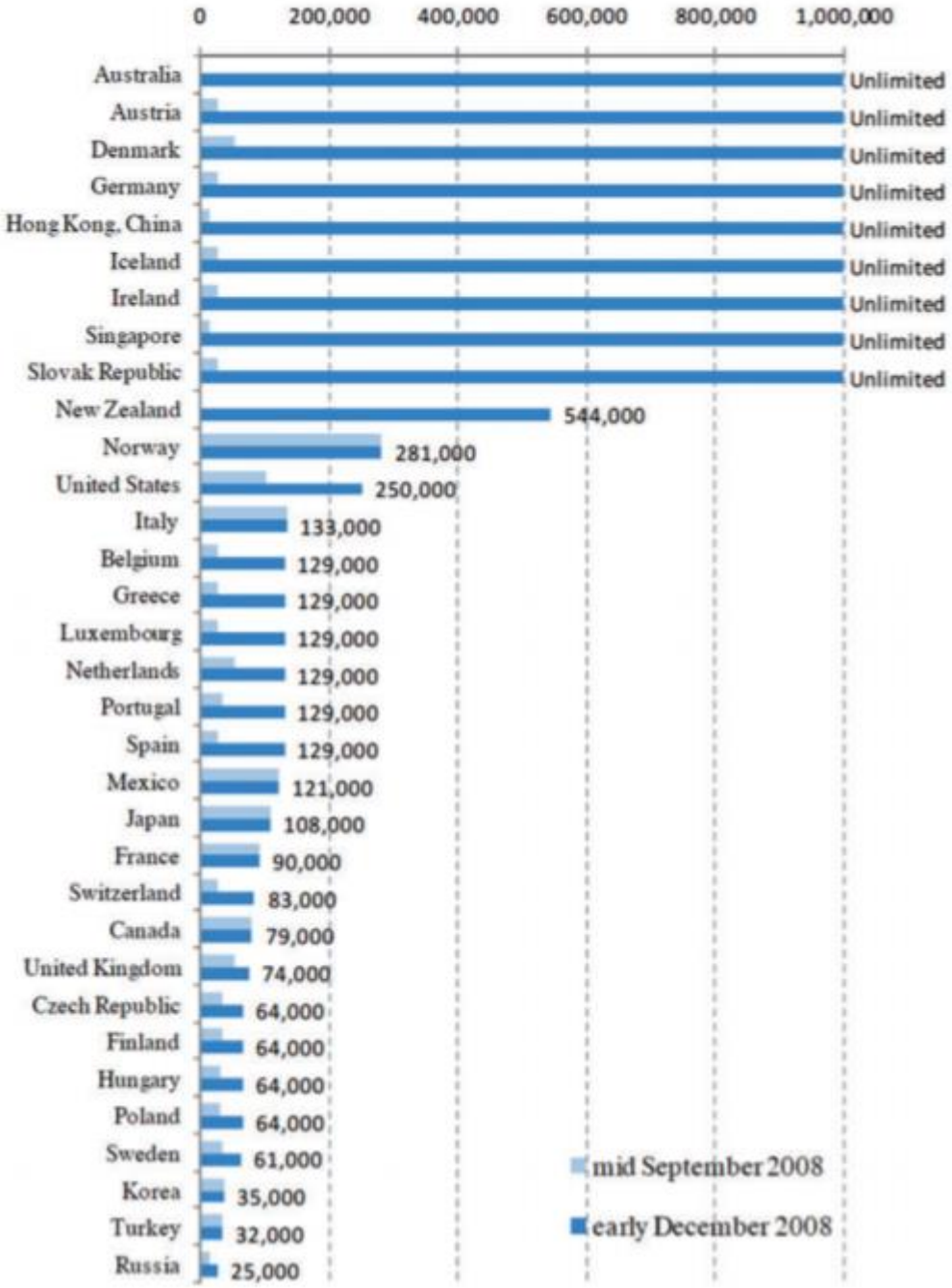
Ireland may be considered and serve as a suitable example with respect to heavy emergency actions taken during the financial crisis. The Irish government set guarantees for six major players in the banking sector. Recapitalisation measures and buyout of toxic instrument was also performed by the country. In total the guarantees reached 400 billion USD which was equivalent to two GDPs of Ireland (Allen et al., 2015). Irish public debt soared during that time, which lead to controversies among the public. The argument against helping the banking sector was also popular, especially when considering that parts of the money owned by the government were from poor taxpayers, while the banking sector industry funds could exceed the GDP of a single country.

Some arguments in favour of the guarantees are also present in the literature. Diamond and Dybvig (1983) wrote that deposit guarantees are helpful during bank runs, especially in case of a crisis. To be more specific, such runs are even prevented from occurring. One should bear in mind, that bank runs may also create uncertainty among the healthy banks, which again may result in a chain reaction. Further, the authors present a model, where bank guarantees turn out to be a cost-effective method to avoid such bank runs.

The real world however, was slightly different. In some cases, the government may not have enough funds to leverage those liabilities. Furthermore, the liquidity is not the only problem of the banks. The uncertainty within the financial sector may also lead to a bankruptcy of a bank, which would require additional action or public policy adjustments. At the end some recent recommendations try to adjust the guarantee systems to the crisis type, namely whether the crisis is a fundamental, or panic based one (Allen et al., 2015).

Figure 13 below summarises the importance of the topic and presents the countries, which changed their guarantee policy in 2008.

Figure 13: Deposit coverage limits of chosen countries in 2008, in USD equivalents, at 2008's exchange rates.




Source: Allen et al. (2015). Moral hazard and government guarantees in the banking industry. *Journal of Financial Regulation, 1(1)*, page 34.

## Liquidity Support

The term is connected with the liability guarantees discussed previously, however it is slightly different in nature. The idea of liability guarantees is to avoid bank runs while, on the other hand, the liquidity support happens after a bank run already occurred. Another possibility

would be, when the banking sector itself triggered a bank run. The uncertainty in financial markets led also large investors and institutions (i.e. other banks) to withdraw their funds. Usually it is not a major problem, but the issue becomes serious if many investors make such a decision. The chain effect started after banks began to sell securities in order to maintain the demand for liquidity. Unfortunately, it was not enough during the financial crisis. Hence the government or other institutions acted. One may think about the EU Fiscal compact or the liquidity programs of US Federal Reserve.

In case of the Fed's support, not only some already existing programs took place, but also many additional ones were created in order to save the banking sector. Among the programs for money injections Fleming (2012) did an in-depth analysis. In general, the Fed is using open market operations in order to manage banks' reserves and adjust the fed funds rate. Buying securities in the secondary market, the Fed adds reserves for the long term to the market. To do it temporary repurchase agreements are being bought (repos) and agreements to resell the securities at a later date. If institutions face funding pressures, they may utilise the discount window. In addition to the existing liquidity boosts before the financial crisis, some after that period were created. Some initial policy responses are dated to August 2007, together with the start of the financial crisis. Such policies include, for instance, central bank liquidity swaps, tranche open-market operations or other facilities like the Term Securities Lending Facility, Primary Dealer Credit Facility, etc. Despite banks, also Dealers and Other Market Participants received support in liquidity. Figure 14 below, summarises action taken by the Fed in order to inject liquidity to the market.

*Figure 14:* Federal Reserve liquidity facilities during the crisis[a]

| Facility | Date announced | Eligible borrowers | Maximum amount outstanding |
|---|---|---|---|
| Discount window | Ongoing | Depository institutions | 111 |
| Term Auction Facility | December 12, 2007 | Depository institutions | 493 |
| Central bank liquidity swaps | December 12, 2007 | Banks | 583 |
| Single-tranche open-market operations | March 7, 2008 | Primary dealers | 80 |
| Term Securities Lending Facility | March 11, 2008 | Primary dealers | 236 |
| Primary Dealer Credit Facility | March 16, 2008 | Primary dealers | 147 |
| Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility | September 18, 2008 | Depository institutions | 152 |
| Commercial Paper Funding Facility | October 7, 2008 | Commercial paper issuers | 351 |
| Money Market Investor Funding Facility | October 21, 2008 | Money market investors | 0 |
| Term Asset-Backed Securities Loan Facility | November 25, 2008 | Asset-backed securities investors | 48 |

[a]Maximum amounts outstanding in billions of dollars based on weekly data, as of Wednesday. Primary Dealer Credit Facility includes other broker-dealer credit. Central bank liquidity swaps are conducted with foreign central banks, which then lend to banks in their jurisdiction.

Source: Fleming, M. J. (2012). Federal reserve liquidity provision during the financial crisis of 2007–2009. *Annu. Rev. Financ. Econ*., 4(1), page 164.

A different perspective, contrary to the Fed's policy, was provided by Berrospide (2012), who argued about the possibility of banks having more liquid assets, than estimated. Analysing the unrealised losses on security holdings, the author indicated, that banks had hoarded liquidity over time, but were not eager to support other banks. This resulted in a more complex problem of trust, which in fact lead again to a stagnation/slowdown.

**Macroprudential Policy**

Last but not least a set of policy measures was created in order to avoid and lower the financial crisis' scope. As for organisational impact, the idea of a Macroprudential Policy is to lower through regulations the systemic risk within the financial sector as a whole. Such reduction of risk can be achieved through many macroprudential tools i.e. enhancement of the financial resistance and maintenance of a long run sustainable growth (Definition of the Polish National Bank, NBP). This is slightly different than the consensus objective of the monetary policy, where price stability and - in case of the Fed - sustainable employment are required. Furthermore, the objectives of the macroprudential policy are still under discussion and far from reaching a consensus.

Galatin and Moessner (2013) summed up, that the goal of the macroprudential policy may be twofold. First view sees there an achievement of a financial system's stability which is robust to external shocks and second view describes the stability to shocks from that financial system (internal). Generally, the goal of this policy is to limit the risk and costs of systematic crises.

It is important to indicate, that the objectives of the macroprudential policy are different from the ones of the microprudential policy, which is focusing more on individuals (i.e. institutions, consumers, etc.) than on the system as a whole. Both of the policies are on the other hand complementary. Hannoun (2010) concluded the differences, presented below in Figure 15. One may also note that the macroprudential policy acts as a countercyclical system, which enhances the economy during a crisis (or tries to avoid it through different measurements and tools) and slows it down during the boom.

*Figure 15:* Federal Reserve liquidity facilities during the crisis

| Prudential policy | Example of reform |
|---|---|
| Microprudential framework: enhanced Basel II | Increase the quantity and improve the quality of capital<br>Adequate capital charges are urgently needed on the trading book<br>Enhance risk management and disclosure<br>Introduce a leverage ratio to supplement risk-weighted measures<br>Address counterparty credit risk posed by OTC derivatives |
| Macroprudential overlay | Address stability over time (procyclicality)<br>• Countercyclical capital charges and forward-looking provisioning<br>• Capital conservation rules for stronger capital buffers<br>Address stability at each point in time (system-wide approach)<br>• Systemic capital surcharge for systemically important financial institutions<br>• Identify interlinkages and common exposures among all financial institutions<br>• Systemic oversight of OTC derivatives (CCP infrastructure) |

Sources: Hannoun, H. (2010). Towards a global financial stability framework. Page 9.

Yellen (2011) described in detail the systemic risk and the macroprudential policy as its outcome after the global financial crisis. Such risk relates to the possibility of a financial sector ending the provision of credit in an economy. If the situation becomes worse, then bank runs may occur and again lead to the collapse of multiple financial institutions. The author mentioned three determinants of systemic risk:

1. Risk and leverage accumulation of the financial sector.
2. Risk Exposures correlation between the institutions.
3. Interconnectedness and complexity within the financial system.

Only analysing and understanding those factors that lead to systemic risk can result in a well-defined and effective macroprudential policy. Another step would be to develop an information system, which rings a bell after a systemic thread is detected. Central Banks and the International Monetary Fund provide detailed stability report which may help in that case. Finally, the policymakers should think how to deal with this specific threat. The EU's Basel III initiative by the Basel Committee and the US Fed developed some tools, or rather initiatives, that can serve as macroprudential policy. Among others one may find:

- Capital Requirements: their role is to reduce procyclicality of credit and leverage. Building up capital buffets in good times may serve as a provision for future purposes.

- Constrain of risk taking: penalties or regulations on financial firms that limit risk exposure to counterparties.
- Reduction of short term debt: institutions should avoid and be more reluctant to rely on short-term capital in order to have a solid level of liquidity also in bad times.

Finally, the author summarised, that the current challenge lies in establishing intelligent policies that foresee future crises and limit their negative effects.

Despite the three above-mentioned and discussed consequences, or rather outcomes of the financial crisis, there are also others. One may count convergence as such an item. The reasons for reopening the convergence debate and finally its results are presented in the next sub-chapter.

### 1.3.2 A review of empirical research performed on the convergence debate

There was some research with respect to convergence at the beginning of 20 century, especially when considering the EU convergence between eastern and western states. It seemed that the essence of the convergence debate has been depleted. However, after the global financial crisis a breakthrough emerged. Although the reasons for the beginning of the 2008's crisis seem to be in toxic financial instruments and the subprime lending popularity, this phenomenon is still broadly discussed among economists and other researchers. There is no difference for the authors interested in economic growth, rather in contrary, a lot of papers about convergence were published after 2008 (e.g. Matkowski, Próchniak and Rapacki, 2016; Cabral and Castellanos-Sosa, 2019).

At the outset, three possible hypotheses may arise:

1. The financial crisis had a negative impact on the convergence process.
2. The financial crisis had a positive impact on the convergence process.
3. The financial crisis did not affect the convergence process at all.

The argument for the first hypothesis is twofold. First of all, it may be that poorer countries were hit much stronger by the global financial crisis than the richer ones. This structural change resulting from the contraction of output could eventually lead to a more difficult recovery, than in case of the richer countries. Capital inflows and exports are directly supporting the convergence process, hence when they decrease the convergence may be smaller (Stanišić, 2012). This may be valid especially in poorer countries which are more depended on FDI. Another reasons for the hypothesis would be smaller funds from the richer countries

towards the poorer ones. One example for this maybe the European Union and its funds for cohesion, sustainable and structural development. The richer countries are usually contributing more towards the so called net receivers countries. Such kind of funds are more government spending related and may not affect the convergence as much.

The second hypothesis is exactly the contrary of the first one. The richer countries may be hit harder by the crisis than the poorer ones, the slowdown of their growth could help the poorer countries to catch-up if they maintained the pre-crisis growth. The growth could also decline less than for the richer countries. Both of these arguments would describe the sigma convergence process, rather than the beta. Also when looking at the whole world countries, the poorer may not be affected that much by the crisis, that emerged in the US, because the globalization process didn't occur or was not completely finalised. This argument would however fit the developing countries and again describe the sigma convergence.

The hypothesis about the neutral effect of the financial crisis seems to be interesting as well, especially when considering heterogeneity. The richer countries are different than poorer ones, but furthermore, the richer are also different among each other, like the poorer ones. So one richer country could be hit harder than another richer one (for instance Ireland compared to Germany) and a poorer one less then another that is on the similar level (for instance Poland and Bulgaria). If no particular trend is found here and the growth impacts vary enormously, then this hypothesis may seem plausible as well.

In order to discuss, which hypothesis fits mostly a priori to empirical investigations, a literature review in this chapter was performed. Unfortunately, even with that respect, there is a lack of consensus. In fact, a lot of papers about convergence were published after the financial crisis, but the methodology involved mostly a simple regression derived initially by Barro and Sala-i-Martin (1990), which compared the pre and post crisis convergence rate. Also when considering the convergence rate itself and its existence, there is no conclusion.

As a starting point, Stanišić (2012) delivered an analysis of the beta and sigma convergence among 25 EU member states, the 15 old ones EU15 and the 10 new ones from Central and Eastern Europe CEE10. The IMF World Economic Database was used as a source, timeframe involved the period from 1993 to 2010. For the beta convergence, the author applied the methodology from Barro and Sala-i-Martin (1990) which is based on the classical regression model. In order to verify the distance between the income of particular countries, the sigma convergence through estimation of a trend line was calculated. In case of beta convergence, both the unconditional and the conditional one were checked. For the unconditional beta convergence with cross section data the OLS estimator was used, whereas for the conditional

one – with panel data – a TSLS estimation was performed. The conditional convergence included the following set of variables:

- INV: Gross Fixed capital formation in % of GDP. This variable represents the investment rate and was utilised by researchers before.
- GGB: General Government Balance in % of GDP. This should represent the fiscal policy and the government involvement of a country.
- EXP: Exports of goods and services in % of GDP. Many researchers suggest a positive effect of the trade openness on the GDP growth. This variable should calculate it.
- Log(EDU): Logarithm of school expectancy which represents the expected years of education over a lifetime. A proxy for human capital.
- Log(FER): The Fertility rate. The variable described also in previous researches, one may think about the Malthusian hypothesis.
- Log(LIF): The Life expectancy. This variable should represent the standard of medical care, the higher it is, the better economic situation is expected.
- INF: Inflation based on HICP. The market situation and its effects on consumption are important determinants used in previous studies as well.

Looking at the results, the sigma convergence was present among all the groups throughout the whole period, namely EU25, EU15 and CEE10. Both the unconditional and the conditional beta convergence took place among the EU25 countries with a speed of 1,7%. When looking at the country groups EU15 and CEE10 only conditional beta convergence was visible there.

The financial crisis was not in favour of the sigma convergence for EU25 and even more for CEE10. The EU15 countries decreased the income dispersion after the financial crisis, but before, the sigma convergence didn't take place at all, there was even a divergence visible especially from 2004 until 2007.

Another interesting article from Rapacki and Próchniak (2009) was published right after the beginning of the global financial crisis. The authors checked 27 transitional countries (CEE & CIS) and the timeframe involved 1990-2005. Both unconditional beta convergence and sigma convergence were verified and the data came from the IMF. No calculations for conditional convergence were done.

The beta convergence is estimated by a regression equation derived from Barro and Sala-i-Martin with a OLS estimator and sigma was calculated based on the standard deviation of the GDP level. Three sub-periods were defined: 1990-2005, 1993-2005 and 2000-2005. Furthermore, the countries were divided into 5 groups. The first set included all 27 transition

countries, the second 12 CIS, the third 15 CSEE, there were also 10 CEE and the final sample of 8 CEE countries. Since the results vary broadly, the table below presents them:

Table 7: Unconditional Beta Convergence Rates

| | **1990-2005** | **1993-2005** | **2000-2005** |
|---|---|---|---|
| **27 Countries** | 0.0017 | 0.0084 | 0.0139 |
| **12 CIS** | 0 | 0.0048 | 0 |
| **15 CSEE** | 0.0385 | 0.0454 | 0.0042 |
| **10 CEE** | 0.0090 | 0.0201 | 0.0371 |
| **8 CEE** | 0.0371 | 0.0509 | 0.0762 |

Source: Rapacki and Próchniak (2009). Real beta and sigma convergence in 27 transition countries, 1990-2005. *Post-Communist Economies 21(3).* Pages: 313-322

Table 8: Presence of the sigma convergence

| | **1990-2005** | **1993-2005** | **2000-2005** |
|---|---|---|---|
| **27 Countries** | no | yes | yes |
| **12 CIS** | no | no | no |
| **15 CSEE** | yes | yes | no |
| **10 CEE** | no | yes | yes |
| **8 CEE** | yes | yes | yes |

Source: Rapacki and Próchniak (2009). Real beta and sigma convergence in 27 transition countries, 1990-2005. *Post-Communist Economies 21(3).* Pages: 313-322

Unfortunately, the conclusion is not clear. Beta convergence seems to exists, it should be mentioned however that many of the calculations have poor statistical significance ($R^2$ less than 15%). Another interesting remark is that, the smaller the sample, the better evidence for unconditional beta convergence was present, for instance among 8 CEE countries. Usually beta convergence implies sigma convergence, this is however not the case in that paper, because of the original methodology. Sigma convergence was verified based on the regression estimation, where the positive or negative slope of the linear function determined its existence. The authors were aware of the shortcomings and presented them as well.

The paper was published in 2009, so no effect on the financial crisis was visible, nor a remark about the motivation of the researcher based on the phenomenon was made in the paper. But Próchniak did more verifications later, hence this paper will serve as a good starting point.

Próchniak (2011) did further solid research about the determinants of economic growth two years after the paper about convergence was published. Not only determinants were verified, there was also an investigation about the unconditional and conditional convergence.

The data came from different sources, namely the World Bank, IMF, EBRD and Heritage Foundation. The sample itself included this time only 10 CEE countries with the timeframe ranging from 1993 to 2009. Because Central and Eastern Europe may include different regions, it is worth to mention which countries were chosen in particular. The sample included Bulgaria, Chech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. From this dataset, five sub-samples were formulated. Each period was three years long, the averages allowed to avoid short-run fluctuations. As leading methodology, coefficient of partial correlation for the determinants and the convergence purposes were used, further, a regression which estimated some variants of economic growth models was performed. The estimator involved an OLS. Worth mentioning are also some assumptions which limit the research:

1. The relationships between the involved variables are linear.
2. The macroeconomic variables are interrelated without any lags and leads between the sub-periods.

To avoid the disturbances throughout the financial crisis, a dummy variable in the period for 2008 and 2009 was included. The variable equalled 1 for 2008 and 2009, and 0 in the other periods. The reason for this is, that the financial crisis was seen by the author as an external, exogenous factor.

Results regarding growth determinants, the investment rate, or rather gross capital formation and net FDI inflow, were subject to the biggest correlation with the growth rate. Human capital had a very strong correlation as well, in fact it was higher than in the previous studies. The reason for this was the variable used. It did not include the school enrolment ratio, but the education of labour force. The higher share of people working with primary education was subject to less economic growth. This is contrary to the higher share of workers with tertiary education, which was positively correlated with the GDP growth. Other variables were subject to a high statistical significance and may be of interest when analysing the conditional convergence.

In terms of convergence, after analysing 10 different models, the convergence hypothesis was confirmed in all of them, despite model no. 10 with the demand formula, where the statistical significance was too low. The correlation analysis did not confirm the existence of the convergence at the first place, which may be due to the averaged three-year sub-periods.

However, another control calculation confirmed the unconditional convergence with a negative correlation of -0.24 (between the initial GDP and it´s growth) and a low p-value of 0.071, which indicated statistical significance.

Some chosen variables with high correlation and statistical significance are presented in Table 9 below.

Table 9: Chosen correlation coefficients of the growth determinants with high statistical significance.

| | **Correlation** | **P-Value** |
|---|---|---|
| **Gross capital formation** | 0.52 | 0.000 |
| **Net FDI inflow** | 0.30 | 0.032 |
| **Labour force with primary education** | -0.45 | 0.001 |
| **Labour force with tertiary education** | 0.32 | 0.028 |
| **Market capitalisation of listed companies** | 0.42 | 0.001 |
| **Private sector share in GDP** | 0.48 | 0.000 |
| **Asset share of state owned banks** | -0.38 | 0.003 |
| **Asset share of foreign-owned banks** | 0.38 | 0.004 |
| **General Government debt** | -0.38 | 0.004 |
| **General Government Balance** | 0.33 | 0.010 |
| **CPI Inflation** | -0.52 | 0.000 |
| **Population growth** | 0.25 | 0.060 |
| **EBRD index FX rate and trade liberalisation** | 0.58 | 0.000 |
| **Personal computers per 100 people** | 0.52 | 0.000 |

Source: Rapacki and Próchniak (2009). Real beta and sigma convergence in 27 transition countries, 1990-2005. *Post-Communist Economies 21(3).* Pages: 453-454.

Looking at the LA region, King and Ramlogan-Dobson (2015) undertook research, which showed this time evidence for the convergence hypothesis (contrary to King and Ramlogan, 2008). The authors did not use unit-root tests like in their paper from 2008, instead they ran Fourier-Type tests for 18 Latin American countries for the period 1950-2009. The result is in favour of the convergence hypothesis, since all countries except Bolivia exhibit convergence towards an external benchmark. As a reason for the failure of previous studies to reject the unit-root test hypothesis, the authors state that the Latin American countries' relationships cannot be described by two or three linear segments. One year later the same authors (King and Ramlogan-Dobson, 2016) wrote another paper presenting similar results.

The main findings are the limitations of relative income measurement and assumptions for unit-root tests when checking the convergence hypothesis in Latin America. Applying a similar methodology, the authors use this time 22 Latin American and Caribbean countries, where Argentina is set as benchmark. A convergence club of eight countries was confirmed and another one with seven countries was suggested based on the visual observation. Other tests confirmed two convergence clubs, first with eight countries and the second with six. The remaining not-classified countries are either very rich, or very poor in the sample. No special difference between the pre- and post-crisis period was identified.

Slightly different research was performed by Kuscevic and Rio Rivera (2014) that investigated one particular LA country – Bolivia – but with respect to its regional catching up process. Panel data consisting for the period 1988-2011 was set as database. As methodology for the beta a regression and for the sigma convergence the Herfindahl/Hirschman index with the standard deviation was used. 3 different linear regression methods were utilised to check the beta convergence and all of them confirmed the beta convergence among Bolivian regions between 4% and 7.2%. Interestingly enough, the authors found signs for solid economic development heterogeneity within the regions in Brazil. Those differences may be the source of uncertainty about the importance of convergence process. For instance, when excluding one region (Tarija) a much stronger sigma convergence effect can be observed.

Sigma convergence was observed only from 1988 with 0.24 standard deviation to 1992 reaching 0.2. Afterwards the income disparities diverged until approx. 1997, then they remained nearly stable at 0.3 in 2010. However, excluding the region Tarija from the analysis, a strong sigma convergence pattern may be observed from 2000 with 0.3 standard deviation to 2010 with 0.18 indicating somehow a positive effect of the financial crisis on convergence.

Another interesting paper with respect to the convergence during the financial crisis was written by Kumo (2011). The article departs from the previous ones with respect to the sample. It included 14 Southern African countries (SADC members excluding Zimbabwe) throughout 1992-2009. The financial crisis period is therefore included in the sample, further, it illustrated the crisis' effects on African countries. These regions are not reviewed by many researchers, especially with respect to convergence. The data came from the IMF and the World Bank.

The methodology for the beta convergence verification is based on the model derived from Sala-i-Martin (1995), which was estimated by OLS. In order to see whether sigma convergence exists or not, the standard deviation between the starting and the end period was performed.

The beta coefficient turned out to be negative (-0.08), implying beta convergence, however the data was statistically irrelevant (Standard Error of 0.14), allowing for the conclusion that convergence didn't take place. Also no sigma convergence was noted, even divergence occurred. In the next section, conditional beta convergence was checked using panel data with 198 observations based on 11 countries. Four variables i.e. saving rate, pop growth, trade and gross fixed capital formation were controlled. Nevertheless, for conditional beta convergence no evidence was found. Also in the third, final approach, using the root test on 12 countries, no convergence was noted (despite Botswana and South Africa).

By the end, the author didn't deal with the financial crisis specially. He only noted the growth decreases in 2007/2008 in nearly all analysed economies. Although the author didn't mention anything, the interesting finding is, that standard GDP at PPP deviation in 1992 was 1.2229, in 2007 before the crisis 1.3370 and in 2009 the deviation was even less, namely 1.3016. This would mean, that the financial crisis contributed to sigma convergence, making the income differences between 14 South African countries smaller in 2 years.

Another paper that did a more complex analysis with respect to the financial crisis and income convergence was published by Begu, Spataru and Constantin (2014). 27 EU countries were analysed, and three periods were considered, 1992-2007, 1995-2012 and 2000-2010. Beyond the convergence, also some indices like the Corruption Perception Index were investigated. The leading methodology included a Markov Chain model, or rather the GDP estimates based on it. It is important to note that the estimates were not very accurate – some tests were performed by the authors. At the end the pure GDP analyses were not enough to contact the judgement and other indices hat to be considered. It turned out, that the convergence process was decreased after the financial crisis.

Siljak (2015) undertook similar research when considering the sample, namely 28 EU countries throughout 1995-2013 with a split for the financial crisis period 2004-2008 and 2009-2013. The applied methodology varied: for the sigma convergence the standard deviation and min/max GDP valuer were utilised, whereas for the beta convergence the model derived by Barro and Sala-i-Martin (1992) with an OLS estimator was used. Generally, the sigma convergence was visible, but also the beta convergence was present with values of 2.08% and 2.34% when considering the unconditional and conditional respectively. With respect to the financial crisis the results were in contrary to the research done by Begu et. all (2014) – the convergence was visible during that period. In fact, the standard income deviation decreased from 46.19 in 2007 to 41.75 in 2009. Further, when considering beta convergence, six Eastern countries seemed to form a club with a positive growth rate, whereas the Western, richer

countries, did not grow at all. Thus, financial crisis favoured the convergence process, because it hit the richer countries harder compared to the poorer ones.

Contrary to some of the described findings, Turganbayev (2017) analysed total factor productivity levels in 16 regions of Kazakhstan. First of all, the region is very specific and secondly the income was not verified, but the TFP levels. It is however assumed, that the productive levels relate to GDP, or rather income directly. This is straightforward: using better technology and having the same inputs, allows to increase the output. The timeframe was quite broad and included the years between 1997 and 2013. Using panel unit root tests and the standard deviation, the author found convergence across all the regions. When looking at the period in 2007, the standard deviation started to decrease in oil rich regions (richer) and increase in non-oil regions (poorer). This would mean, that the divergence in case of sigma occurred after the financial crisis. There were no tests of unit roots that considered this period in particular.

Similar to Turganbayev (2017), also Rodrik (2013) analysed the convergence when comparing labour productivity across countries, not GDP only. In fact, the manufacturing industry was subject to solid conditional convergence rates of 2-3% using sample across 118 countries. Rodrik's explanation for convergence in the manufacturing sector lies in the sector's nature. The industry does not only profit from technological progress, but it also needs to work connately on improvements in order to face competition both inside and outside the country. Smaller companies not operating abroad, also need to consider outside competitors with the import prices. Furthermore, the author concludes that the convergence can be enhanced by the speed of structural reallocation rather than by economy-wide governance. Pooled regression was used. No remarks about the global financial crisis were made.

Interesting appears to be the research performed by Das et al. (2019), where the authors tried to investigate the impact of a crisis on stock market. Using a functional regression model and solving it with numerical integration, the authors found that any global crisis affects the convergence of global stock markets in a positive way. A reason for this may be the risk allocation and awareness, where the nature of the crisis plays a significant role.

Another paper however (Shadab, 2009) suggests a weakness of the convergence process after the crisis for the alternative investment funds (hedge funds and private equity funds). This time the author compared the strategies of the funds that were converging before the crisis and stopped to do so afterwards. So even in the financial sector, which of course affects the income, there is no clear conclusion about the convergence process.

Looking at all the findings of the analysed literature above it is difficult to say which of the three potential hypotheses mentioned at the beginning is true:

1. The financial crisis had a positive impact on convergence.
2. The financial crisis had a negative impact on the convergence process.
3. The financial crisis did not affect the convergence process at all.

The reason for such disparities may include the methodology, the sample and the time period analysed. But this only highlights the importance of the research performed and puts a potential for the convergence heterogeneity hypothesis, that the countries behave independently of each other with respect to the GDP growth.

As another observation for this section and the post-crisis period one may see, that the CEE region was interesting in particular for the convergence hypothesis. This interest was not shared for the LA countries. Only a few relevant LA papers were found among the literature.

# Chapter 2: Testing the heterogeneity of convergence effect in a SURE environment

## 2.1 Seemingly Unrelated Regression Equations (SURE) – assumptions and methods of estimation

The point of departure for the SURE model utilised in this thesis is the single-equation Generalised Linear Regression model (GLM). First, let us denote by $y = (y_1, \dots, y_n)$ the vector of *n* observations, so the depended variables and by $\varepsilon = (\varepsilon_1, \dots, . \varepsilon_n)$ the column vector with *n* disturbances. Let $x_k$ be the *n* observations on the independent variable $x_k$, k = 1, …, K. **X** will be the matrix of those independent variables with $n\,x\,K$ elements. $\beta$ is a vector of parameters of the probability distribution of *y* and the variance of the error term is described by $\sigma^2$.

Thus an overview of the basic assumptions of the Classical Linear Regression Model (CLRM) will serve as the starting point:

1. Linearity: $y = X\beta + \varepsilon$.
2. Full rank: The independent variables in the model have no exact linear relationship.
3. Exogeneity of the independent variables: $E(\varepsilon_i) = 0$.
4. Homoscedasticity and non-autocorrelation: $Var(\varepsilon_i) = \sigma^2$ meaning that each disturbance has the same variance and $\varepsilon_i$ is uncorrelated with other $\varepsilon_j$.
5. Exogenously generated data: The independent variables are set, this means that they are generated independently of $\varepsilon_i$.
6. Normal distribution: The disturbances are distributed normally.

Thus the Classical Linear Regression Model can be summarised and written in the form of the first linear assumption:

$$y = X\beta + \varepsilon \tag{16}$$

It is also required to assume, that data „behaves well“, especially when considering large data bases and analyses. In order to do so two things need to be considered:

$$(x_i, \varepsilon_i)\ i = 1, \dots, n\ is\ a\ sequence\ of\ independent\ observations.$$

which is a modification of assumption 5 regarding the exogeneity of the data. In addition:

$$plim \frac{X'X}{n} = Q, a\ positive\ definite\ matrix. \tag{17}$$

so b, the following consistent estimator of $\beta$ for the classical regression model may be considered:

$$b = \beta + \left(\frac{X'X}{n}\right)^{-1} \left(\frac{X'\varepsilon}{n}\right) \tag{18}$$

This is because when dealing with large data sets, when n increases, the leading scalar can dominate the product and the variance will collapse to zero. The CLRM has multiple varieties and extensions, even some where the function is replaced with a non-linear one. For the purposes of this thesis and the SURE model, one particular extension is especially interesting, namely the Generalised Linear Regression Model (GLRM). The disturbances can take here a special form and one may depart from the CLRM assumption 4, related to homoscedasticity and the non-autocorrelation of the error terms. Therefore, after knowing all of the CLRM assumptions, it is much easier to understand how the GLM works.

The GLRM can be presented in the following form:

$$\begin{aligned} y &= X\beta + \varepsilon, \\ E[\varepsilon \mid X] &= 0, \\ E[\varepsilon\varepsilon' \mid X] &= \sigma^2\Omega = \sum, \end{aligned} \tag{19}$$

where Ω is a symmetric, non-singular and positive definite matrix.

In order to depart from the homoscedasticity assumption one needs to assume, that the disturbances are different variances, meaning that there is heteroscedasticity. This assumption is mostly used for high frequency time-series, for instance when dealing with daily financial market analyses. Another application may be found within cross-sectional databases with low

or rather variable explanatory powers of models, that depend on the observations chosen. One may think about club convergence in the first place. With the assumption of heteroscedasticity, the covariance matrix takes the following form:

$$\sigma^2\Omega = \sigma^2 = \begin{bmatrix} \omega_{11} & 0 & \dots & 0 \\ 0 & \omega_{22} & \dots & 0 \\ & & \vdots & \\ 0 & 0 & \dots & \omega_{nn} \end{bmatrix} = \begin{bmatrix} \sigma^2{}_1 & 0 & \dots & 0 \\ 0 & \sigma^2{}_2 & \dots & 0 \\ & & \vdots & \\ 0 & 0 & \dots & \sigma^2{}_n \end{bmatrix} \quad (20)$$

It is important to note that (20) still does not consider autocorrelation, which can be found in time-series data as well, for example when considering a seasonally adjusted price. The data here or rather the time observations are depended within each other from one period to the other. But, contrary to the above-mentioned heteroscedasticity example, time-series data, such as prices over a period, may exhibit homoscedasticity instead. Therefore, the following (21) covariance matrix represents autocorrelation without heteroscedasticity:

$$\sigma^2\Omega = \sigma^2 = \begin{bmatrix} 1 & p_1 & \dots & p_{n-1} \\ p_1 & 1 & \dots & p_{n-2} \\ & & \vdots & \\ p_{n-1} & p_{n-2} & \dots & 1 \end{bmatrix}. \quad (21)$$

Looking at the estimation, the OLS from (18) is still unbiased, consistent and asymptotically normally distributed, but it is not efficient in that case. This leads to non-usual inference procedures, because the standard ones are not applicable anymore. Couple of theorems regarding the GLM model were therefore established (Greene, 2003) in order to utilise the OLS estimation. There are also other worth-mentioning estimators like the GMM, which is robust and semiparametric, but this would extend the scope of this thesis and is not relevant for further understanding.

To summarise, GLM is a variation of the CLRM, which allows to analyse cross sectional data that exhibit heteroscedasticity or time series data that are assumed to be auto-correlated. But when dealing with panel data, like the convergence hypothesis, one may like to consider both of the characteristics. Here is where the SURE model comes into place. When comparing to the GLM, the advantage of the SURE model is its more practical application. It can indeed combine both of the cases and assumptions regarding the error terms from (20) and (21). Therefore, the SURE approach allows the equations to be linked by disturbances.

The reason why to apply SURE models, or rather the multi-equation systems, instead of single equation models is therefore purely related to the practical nature of the data. As mentioned previously, homoscedasticity did not allow the error terms to correlate within each other which may make sense for some cross-sectional data, but requires rethinking in many cases within panel data when considering time series in addition.

As a standard example one may consider the capital asset pricing model, where the return rate of a security over a specific period of time is calculated. Knowing the surplus of a particular security's return rate over a risk-free give also information about the excess of other securities' returns. Hence the joint estimation of the equations with the SURE model makes the information useful and takes it into account. One may think about a similar analogy and application when considering the error terms of initial GDP levels and their effects on future periods. The disturbances may indeed contain factors that are common for multiple periods or even in some countries.

Looking from the formal perspective, the multiple equation structure may be written as:

$$\begin{aligned} y_1 &= X_1\beta_1 + \varepsilon_1 \\ y_2 &= X_2\beta_2 + \varepsilon_2 \\ &\vdots \\ y_M &= X_M\beta_M + \varepsilon_M \end{aligned} \qquad (22)$$

Hence the SURE model is as follows:

$$y_i = X_i\beta_i + \varepsilon_i, \qquad i = 1, \ldots, M \qquad (23)$$

Where

$$\varepsilon \quad = [\varepsilon'_1, \varepsilon'_2, \ldots \varepsilon'_M]'$$

And

$$E[\varepsilon \mid X_1, X_2, \ldots, X_M] = 0$$
$$E[\varepsilon\varepsilon' \mid X_1, X_2, \ldots, X_M] = \Omega$$

Further, it is assumed that a total of T observations is used when estimating the parameters from M equations. $K_M$ regressors are involved for each equation considering a total

of K = $\sum_{i=1}^{n} K_i$ . In addition T > $K_i$. Assuming - for now - that disturbances are uncorrelated across observations, one may obtain:

$$E\left[\varepsilon_{it}\varepsilon_{js} \left| X_1, X_2, \ldots, X_M\right.\right] = \sigma_{ij}, \text{ if } t = s \text{ and } 0 \text{ otherwise.} \quad (24)$$

Hence the disturbance formulation can be summarised in two ways, presented below namely as equation (25) or (26) in form of a matrix Ω.

$$E\left[\varepsilon_i \varepsilon'_j \left| X_1, X_2, \ldots, X_M\right.\right] = \sigma_{ij} I_T \quad (25)$$

$$E[\varepsilon\varepsilon' \,|X_1, X_2, \ldots, X_M] = \Omega = \begin{bmatrix} \sigma_{11}I & \sigma_{12}I & \ldots & \sigma_{1M}I \\ \sigma_{21}I & \sigma_{22}I & \ldots & \sigma_{2M}I \\ & \vdots & & \\ \sigma_{M1}I & \sigma_{M2}I & \ldots & \sigma_{MM}I \end{bmatrix} \quad (26)$$

It is visible that model (22) is an extension of the general regression model, however the parameter vector is allowed here to vary across groups.

## 2.2 Economic convergence hypothesis in a SURE model

The research methodology purely used for convergence testing in this thesis is based on the previously described Seemingly Unrelated Regression Equations Model and the estimator formulated by Zellner (1962). Following Pipień and Roszkowska (2018) and Pipień and Jarco (2020) it is possible to apply the system for checking the convergence rates and its heterogeneity across countries.

The conditional convergence equation for a single country looks as follows:

$$\Delta \ln(y_t) = \alpha_0 + \sum_{i=1}^{m} \alpha_i z_{it} + \beta \ln(y_{t-1}) + \varepsilon_t, \qquad t = 1, \ldots, T, t = 1, \ldots, T \quad (27)$$

where: $y_t$ denotes labour productivity (GDP per employed) in year t (in PPP); z's are sets of additional explanatory variables determining productivity in an equilibrium. Parameter $\beta$ describes the speed of convergence; should convergence exist according to the theory the parameter is expected to be negative. The set of explanatory variables in (27) conditioning analysed effect can be determined empirically.

As described in Chapter 1, both Barro and Sala-i-Martin provided a huge contribution towards empirical convergence testing. For instance, Sala-i-Martin (1997) conducted research on the importance of specific factors determining the per capita output growth rates across the countries. From the set of proposed observables, the following ones were chosen initially: investment rates, the government consumption to GDP rate, the inflation rate, the investment rate, a human capital index and trend as a proxy for institutional or technological changes.

Such a set of explanatory variables were analysed by Pipień and Roszkowska (2018) and (2019) in case of CEE and CIS countries, and by Jarco and Pipień (2020) for Latin America country club.

Although the variables chosen are in line with Sala-i-Martin (1997), nowadays many studies also raise the importance of the impact of institutional factors, especially reflected in indices such as Economic Freedom of the World (EFW) or Index of Economic Freedom (IEF). Some studies confirm the positive impact of better institutions on GDP growth, although there are also those that show no significant relationship between institutions and GDP dynamics. A broad discussion and comprehensive review of the papers has been prepared by Berggren (2003). Unfortunately, the EFW and IEF indicators are not available for the whole analysed period in the CEE and LA groups, but other structural measures included in the analyses are a proxy for economic freedom measures. This is because aggregate EFW and IEF indicators are not homogenous measures of the market economy, and measures related to government expenditure and investment rates are included in the mentioned economic freedom indices and seem to be a good proxy for them.

Hence for a specific country, equation (27) may have the following form:

$$\Delta\, ln(y_t) = \alpha_0 + \alpha_1 \left(\frac{G_t}{Y_t}\right) + \alpha_2 \pi_t + \alpha_3 \pi_t^2 + \alpha_4 i_t + \alpha_5 h_t + \alpha_6 t + \beta\, ln(y_{t-1}) + \varepsilon_t, \quad t = 1, \ldots, T \tag{28}$$

where $y_t$ denotes GDP in the country at year $t$, $G_t$ denotes government consumption expenditure in country at year $t$, $i_t$ is the investment rate (gross fixed capital formation in relation to GDP), $\pi_t$ is the inflation rate (percentage change of consumer prices over previous year), $h_t$ is the human capital based on years of schooling, and $t$ is the time trend component.

The convergence rate in (28) is the parameter $\beta$, however, some additional information about the long-term growth rate of labour productivity can be analysed according to Pipień and Roszkowska (2018) by estimating nonlinear function of parameters given by:

$$g = -\frac{\alpha_6}{\beta} \tag{29}$$

Since the empirical part of dissertation is mainly based on the SURE model for panel data in CEE and LA countries, the following convergence regression for *n* countries, and for *j*-th country (j = 1, …, n) is utilised:

$$\Delta \ln(y_{t,j}) = \alpha_{0j} + \alpha_{1j}\left(\frac{G_{tj}}{Y_{tj}}\right) + \alpha_{2j}\pi_{tj} + \alpha_{3j}\pi_{tj}^2 + \alpha_{4j}i_{tj} + \alpha_{5j}h_{tj} + \alpha_{6j}t + \beta_j \ln(y_{t-1,j}) + \boldsymbol{\varepsilon_{tj}}, \qquad t=1,\ldots,T,\ j=1,\ldots,n \tag{30}$$

In order to test the hypothesis about the relevance of human capital, equation (31) was formulated. It is the duplicate of equation (30) but without *h*, referred as the human capital variable:

$$\Delta \ln(y_{t,j}) = \alpha_{0j} + \alpha_{1j}\left(\frac{G_{tj}}{Y_{tj}}\right) + \alpha_{2j}\pi_{tj} + \alpha_{3j}\pi_{tj}^2 + \alpha_{4j}i_{tj} + \alpha_{6j}t + \beta_j \ln(y_{t-1,j}) + \boldsymbol{\varepsilon_{tj}}, \qquad t=1,\ldots,T,\ j=1,\ldots,n \tag{31}$$

However, depending on the correlation of the Gaussian error terms $\boldsymbol{\varepsilon_{tj}}$ for each *j* in (30) or (31), the system of regressions may be independent, or treated as a SURE model. Both possibilities are denoted in the following way. $M_0$ describes the case if the error terms are uncorrelated and the system is independent. This way allows to estimate the convergence

parameters separately for a particular *j*-th regression in a rather classical approach for convergence testing. On the other hand $M_1$ represents structure allowing for correlation of the error terms making our model an unconstrained case of the SURE (Zellner, 1962). With a nonzero contemporaneous correlation, some linkages in the variability of related parameters across countries may be checked. This is a special case for testing $M_0$.

$$\varepsilon_t = (\varepsilon_{t1}, \dots, \varepsilon_{tm})$$

represents the row vector of error terms at time *t* with the covariance matrix Σ. In the case of model $M_1$, the Σ matrix is symmetric and positive definite with $\frac{n(n+1)}{2}$ free elements $\sigma_{ij}^2$, $i = 1, \dots, n$ and $j = 1, \dots, n$. The variance of the error terms in the *i*-th country is denoted by $\sigma_{ii}^2 > 0$ and covariance between error terms in the *j*-th and *i-th* country stays as $\sigma_{ij}^2$. The system of equations (30) can be formulated in the following standard regression form::

$$y^{(j)} = z^{(j)}\alpha^{(j)} + y_{-1}^{(j)}\beta_j + \varepsilon^{(j)}, j=1,\dots,n \quad (32)$$

where $y_{[tx1]}^{(j)} = (y_{1j}, \dots, y_{Tj})'$, $z_{[Tx6]}^{(j)} = ({z_{1j}}', \dots, {z_{Tj}}')'$, with $z_{tj} = (1, \frac{G_{tj}}{Y_{tj}}, \pi_{tj}, \pi_{tj}^2, i_{tj}, t)$, $y_{[tx1]}^{(j)} = y_{-1}^{(j)} = (y_{0j}, \dots, y_{T-1,j})', = \varepsilon^{(j)} = \left(\varepsilon_{1j}, \dots, \varepsilon_{T,j}\right)$' and $\alpha^{(j)} = \left(\alpha_{0j}, \alpha_{1j}, \alpha_{2j}, \alpha_{3j}, \alpha_{4j}, \alpha_{5j}, \alpha_{6j}\right)'$.

In the next step, we stack the observations expressing the system of regression equations in the closed form:

$$Y = Z\alpha + Y_{-1}\beta + \varepsilon \quad (33)$$

where: $Y_{[nTx1]} = \left(y^{(1)\prime}, \dots, y^{(n)\prime}\right)'$, $\varepsilon_{[nTx1]} = \left(\varepsilon^{(1)\prime}, \dots, \varepsilon^{(n)\prime}\right)'$, $\alpha_{[n6x1]} = \left(\alpha^{(1)\prime}, \dots, \alpha^{(n)\prime}\right)'$, $B = (\beta_1, \dots, \beta_n)'$ and:

$$Z_{[nTxn6]} = \begin{bmatrix} Z^{(1)} & 0_{[Tx6]} & \cdots & 0_{[Tx6]} \\ 0_{[Tx6]} & Z^{(2)} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0_{[Tx6]} \\ 0_{[Tx6]} & \cdots & 0_{[Tx6]} & Z^{(n)} \end{bmatrix}, Y_{-1} = \begin{bmatrix} y_{-1}^{(1)} & 0_{[Tx6]} & \cdots & 0_{[Tx6]} \\ 0_{[Tx6]} & y_{-1}^{(2)} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0_{[Tx6]} \\ 0_{[Tx6]} & \cdots & 0_{[Tx6]} & y_{-1}^{(n)} \end{bmatrix},$$

The system (33) can be written in the following form:

$$Y = X\theta + \varepsilon \tag{34}$$

where:

$$X_{[nTxn7]} = \begin{bmatrix} X^{(1)} & 0_{[Tx6]} & \cdots & 0_{[Tx6]} \\ 0_{[Tx6]} & X^{(2)} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0_{[Tx6]} \\ 0_{[Tx6]} & \cdots & 0_{[Tx6]} & X^{(n)} \end{bmatrix} = \begin{bmatrix} [Z^{(1)} : y_{-1}^{(1)}] & 0_{[Tx7]} & \cdots & 0_{[Tx7]} \\ 0_{[Tx7]} & [Z^{(2)} : y_{-1}^{(2)}] & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0_{[Tx7]} \\ 0_{[Tx7]} & \cdots & 0_{[Tx7]} & [Z^{(n)} : y_{-1}^{(n)}] \end{bmatrix},$$

and $\theta = (\alpha^{(1)'}, \beta_1, \ldots, \alpha^{(n)'}, \beta_n)'$.

Considering the estimation of the models, the covariance matrix for the error term $\varepsilon$ from Equation (34) has the following form:

$$V(\varepsilon) = \sum \otimes \mathrm{I_n}$$

Where $\otimes$ denotes the Kronecker product. When looking at the form of the $\varepsilon$-covariance matrix, system (34) can be treated as a generalized linear regression.

Because of the $\sum$ one may apply the Aitken Generalized Least Squares estimator as below for all of the parameters in the system:

$$\hat{\theta}_{GLS} = (X'(\sum \otimes I_n)^{-1}X)^{-1}X'(\sum \otimes I_n)^{-1}y$$

with the following covariance matrix:

$$\hat{V}(\hat{\theta}) \quad = (X'(\sum \otimes I_n)^{-1}X)^{-1}$$

However, two models are going to be considered in the dissertation. Model M0 which estimates each equation separately and model M1 where equations are estimated jointly.

Since M0 has $\sum = diag(\sigma_{11}^2, \dots, \sigma_{nn}^2)$ the equivalence of Aitken's GLS to the OLS estimator has the following form:

$$\hat{\theta}_{OLS} = (X'X)^{-1}X'y$$

The general case described as M1 requires the estimation of the covariance matrix $\sum$. This can be done with the Zellner estimator (1962), where elements of the $\sum$ matrix are estimated based on the OLS residuals. The residuals are denoted as below:

$$\hat{\varepsilon}_{[nTx1]} = (\hat{\varepsilon}^{(1')}, \dots, \hat{\varepsilon}^{(n')})'$$

While the Zellner (1962) GLS estimator is described as follow:

$$\hat{\theta}_{EGLS} = (X'(S \otimes I_n)^{-1}X)^{-1}X'(S \otimes I_n)^{-1}y,$$

And has the following approximation of a covariance matrix for small samples:

$$\hat{V}(\hat{\theta}_{EGLS}) = (X'(S \otimes I_n)^{-1}X)^{-1}, where\ S = \frac{1}{T}(\hat{\varepsilon}^{(1')}, \dots, \hat{\varepsilon}^{(n')})\,(\hat{\varepsilon}^{(1')}, \dots, \hat{\varepsilon}^{(n\ )}).$$

Last but not least models M0 and M1 are going to be calculated in two ways. One as per the Equation (30) referred as M0 and M1, and one as per the Equation (31) which excludes the human capital variable referred as Meh0 and Meh1 accordingly.

Despite using an OLS regression, Olszak and Pipień (2016) also applied the SURE methodology in order to verify the impact of some specific variables on loan loss provisions in the banking sector. The sample consisted of 13 OECD countries and the time period ranged from 1995-2009. Since in this subject the leading methodology consisted of a regression, the application of the SURE model was considered as an original approach. The SURE method supported more countries with respect to the capital management hypothesis, than the OLS regression. Further, despite confirming the procyclicality of loan loss provisions, the SURE method found out, that this feature is predominant.

A later article from Pipień and Roszkowska (2019), which utilised the SURE approach as well, deals with a more similar problem chosen for the dissertation – convergence and its heterogeneity. Analysing 24 CEE and CIS countries throughout 1992-2015, the authors found evidence for both convergence and the heterogeneity of parameters based on the method and country. The beta parameter responsible for the convergence speed in CEE countries varied from -1.4 to 0.06. However, the differences between the convergence magnitudes decreased in

time, due to a more homogenous structure of the CEE economies. The CIS countries were subject to strong variability of the parameters as well. Finally, yet importantly, the long-term productivity growth rate as given by equation (29) was verified. Huge differences were reported among the various countries with respect to this ratio as well. Further details about the estimation method are provided in Olszak and Pipień (2016) and Pipień and Roszkowska (2019).

## 2.3 Database and Software utilised

In order to perform a comparative empirical analysis a well-suited database with panel data containing economic indicators across Latin American (LA) and Central & Eastern European (CEE) countries is needed. Such a database that could fit into the cross-country comparison and convergence testing was published by Feenstra, Inklaar and Timmer (2015) as the Penn World Tables.

Penn World Tables contain free information on relative income, output, input and productivity. Two versions of the database were utilised. For the economic performance review PWT 9.1 were the most up to date and covered 182 countries and the period ranges between 1950 and 2017. The convergence testing was done after the economic performance review, in the meantime a newer version of Penn World Tables was published, namely PWT 10. PWT 10 covered the period between 1950 and 2019 and were therefore chosen for the convergence testing in order to get the most up-to-date analysis and results.

The initial tests, data analyses and preparations were performed using MS Excel. Further, the SURE method was applied using Gauss software.

# Chapter 3: Empirical analysis of economic convergence in CEE countries

## 3.1 An overview of economic performance of analysed CEE region

### 3.1.1 CEE countries as a suitable example for convergence testing

In case of any scientific empirical analysis, the question about the chosen sample and its justification seems one of the most important one. In the case of analysing income convergence and its heterogeneity a selection of countries should rather have a specific explanation, instead of random selection. Both Central and Eastern European (CEE) and Latin American (LA) countries seem very interesting for the purposes of convergence analysis. One may consider the broad definition of an emerging economy, cultural variety, political differences or, for instance, the historical aspects.

An emerging economy may be interpreted in many ways. A commonly accepted set of emerging economy characteristics were provided by Hoskisson et al. (2000), where the countries were described as low-income ones with rapid growth resulting from economic liberalisation. Such countries are also bearing higher institutional risk, as compared to developed economies. Furthermore, there are many interesting groups of emerging economies: while the transition economies from former Soviet Union being the most important for this thesis and the remaining ones were geographically divided between Asia, Latin America, Africa and Middle East. Also, Peng, Tan and Tong (2004) highlight the importance of treating the transition economies in a different way, since the diverse nature of the ownership of a company plays a crucial role there. Similar to the previous authors Meyer and Peng (2016) suggest that CEE countries should rather be analysed as emerging economy with respect to business research rather than a geographic entity. However, contrary to the traditional approach towards emerging economies having a somehow constant, rather high institutional risk, Chung and Beamish (2005) highlight the importance of the environmental stability. The authors are of the opinion, that emerging economies' institutions bear different risks in different times, hence these variability should be considered. Regardless of the definitions, the cited authors are mostly in agreement, that transition countries should be treated in a special way.

Therefore, when looking at Central & Eastern European performance and history, the simple generalised term "emerging economy" is not enough to designate these countries. From

the historical perspective the word “transition” was not randomly chosen in that case. After the fall of the Berlin Wall and, more symbolically the Iron Curtain in 1989, the former Soviet Union faced multiple transformations from central planning into the market competition oriented economy. In addition to the economic changes, the authoritarian governments governed by multiple variations of the Central Executive Committee were replaced with democratic governments, which led to further massive institutional transitions. Exactly this transition is what makes the CEE countries a very interesting topic for income catching-up analyses. Both in terms of catching-up to the developed, western economies and also among each other.

Hence, as could be expected, the political and public policy history of CEE countries had an enormous effect on their economic development. Shortly after their transformation, the CEE countries became a very popular area for growth researchers. Fischer, Sahay and Vegh (1996) investigated couple of years after the Iron Curtain fall the economic performance of those regions. In their work, 26 countries were considered as transition economies, which reflects the former Soviet Union countries. It was particularly difficult to study that region during this time, because data was partly not available and could possibly be of poor quality. The authors however undertook effective research on the current situation and Key Performance Indicators (KPIs), such as inflation or GNP p.c. Already during the first half of 1995, the majority of the transition countries were subject to better growth results. In fact, all of them except Macedonia and former Yugoslavia experienced expansion. One of greatest challenge for the observed countries was a hyperinflation. Huge price instability always precludes sustainable growth and is mostly correlated with enormous economic imbalances. Since a stable political and economic environment offers better investment potential, the results were not surprising: growth was mostly observed among countries with a lower annual inflation than 50%, which back then was a reasonable threshold. Only two countries exhibited growth despite having an inflation higher than 50% – and ultimately turned to a lower inflation rate – which serves as a confirmation of the stability requirement for further growth opportunities. Fischer, Sahay and Vegh (1996) also highlight the importance of an inflation lower than 4% in order to achieve not only growth, but to consider it as sustainable. Finally, the authors modelled that transition countries’ growth was about to be increased after 1996, which ultimately turned out to be true. Other remarkable papers dealing with the CEE transition were published during this time (Aghion, Philippe and Blanchard, 1994; Melo, Denizer and Gelb, 1996).

Nowadays there is no doubt about the transition economies’ higher growth rates and the CEE countries are considered to be well performing. For instance, Levenko, Oja and Staehr (2019) analysed the total factor productivity (TFP) level for 11 CEE countries within the EU,

during 1996-2016. The period is not only interesting, because it covers a long range, but also it involves two crisis periods: the 2001 "Dot Com" bubble and the 2008 global financial crisis. Furthermore, the authors analysed how the GDP p.c. growth was accomplished, to be specific, and how other components, or determinants, effected the income changes. The methodology utilised for this exercise included growth accounting. This process involves the decomposition of the GDP into additional, more detailed, figures. As a base for the decomposition methodology, the Solow Model was utilised (for instance capital and labour). Based on specific assumptions, the TFP was considered as the so called "Solow Residual" and can be also described as technological progress. The growth within CEE was substantially lower during the latest period of 2010-2016, than it was previously, but these results are still higher than comparable 15 countries from Western Europe. On average, the CEE countries' GDP growth was affected because of capital by around 50%, of TFP by 33%, of increased capital utilisation by 16% and the employment did not play a huge role at all. In general, the CEE countries were performing quite well with respect to GDP growths during the whole period.

Although it may not seem material for CEE, the reader should also be aware about the so-called middle-income trap. This phenomenon describes the situation, when transition countries manage to jump from a low-income level into the middle one, but struggle to go beyond. The reason for being in this trap may be the application of wrong growth models by policymakers; i. e. the lack of trade openness, innovations, productivity and well-established stability institutions (Islam, 2014; Gill and Kharas 2015, Amin, Islam and Khalid, 2019). Spence (2011) delivered some empirical findings about growth, and observed some countries, which were not able to go above the 10,000 USD per capita income in the long run. These were supposed to be in the middle-income trap. On the other hand, there are authors who don't agree that there is a trap at all. For instance, Bulman, Eden and Nguyen (2017) did not find evidence for the middle-income trap but agree that growth determinants vary on the income level.

After the brief literature review on the economic performance, the actual data will be presented in the next step. The economic indicators presented in the next sub-chapters are relevant from the neoclassical and endogenous economic growth perspective as described in the first section of this thesis when analysing growth models. Therefore, an in-depth analysis of those indicators will deliver a solid contribution towards the economic performance understanding of the selected countries, which, according the OECD definition include 12 economies, i.e. Albania, Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.

### 3.1.2 GDP development and comparison throughout 1990-2017

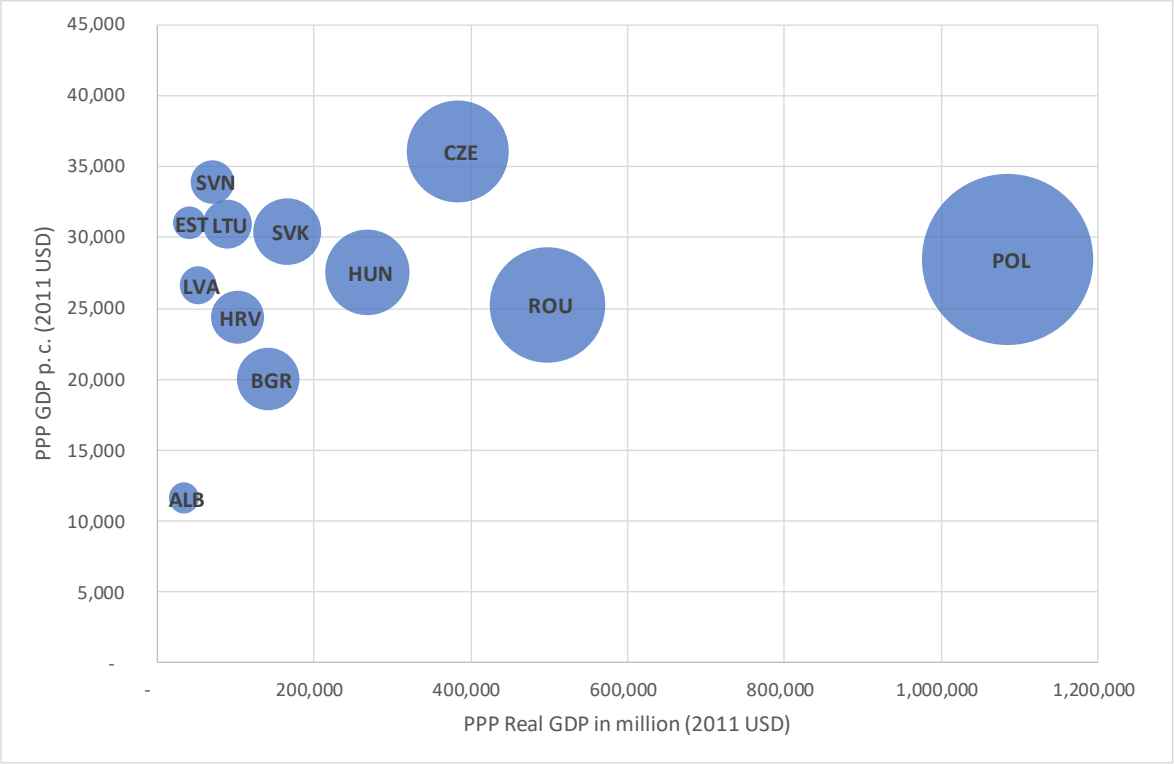
Although not perfectly describing the welfare, the GDP indicator is commonly used for cross-country - and cross-regional – comparative studies of economic performance. Further, this indicator is also plausible to compare development perspectives of a specific region over the timespan.

The bubble chart in Figure 16 may serve as a handy point of departure to give a general idea of the comparison of development of CEE region. Further, when comparing the CEE *Figure 16* to *Figure 31,* which plots the LA countries in the same way, one may see the enormous heterogeneity present. The vertical axis represents the values of the GDP per capita (in USD) for 2017. The horizontal axis represents the values of the real GDP (in USD) for 2017. Further, the real GDP is linked with the bubble size. Based on that one may see that Albania being on the very bottom has the lowest per capita GDP of around 12,000 USD and the smallest real GDP of approx. 34 billion USD. In contrary to this we have Czechia with the highest per capita GDP of 36.000 USD but a real GDP of 380 billion. Poland is an outlier when considering the real GDP. It has reached nearly 1.1 trillion in 2017. This is more than twice as much as the second largest country based on the real GDP values – Romania with around 500 billion USD. If we exclude those four countries (Albania, Czechia, Romania and Poland), then the CEE group could be treated as one with countries that have similar economic performance and potential. The bubble chart axes would become much smaller. But considering the population and looking at the GDP p.c. amounts only, nearly all of the CEE countries seem pretty similar. The average GDP p.c. amount reached 27,189 USD for all CEE countries. Excluding Albania, the average amount was higher by approx. 2,000 USD and reached 28,604 USD. Now, excluding 20% of the richest and 20% of the poorest countries, we can see that only 4 countries will be excluded (Albania, Bulgaria, Czechia and Slovenia) and 8 remain, which only highlights how similar their performance based on GDP p.c. is. The average reached in that case 28,076 USD.

Another interesting issue can be observed on *Figure 17* where the evolution over time of the GDP p.c. in CEE region is presented. In addition, to present a better growth overview regardless of the initial income level, a chart with the GDP index set as 1990=100 was added. Probably the most important observation from the chart is that all CEE countries were subject to growth over time. The average GDP p.c. was 12,598 USD in 1990 compared to 27,189 USD in 2017. It is a huge difference; the CEE countries were able to more than double their p.c.

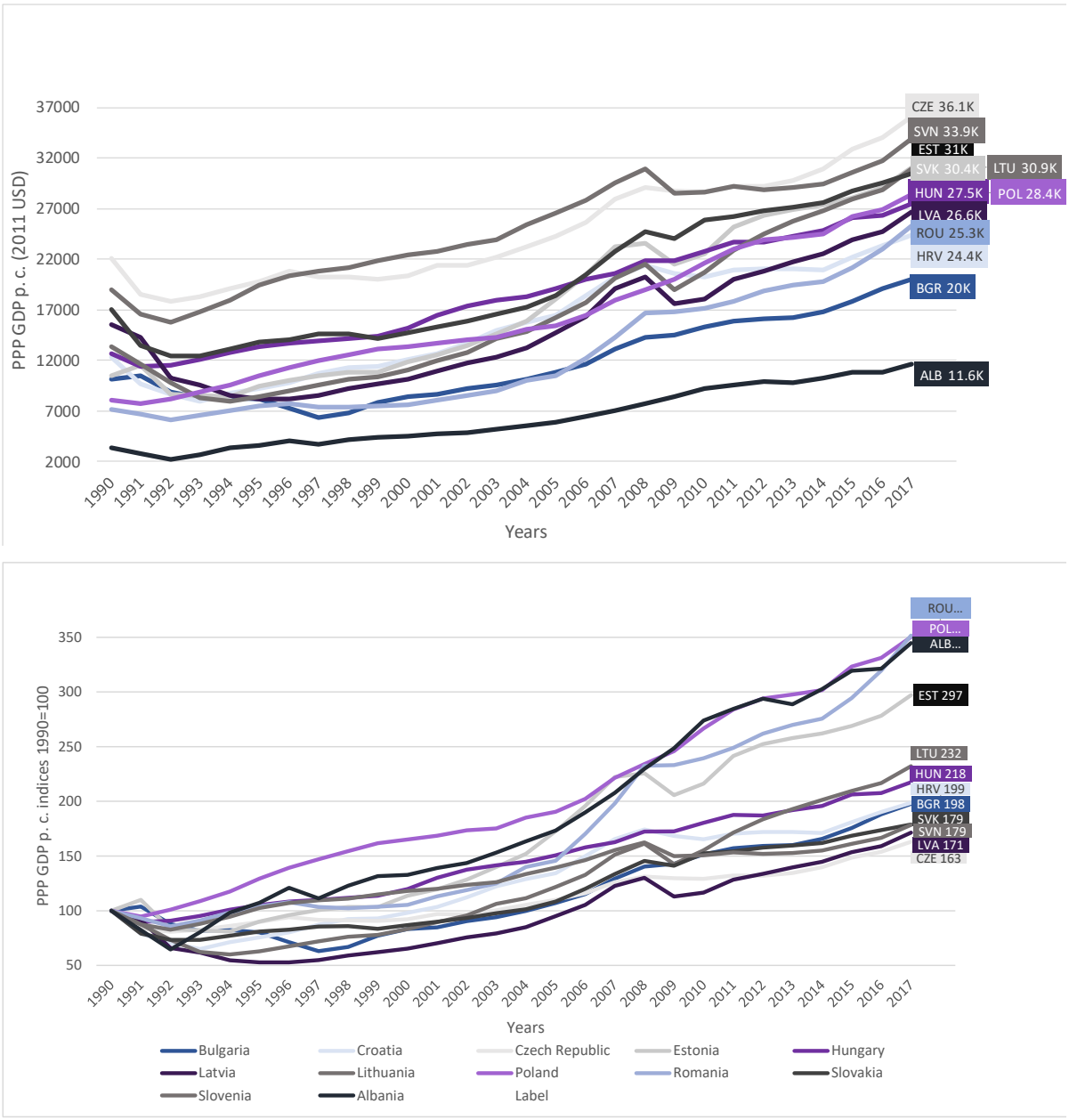
GDPs in average in 27 years. It is interesting to compare, which countries outperformed others during this period. When considering the order from the lowest to the highest GDP p.c. in 1990, the ranking looked as follows: Albania, Romania, Poland, Bulgaria, Estonia, Croatia, Hungary, Lithuania, Latvia, Slovakia, Slovenia and Czechia. When looking on the GDP p.c. in 2017 the countries looked as follows: Albania, Bulgaria, Croatia, Romania, Latvia, Hungary, Poland, Slovakia, Lithuania, Estonia, Slovenia and Czechia. Czechia and Slovenia remained the richest countries and Albania the poorest. Poland and Estonia can be considered as best convergence examples – they started with a low level and were able to outperform the majority of others.

*Figure 16:* CEE GDP p.c. and real GDP in 2017 (PPP, 2011 USD)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

*Figure 17:* GDP p.c. development from 1990 - 2017 in CEE and indices 1990=100 (PPP, 2011 USD)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

An indicator particularly relevant for convergence analyses is the annual growth rate of the GDP p.c.. *Table 10* presents the annual GDP p.c. growth rates across the whole CEE sample from 1991-2017. Further, the table was coloured to better visualize the effect of the differences among countries. The values of the annual growth rates ranged from -28% to +25%. Best performing cells, the ones with the highest values from the sample, were coloured blue. The red coloured represented in contrary the worse cases of economic contraction.

Several interesting observations may be drawn here. First of all, the transformation period and resulting instabilities and imbalances are visible in the years 1991, 1992 and 1993. During these years the biggest GDP p.c. slowdown was observed. On average the CEE's GDP declined by 11% both in 1991 and 1992. The year 1993 was not so harmful, because instead of a decrease, a stagnation was visible. With 1994 the era of solid growth rates among the CEE countries began.

Analysing the year 1991 in detail yields another remark. The GDP p.c. growth rates ranged from +10% to -21%. It should be highlighted, that only Estonia and Bulgaria faced an expansion, as measured by positive GDP p.c. growth (10% and 4% respectively). All remaining countries faced contraction of their GDP p.c. Estonia's original path of transition was broadly discussed among the researchers (Budina and Windbergen, 1997, Panagiotou, 2001). It's success can be categorised in several areas, where Estonia performed better than the average CEE country and also the remaining Baltic states, namely the macroeconomic choices after independence, the economic structure, geography, political differences (Norkus, 2007). Bulgaria on the other hand can be treated as a special country with its own transition crisis. As one may see the GDP declined there from 1992-1997 each year and 1994 was definitely an exception. Bulgaria was unique when compared to the remaining CEE countries. Unfortunately, this uniqueness related to problems that arose in many areas, like fiscal policy, banking sector and currency (Dobrinsky, 2000). Looking at the remaining years no special outliers - despite the global financial crisis - can be identified. But exactly this financial crisis is a very important point of interest – also when analysing the convergence and the related hypotheses described in Chapter 1. The period 2004-2008 was the one with the greatest growth rates for the CEE region on average. The maximum average growth was achieved in 2007, prior to the global financial crisis. The outperforming countries with growth rates >10% in that year included Latvia (+17%), Romania (+16%), Estonia (+14%), Lithuania (+14%), Bulgaria (+12%) and Croatia (+10%). Only Romania managed to continue the growth and carry it over to 2008 while achieving +17%. 2009 was the year where the slowdown became visible. Just as a reminder, the data considers GDP p.c. values adjusted for Purchase Power Parity, therefore the slowdowns are not so dramatic as they appeared in nominal values, not considering the purchasing power parity. Regardless of the calculations that were adjusted, the CEE countries' GDP p.c. declined in average by 4%. All three Baltic states that counted as fastest growers were hid the hardest and when looking at the data were subject to the boomerang effect. Their GDPs declined by -13% (Latvia), -12% (Lithuania) and -9% (Estonia). Also, Slovenia was hit by the financial crisis and exhibited a huge slowdown of -8%. After this year, all of the countries, despite Croatia,

achieved growth rates again. But many of them did not return to the growth from the pre-crisis period, which can be easily explained with economic cycles, but the theoretical roots should be analysed deeper within the research done on the financial crisis itself.

*Table 11* summarises the findings from *Table 10* when looking at the line chart in the middle, showing the trend from 1991-2017. Further, it shows the initial and ending GDP p.c. values per country as well as the average and compound annual growth rate. It is also worth mentioning, that the charts include the new short form of Czechia called Czechia.

The top five countries with the highest GDP p.c. value in 1990 include Czechia (22,122 USD), Slovenia (19,018 USD), Slovakia (17,016 USD), Latvia (15,542 USD) and Lithuania (13,328 USD). On the other hand, the 5 worst performing countries in 1990 were Albania (3,374 USD), Romania (7,183 USD), Poland (8,114 USD), Bulgaria (10,131 USD) and Estonia (10,441 USD). When looking at the homogeneity of the group in 1990, the GDP p.c. values varied a lot. For instance, Czechia as the richest country, had a GDP p.c. which was more than 6 times higher than Albania, or around 3 times higher than Romania or Poland - this should be considered, because Albania was definitely an outlier and was facing nearly an economic collapse shortly after the transition. Luckily enough, Albania was successful to rebuild its economy and reach a sustainable growth path similar to other fast-growing CEE countries. One of the biggest contributions there were the underestimated by the IMF remittances of around 700 million USD per year, which could serve as potential investment (Korovilas, 1999).

Another issue that should be considered in *Table 11* are the growth rates. 4 countries that had the lowest initial GDP p.c. level in 1990 were among the top 5 fastest growing ones for the whole period. Albania grew in average by 4.69%, Poland by 4.75%, Romania by 4.77%, Estonia by 4.11% and Bulgaria unfortunately by only 2.56% (due to the previously mentioned problems after transition). Thus, on the first point of view - when looking at the simple correlation between the initial GDP p.c. level and the average growth rate - some convergence patterns can be seen here. Looking at the 5 worst growing countries one may find Czechia (1.83%), Latvia (2.02%), Slovenia (2.17%), Slovakia (2.18%) and Bulgaria (2.56%). Also, here 4 out of 5 countries with the lowest GDP p.c. growth rate were included in the ones having the highest initial GDP p.c. level. Once more, the convergence signs can be found here.

Table 10: CEE annual GDP p.c. growth rates with colour coding*.

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Albania** | -18% | -22% | 25% | 22% | 9% | 13% | -8% | 10% | 7% | 1% | 5% | 3% | 7% | 7% | 6% | 10% | 9% | 10% | 8% | 10% | 4% | 3% | -2% | 5% | 6% | 1% | 7% |
| **Bulgaria** | 4% | -15% | -7% | 1% | -2% | -11% | -11% | 6% | 16% | 8% | 2% | 7% | 4% | 6% | 7% | 8% | 12% | 9% | 2% | 6% | 4% | 1% | 1% | 4% | 6% | 7% | 5% |
| **Croatia** | -21% | -10% | -8% | 9% | 6% | 6% | 9% | 6% | 1% | 6% | 6% | 8% | 9% | 5% | 4% | 12% | 10% | 5% | -3% | -2% | 3% | 1% | 0% | -1% | 6% | 5% | 4% |
| **Czechia** | -16% | -4% | 2% | 4% | 4% | 5% | -3% | -1% | -1% | 2% | 5% | 0% | 4% | 5% | 4% | 6% | 9% | 4% | -1% | 0% | 2% | 0% | 2% | 4% | 6% | 4% | 6% |
| **Estonia** | 10% | -24% | -2% | -1% | 11% | 6% | 5% | 3% | 0% | 10% | 5% | 7% | 9% | 9% | 14% | 13% | 14% | 2% | -9% | 5% | 12% | 4% | 2% | 2% | 3% | 4% | 7% |
| **Hungary** | -10% | 1% | 5% | 6% | 4% | 3% | 2% | 2% | 2% | 5% | 8% | 6% | 3% | 2% | 4% | 5% | 3% | 6% | 0% | 4% | 4% | 0% | 3% | 2% | 5% | 1% | 5% |
| **Latvia** | -9% | -28% | -6% | -12% | -3% | 0% | 4% | 8% | 5% | 5% | 8% | 8% | 5% | 7% | 12% | 11% | 17% | 6% | -13% | 3% | 10% | 4% | 4% | 4% | 6% | 4% | 8% |
| **Lithuania** | -13% | -16% | -15% | -4% | 5% | 7% | 7% | 6% | 2% | 7% | 7% | 7% | 11% | 5% | 9% | 9% | 14% | 7% | -12% | 9% | 11% | 7% | 5% | 4% | 4% | 3% | 7% |
| **Poland** | -5% | 7% | 8% | 8% | 10% | 8% | 6% | 5% | 5% | 2% | 2% | 3% | 1% | 6% | 3% | 6% | 9% | 6% | 5% | 8% | 6% | 4% | 1% | 1% | 7% | 2% | 6% |
| **Romania** | -7% | -8% | 6% | 8% | 6% | 4% | -4% | -1% | 1% | 2% | 7% | 5% | 5% | 12% | 4% | 17% | 16% | 17% | 0% | 3% | 4% | 5% | 3% | 2% | 7% | 8% | 10% |
| **Slovakia** | -21% | -7% | 0% | 5% | 5% | 2% | 3% | 0% | -3% | 4% | 3% | 4% | 5% | 4% | 7% | 11% | 11% | 9% | -3% | 8% | 1% | 2% | 1% | 1% | 4% | 3% | 3% |
| **Slovenia** | -13% | -5% | 7% | 7% | 9% | 4% | 2% | 1% | 3% | 3% | 2% | 3% | 2% | 6% | 4% | 5% | 6% | 4% | -8% | 0% | 2% | -1% | 0% | 1% | 4% | 3% | 7% |
| **Average** | -11% | -11% | 0% | 4% | 5% | 4% | 2% | 3% | 2% | 4% | 5% | 5% | 5% | 6% | 6% | 9% | 10% | 6% | -4% | 4% | 5% | 2% | 2% | 2% | 5% | 4% | 6% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

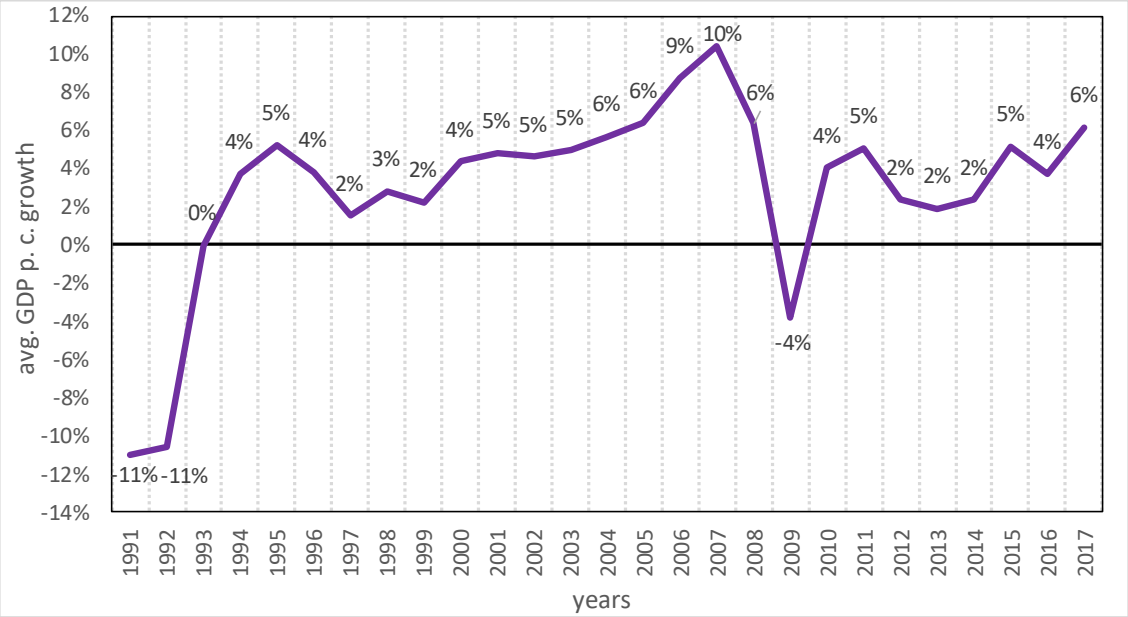
Table 11: CEE annual GDP p.c. growth rate trend and growth KPIs..

| Country | Yearly GDP p.c. Growth trend (1991-2017) | 1990 GDP p.c. | 2017 GDP p.c. | Avg. growth | CAGR |
|---|---|---|---|---|---|
| Albania |  | 3,374 | 11,629 | 4.78% | 4.69% |
| Bulgaria |  | 10,131 | 20,027 | 2.91% | 2.56% |
| Croatia |  | 12,261 | 24,368 | 2.84% | 2.58% |
| Czechia |  | 22,122 | 36,061 | 1.94% | 1.83% |
| Estonia |  | 10,441 | 31,013 | 4.43% | 4.11% |
| Hungary |  | 12,652 | 27,531 | 2.87% | 2.92% |
| Latvia |  | 15,542 | 26,643 | 2.46% | 2.02% |
| Lithuania |  | 13,328 | 30,936 | 3.50% | 3.17% |
| Poland |  | 8,114 | 28,420 | 4.25% | 4.75% |
| Romania |  | 7,183 | 25,262 | 4.65% | 4.77% |
| Slovakia |  | 17,016 | 30,433 | 2.37% | 2.18% |
| Slovenia |  | 19,018 | 33,947 | 2.28% | 2.17% |
| Average |  | 12,598 | 27,189 | 2.28% | 2.89% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

Figure 18 presents a line chart which plots the average GDP p.c. values for the whole CEE group on the vertical axis and the years on the horizontal one. This view allows for better timeframe comparison and makes the cyclical nature of economic fluctuations visible. First important observation is the transformation period right after 1990. After that, the CEE countries never faced such major downfalls of -11%. After 1993, rapid growth was visible, which stopped right after 1995 mostly driven by huge GDP p.c. decreases in Bulgaria (banking crisis, structural problems, etc.). After recovery of Bulgaria, the CEE group as a whole followed an era of increasing growth rates, especially after the important EU accession of 8 CEE countries in 2004. The growth trend continued until the global financial crisis of 2007-2008. After this period, the return to a sustainable growth path is not clearly visible, there are some ups and downs with an increasing trend until 2017. At the end of the analysed period all CEE countries, except Albania, can be considered as highly developed and have a GDP p.c. of > 20,000 USD.

*Figure 18:* CEE average GDP p.c. annual growth from 1991 – 2017.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

### 3.1.3 Capital Stock development and comparison throughout 1990-2017

Capital stock development can be considered as another interesting indicator of economic progress. Some economic growth models focusing on the long run see a fair capital distribution as a crucial factor for sustainable development and a steady state (i.e. the Ramsey model; see: Ramsey, 1928; Cass, 1965 and Koopmans, 1963). Taking into account the empirical perspective, Arestis, Baddeley and & Sawyer (2007) analysed the capital stock's impact on unemployment and wages, which turned out to be an important determinant. Although some researchers argue about capital's impact on the wages and unemployment rates (Nicjekk, Nunziata and Ochel, 2005) there seems to be an agreement about its importance for growth among both, the neoclassical and the endogenous school of economic growth.

Therefore, this section of the thesis is focused on the capital stock development among the Central and Eastern European countries. Similar to previously described GDP, also for the capital stock development specific charts and tables are presented.

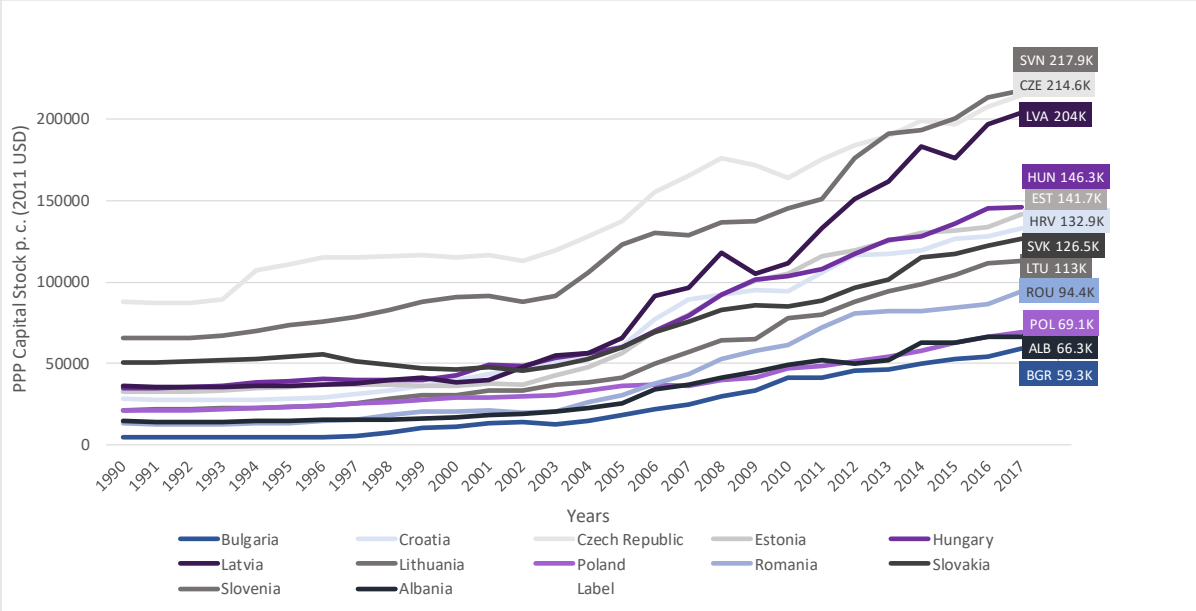
Figure 19 below shows the comparison of capital stock between the CEE countries throughout 1990-2017. Although the trend shows increases such as in GDP p.c., different

leaders and catching up countries can be defined here. Basically, the per capita capital stock in 1990 ranged from 4,395 USD (Bulgaria) to 87,663 USD (Czechia), while the magnitude of capital stock p.c. in 2017 was between 59,310 USD (Bulgaria) and 217,925 USD (Slovenia).

Unlike GDP p.c. development, the capital stock was not subject to a catching up, or rather the convergence process. Most of the CEE countries with poor capital stock level remained at it, and the richer ones were richer in 2017 as well. The five best performing countries in 1990 included Czechia (87,663 USD), Slovenia (65,554 USD), Slovakia (50,535 USD), Latvia (36,441 USD) and Hungary (34,636 USD). Remarkable at this point is not the order of the countries, but the incredible differences between the starting capital of the richest and the poorest country – also among the 5 best performing ones. Bulgaria (4,395 USD), Romania (13,227 USD), Albania (14,581 USD), Poland (21,144 USD) and Lithuania (21,387 USD) were the five countries with the lowest per capita capital stock level in 1990. Czechia had a capital stock p.c. that was nearly 3 times bigger than Hungary, which was the 5$^{th}$ best performer in 1990. The difference is even much bigger if the worst CEE performed in 1990, Bulgaria, is compared against. Then, it appears that Czechia's capital stock was nearly 20 times higher than Bulgaria's.

Did the situation from 1990 until 2017 change? Not at all. The ranking of the top five countries did not change much, with only Estonia managed to improve from 6$^{th}$ place to the 5$^{th}$, while Slovakia fell from 3$^{rd}$ to 7$^{th}$ place. Also, Slovenia managed to catch up Czechia, but the biggest catching up process can be visible when looking at Latvia. Their capital increased by far. At the end, when looking at the graph in Figure 19, several "clubs" could be defined. Slovenia, Czechia and Latvia (range 204,000 – 217,900 USD) as the best performers, Hungary, Estonia, Croatia, Slovakia, Lithuania and Romania (range 94,400 – 146,300 USD) as the middle performers and finally the countries with the lowest capital stock level include Poland, Albania and Bulgaria (range 59,300 – 69,100 USD). There are not many papers dealing with capital stock convergence, especially when considering the CEE countries, thus this could be a good topic for further research. Among the best cited articles, one may find Wolff (1991), who found a relationship between the Total Factor Productivity level and the Capital Stock development. Also Garofalo and Yamarik (2002) analysed the capital stock levels (through their estimates) among some US states and found a convergence of around 2%, which could be explained by the Solow model and is in line with the research done by Barro (see: Barro and Sala-i-Martin, 1990).

*Figure 19:* Capital Stock p.c. development from 1990 - 2017 in CEE (PPP, 2011 USD)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

This theoretical investigation leads to the review of *Table 12* below, together with the famous Kaldor (1957) statement that Capital Stock per worker growth levels are subject to a more or less constant magnitude in the long run. 27 years can certainly be considered as the long run, but instead of capital per worker, the *Table 12* contains capital stock per capita, which should be treated as a roughly estimate of capital per worker magnitudes. Indeed the capital stock p.c. growth rates did not vary significantly between 1991-2000, until the Dot Com crisis occurred. After that period short decreases were visible but at the end, sizeable, unusual growth rates were observed during the pre-crisis period between 2003-2008. These enormous growth rates, even higher than 15% among 9 of the analysed countries in 2006, could explain and highlight the economic bubble burst in 2007/2008. After the post crisis period, the growth rates remained higher than during 1991-2000, but were pretty stable.

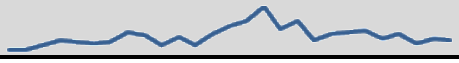
Table 12: CEE annual Capital Stock p.c. growth rates with colour coding*.

| Country | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albania | -3% | -3% | 2% | 3% | 3% | 2% | 1% | 2% | 3% | 5% | 7% | 6% | 8% | 11% | 12% | 33% | 9% | 12% | 9% | 9% | 5% | -3% | 4% | 22% | 0% | 6% | 0% |
| Bulgaria | -1% | -1% | 1% | 2% | 3% | 1% | 17% | 45% | 37% | 6% | 14% | 9% | -9% | 13% | 24% | 20% | 15% | 19% | 12% | 23% | 1% | 10% | 2% | 8% | 6% | 3% | 9% |
| Croatia | -2% | -2% | 1% | 1% | 2% | 3% | 5% | 8% | 9% | 9% | 10% | 9% | 9% | 8% | 9% | 27% | 16% | 4% | 2% | -1% | 12% | 11% | 0% | 2% | 6% | 1% | 4% |
| Czechia | -1% | 0% | 2% | 20% | 4% | 3% | 0% | 1% | 0% | -1% | 1% | -3% | 6% | 7% | 7% | 13% | 6% | 7% | -3% | -4% | 7% | 5% | 3% | 5% | -1% | 6% | 3% |
| Estonia | 1% | 0% | 3% | 3% | 3% | 3% | 1% | 0% | -1% | -1% | 4% | -2% | 16% | 13% | 18% | 24% | 14% | 15% | 10% | 4% | 10% | 3% | 5% | 4% | 1% | 2% | 6% |
| Hungary | 1% | 1% | 4% | 4% | 4% | 2% | -2% | 0% | 0% | 8% | 16% | -2% | 10% | 5% | 6% | 17% | 12% | 16% | 10% | 2% | 4% | 8% | 8% | 2% | 6% | 7% | 0% |
| Latvia | -2% | -2% | 1% | 1% | 2% | 1% | 2% | 5% | 3% | -7% | 4% | 20% | 16% | 2% | 16% | 39% | 6% | 23% | -11% | 7% | 19% | 13% | 7% | 13% | -4% | 12% | 4% |
| Lithuania | 1% | 1% | 2% | 2% | 2% | 3% | 6% | 10% | 8% | 2% | 9% | -2% | 11% | 5% | 6% | 21% | 15% | 13% | 0% | 20% | 3% | 10% | 8% | 5% | 5% | 7% | 2% |
| Poland | 0% | 0% | 3% | 3% | 4% | 5% | 3% | 5% | 4% | 4% | 1% | 3% | 1% | 9% | 10% | 2% | -3% | 11% | 3% | 13% | 4% | 6% | 5% | 6% | 8% | 5% | 5% |
| Romania | -3% | -2% | 1% | 2% | 3% | 8% | 9% | 17% | 12% | 0% | 1% | -5% | 4% | 26% | 18% | 24% | 15% | 20% | 9% | 7% | 17% | 12% | 2% | 0% | 2% | 3% | 9% |
| Slovakia | 1% | 0% | 2% | 2% | 2% | 2% | -7% | -4% | -4% | -2% | 4% | -4% | 5% | 10% | 12% | 16% | 9% | 9% | 3% | 0% | 4% | 8% | 5% | 14% | 1% | 4% | 4% |
| Slovenia | 0% | -1% | 3% | 4% | 5% | 3% | 4% | 5% | 6% | 3% | 1% | -4% | 4% | 16% | 16% | 6% | -1% | 6% | 0% | 5% | 4% | 17% | 8% | 1% | 4% | 7% | 2% |
| Average | -1% | -1% | 2% | 4% | 3% | 3% | 3% | 8% | 6% | 2% | 6% | 2% | 7% | 10% | 13% | 20% | 9% | 13% | 4% | 7% | 8% | 8% | 5% | 7% | 3% | 5% | 4% |

Sources: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

*Table 13* below summarises the overall findings and includes both the starting and ending capital stock p.c. values. Although it was not possible to catch up the richer countries in case of Bulgaria, the country had the highest average growth rate (10.12%). When looking at the top five growing countries, after Bulgaria one may find Romania (7.55%), Latvia (6.59%), Lithuania (6.36%) and Croatia (5.89%). Furthermore, the trend line presented in *Table 13* for each country confirms the previously described observations. Before and after the financial crisis the per capita capital stock growth rates were pretty stable.

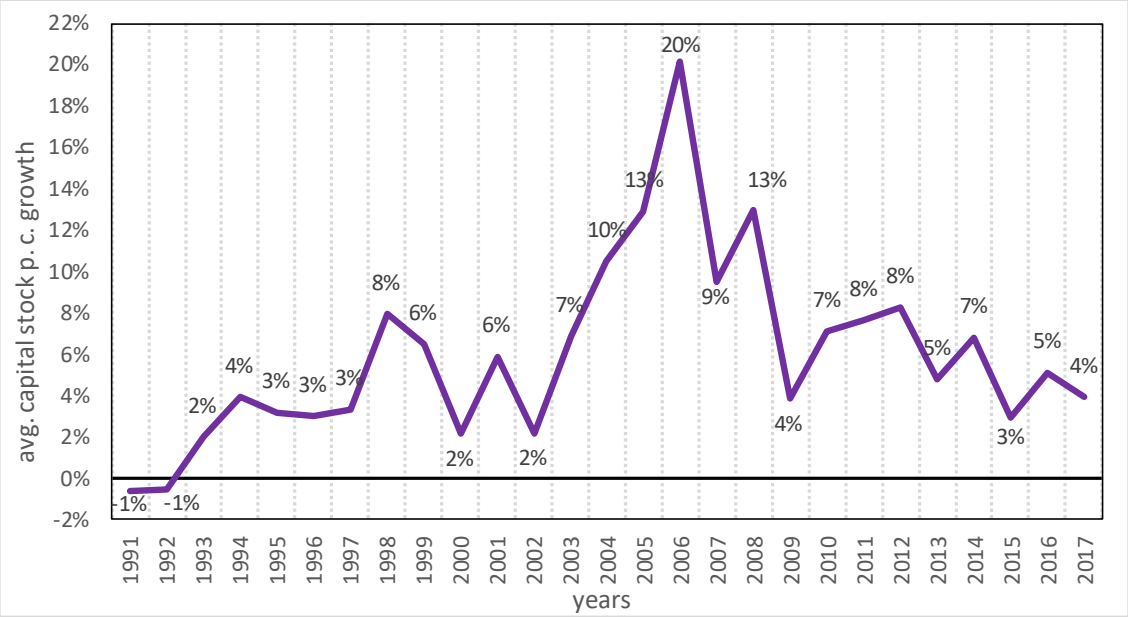
Table 13: CEE annual Capital Stock p.c. growth rate trend and growth KPIs.

| Country | Yearly Capital Stock p.c. growth trend (1991-2017) | 1990 Capital Stock p.c. | 2017 Capital Stock p.c | Avg. growth | CAGR |
|---|---|---|---|---|---|
| Albania |  | 14,581 | 66,257 | 5.86% | 5.77% |
| Bulgaria |  | 4,395 | 59,311 | 10.37% | 10.12% |
| Croatia |  | 28,333 | 132,893 | 6.06% | 5.89% |
| Czechia |  | 87,663 | 214,620 | 3.49% | 3.37% |
| Estonia |  | 32,402 | 141,651 | 5.81% | 5.62% |
| Hungary |  | 34,636 | 146,273 | 5.49% | 5.48% |
| Latvia |  | 36,441 | 204,021 | 7.06% | 6.59% |
| Lithuania |  | 21,388 | 113,002 | 6.50% | 6.36% |
| Poland |  | 21,145 | 69,112 | 4.41% | 4.48% |
| Romania |  | 13,228 | 94,394 | 7.55% | 7.55% |
| Slovakia |  | 50,535 | 126,503 | 3.61% | 3.46% |
| Slovenia |  | 65,555 | 217,926 | 4.66% | 4.55% |
| Average |  | 34,192 | 132,164 | 5.99% | 5.14% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

The chart in Figure 20 below highlights the pre and post crisis period even more. An investment bubble from 2003 to 2006 can be clearly visible.

*Figure 20:* CEE average Capital Stock p.c. annual growth from 1991 – 2017.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

### 3.1.4 Total Factor Productivity development and comparison throughout 1990-2017

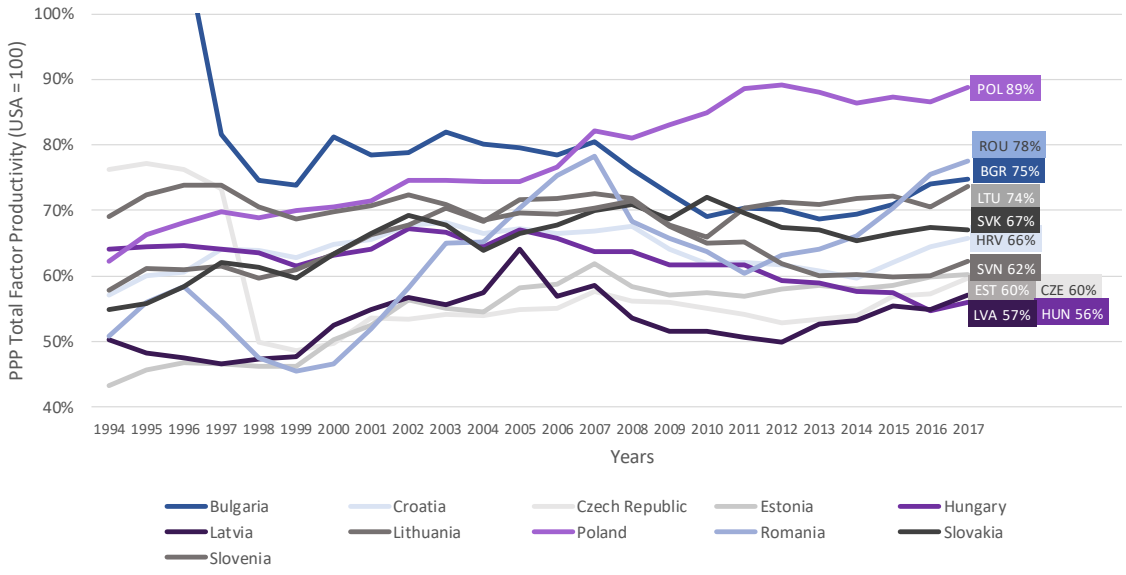
The next indicator discussed, representing the total factor productivity (TFP) can be very relevant when comparing not only the productivity growth, but the income growth rates in general. Most researchers see the technological progress as a major driver for income growth. It's meaningfulness can be also highlighted by how its name evolved. It is not uncommon to describe it as the so-called "Solow residual" that is meant to consider the majority of the unexplained determinants of income growth in the Solow model. TFP, although still a subject of debate, can be considered as a proxy for technological progress in empirical analysis. Chen (1997) wrote a solid literature and empirical review of how the TFP affects the GDP growth in Asia. The growth miracle among the Asian countries can be considered as huge export oriented industrialisation, where TFP may have played a significant role if it is calculated properly. Therefore, the growth impact itself turned out to be very related with the TFP calculation and methodology used. The reason for this is because TFP is many times considered as a residual and the inclusion of additional factors make its impact lower. The PWT 9.1 calculate the TFP based on revenue functions measuring the real output of a specific country depended on the one from the other. More details can be found in Feenstra, Inklaar and Timmer (2015). Also the TFP level measured in PWT 9.1 considers the United States as 100%, whereas other countries

can overachieve or fall behind this country. It is plausible to look at this indicator when comparing the performance among other countries or country groups like LA and CEE.

Figure 21 represents the TFP levels among the CEE countries from 1994-2017. Unfortunately the database does not contain data for some countries in the period before 1994. Also, the PWT 9.1 TFP levels do not include Albania. Nevertheless, the conclusions and trends here are interesting and different than the ones for GDP or capital. First of all, this particular TFP level is a ratio compared to the US, so when a percentage is growing, than the country is catching up with the US, it does not necessary mean that either stagnation or growth is visible.

Bulgaria (130%), Czechia (76%), Slovenia (69%), Hungary (64%) and Poland (62%) can be considered as the top performing countries with respect to the TFP in 1994. A worth mentioning observation is, that Bulgaria's TFP level was higher than the US one until 1996. It stopped growing, or even substantially declined in 1997, undoubtfully due to the transformation processes. But from that period onwards, the TFP level remained stable in that country until 2017. Looking at the catching up process Poland and Romania can be considered as the best performing countries when considering the TFP development. In the period 1994-2017 Poland managed to improve the TFP level by 43% while Romania even by 53%. Several countries have a declining trend in the chart presented below. Czechia, Hungary and Slovenia were not able to maintain their solid TFP levels until 2017.

*Figure 21:* Total Factor Productivity (TFP) development from 1994 - 2017 in CEE* (PPP, USA = 1)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

**Albania is not included in the dataset.*

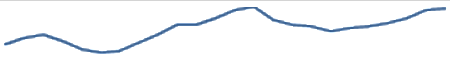
Table 14: CEE* annual TFP levels with colour coding** (PPP, USA = 1).

| Country | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bulgaria | 130% | 123% | 111% | 82% | 75% | 74% | 81% | 78% | 79% | 82% | 80% | 80% | 78% | 80% | 76% | 73% | 69% | 70% | 70% | 69% | 69% | 71% | 74% | 75% |
| Croatia | 57% | 60% | 60% | 64% | 64% | 63% | 65% | 65% | 68% | 68% | 66% | 67% | 66% | 67% | 68% | 64% | 62% | 62% | 62% | 61% | 60% | 62% | 64% | 66% |
| Czechia | 76% | 77% | 76% | 73% | 50% | 48% | 50% | 53% | 53% | 54% | 54% | 55% | 55% | 58% | 56% | 56% | 55% | 54% | 53% | 53% | 54% | 57% | 57% | 60% |
| Estonia | 43% | 46% | 47% | 46% | 46% | 46% | 50% | 52% | 56% | 55% | 55% | 58% | 59% | 62% | 58% | 57% | 57% | 57% | 58% | 59% | 58% | 58% | 60% | 60% |
| Hungary | 64% | 64% | 65% | 64% | 64% | 62% | 63% | 64% | 67% | 67% | 64% | 67% | 66% | 64% | 64% | 62% | 62% | 62% | 59% | 59% | 58% | 57% | 55% | 56% |
| Latvia | 50% | 48% | 48% | 47% | 47% | 48% | 52% | 55% | 57% | 56% | 57% | 64% | 57% | 59% | 54% | 51% | 52% | 51% | 50% | 53% | 53% | 55% | 55% | 57% |
| Lithuania | 58% | 61% | 61% | 61% | 60% | 61% | 63% | 66% | 68% | 70% | 68% | 72% | 72% | 72% | 72% | 68% | 66% | 70% | 71% | 71% | 72% | 72% | 71% | 74% |
| Poland | 62% | 66% | 68% | 70% | 69% | 70% | 71% | 71% | 75% | 75% | 74% | 74% | 77% | 82% | 81% | 83% | 85% | 89% | 89% | 88% | 86% | 87% | 87% | 89% |
| Romania | 51% | 56% | 58% | 53% | 47% | 45% | 47% | 52% | 58% | 65% | 65% | 70% | 75% | 78% | 68% | 66% | 64% | 60% | 63% | 64% | 66% | 70% | 75% | 78% |
| Slovakia | 55% | 56% | 58% | 62% | 61% | 60% | 63% | 66% | 69% | 68% | 64% | 66% | 68% | 70% | 71% | 69% | 72% | 70% | 67% | 67% | 65% | 66% | 67% | 67% |
| Slovenia | 69% | 72% | 74% | 74% | 70% | 69% | 70% | 71% | 72% | 71% | 68% | 70% | 69% | 70% | 71% | 68% | 65% | 65% | 62% | 60% | 60% | 60% | 60% | 62% |
| **Average** | 65% | 66% | 66% | 63% | 59% | 59% | 61% | 63% | 66% | 66% | 65% | 68% | 67% | 69% | 67% | 65% | 64% | 65% | 64% | 64% | 64% | 65% | 66% | 68% |

Sources: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Albania is not included in the dataset.*
***Colour coding: blue = best performance, red = worse performance.*

*Table 14* on the top presents more details for each year and a colour coding in addition, similar to the indicators described in previous chapters. *Table 15* below shows on the other hand a good summary for all of the analysed countries (despite Albania) together with the CAGR from 1994-2017. As indicated previously, Romania had the best average growth rate (1.58%) followed by Poland (1.33%), Estonia (1.24%), Lithuania (0.9%) and Slovakia (0.75%). Bulgaria can be considered as the worst case having a negative growth rate of -2.02% followed by Czechia (-0.9%), Hungary (-0.5%), Slovenia (-0.39%) and Latvia (0.48%).

Table 15: CEE* annual TFP trend and growth KPIs.

| Country | Yearly TFP trend (1994-2017) | 1994 TFP | 2017 TFP | CAGR |
|---|---|---|---|---|
| Bulgaria |  | 130% | 75% | -2.02% |
| Croatia |  | 57% | 66% | 0.53% |
| Czechia |  | 76% | 60% | -0.90% |
| Estonia |  | 43% | 60% | 1.24% |
| Hungary |  | 64% | 56% | -0.50% |
| Latvia |  | 50% | 57% | 0.48% |
| Lithuania |  | 58% | 74% | 0.90% |
| Poland |  | 62% | 89% | 1.33% |
| Romania |  | 51% | 78% | 1.58% |
| Slovakia |  | 55% | 67% | 0.75% |
| Slovenia |  | 69% | 62% | -0.39% |
| Average |  | 65% | 68% | 0.14% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Albania is not included in the dataset.*

### 3.1.5 Labour force and human capital in CEE

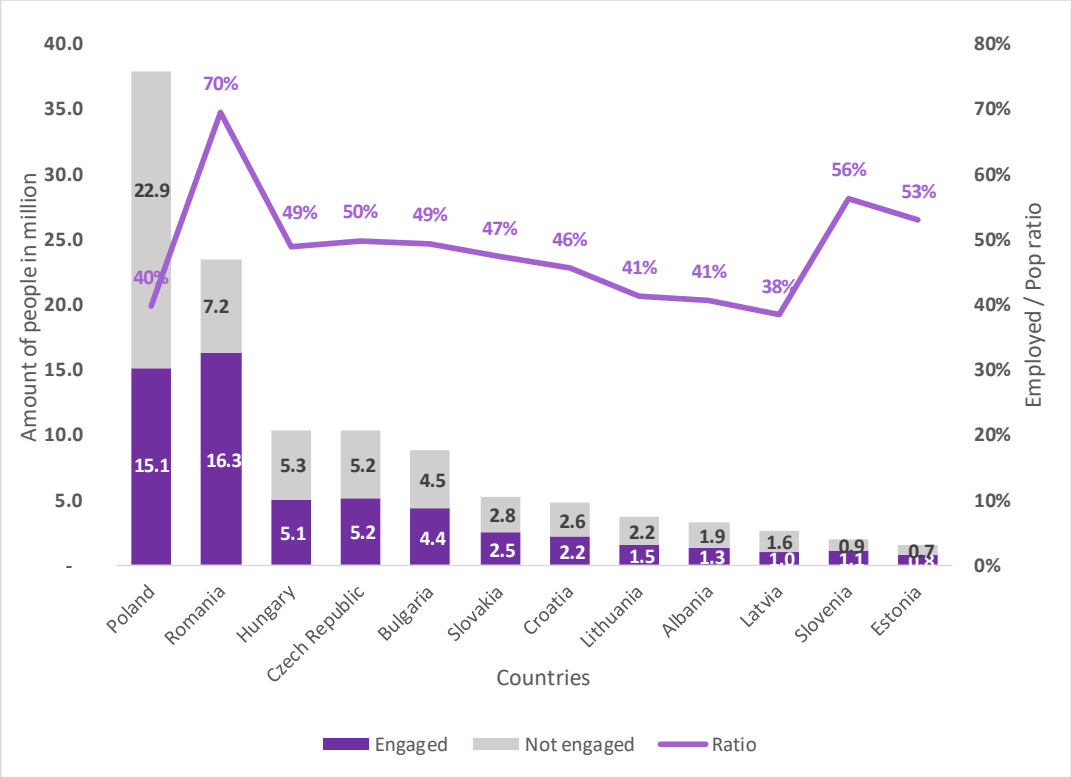
Although a low unemployment rate and well-developed labour market are undoubtedly important drivers for a country's performance, discussion about an optimal human capital level is still ongoing. Especially when considering an indicator which is calculated based on years of schooling (Keller, 2006; Ogundari and Awokuse, 2018). A reason for such dilemma is, that a too high share of highly educated people in a country does not necessary imply the country's better economic performance. It could even have a negative effect, where over skilled people migrate to other countries for job seeking. Although brain drain is a commonly known problem for poorer, developing countries, it was visible in CEE as well (Balaz, Williams and Kollar, 2004). Finally, human capital is still subject of a debate between followers of the neoclassical and endogenous growth theory, described in the Chapter 1 of this thesis.

Labour force, considered as one of the two important and reference production factors (together with capital), is measured here as the number of people engaged compared to the entire population. Furthermore, also a discussion a human capital indicator based on the number of years of schooling and returns to education is performed.

In Figure 22, the chart presents both the amounts of people engaged in labour (violet colour) and people not employed (grey colour) in the year 1990. The line in the chart describes the according engagement ratio of people working in the whole population. Considering the size of population three groups of countries may be defined within Central and Eastern Europe. Poland and Romania can be treated as the largest countries with a population reaching far beyond 20 million, Hungary, Czechia and Bulgaria have a population around 10 million and finally the remaining countries have less than 5 million (although Slovakia has slightly more than 5). The ratio of people employed is the greatest for Romania (70%), Slovenia (56%) and Estonia (53%). All remaining countries have a share lower than 50%, whereas Lithuania, Albania, Poland and Latvia are oscillating around 40% with the lowest percentage rates.

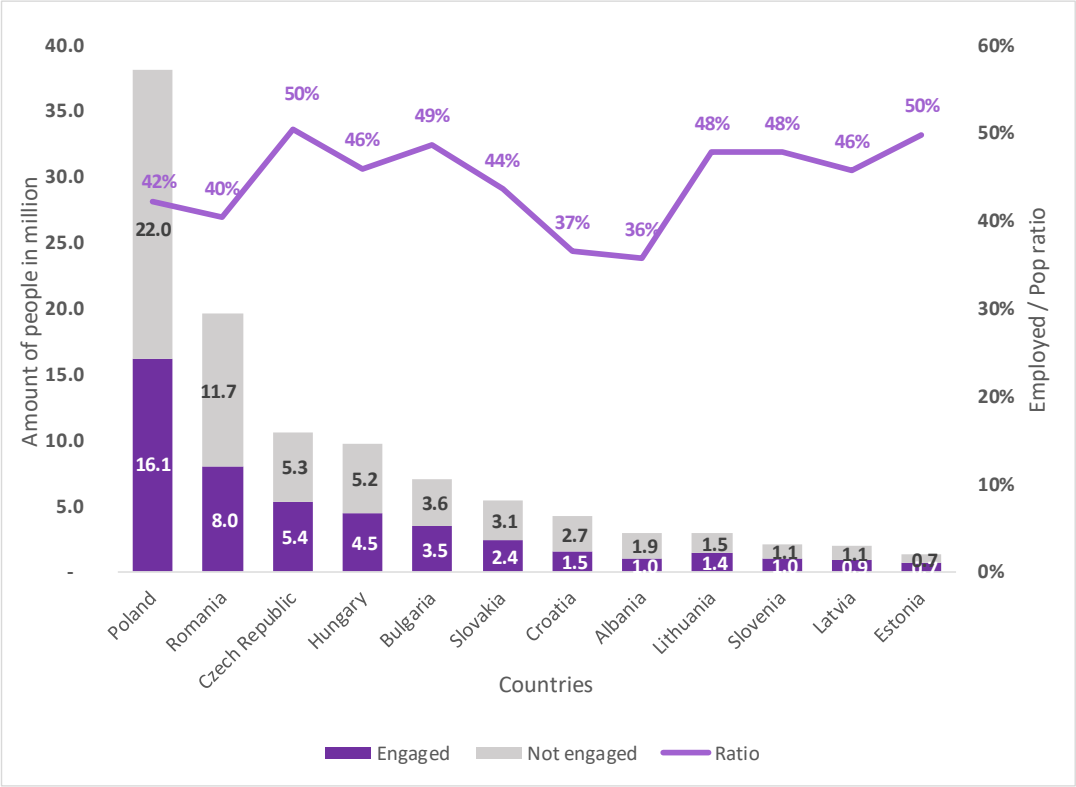
Figure 23 presents the same set of information as in Figure 22, but now the situation reflects the year 2017. In general, the total population of CEE decreased from 114 to 106 million, similar to the overall engagement ratio which went lower from 49% to 44%. No convergence trend can be seen when looking at the charts and the engagement ratio, despite Romania, which went to a much lower level of 40%. The rest of the countries remained more or less stable.

*Figure 22:* Labour Force and Population Indicators during 1990 in CEE (in million and %)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

*Figure 23:* Labour Force and Population Indicators during 2017 in CEE (in million and %)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Table 16: CEE annual Human Capital Index based on years of schooling and returns to education with colour coding*.

| Country | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Albania | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 |
| Bulgaria | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 |
| Croatia | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.5 | 3.5 |
| Czechia | 3.1 | 3.2 | 3.2 | 3.3 | 3.3 | 3.4 | 3.4 | 3.5 | 3.5 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.7 | 3.7 | 3.7 | 3.7 |
| Estonia | 2.8 | 2.8 | 2.9 | 2.9 | 3.0 | 3.0 | 3.1 | 3.1 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 |
| Hungary | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 |
| Latvia | 2.4 | 2.5 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 |
| Lithuania | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.3 |
| Poland | 2.7 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 |
| Romania | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 |
| Slovakia | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.5 | 3.5 | 3.5 | 3.6 | 3.6 | 3.6 | 3.6 | 3.7 | 3.7 | 3.7 | 3.7 | 3.8 | 3.8 |
| Slovenia | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 | 3.4 | 3.4 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Average | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 |

Sources: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

*Table 16* above, shows details about the human capital in the CEE sample throughout the analysed period. The index is based on average years of schooling and a return rate for primary, secondary and tertiary education (Feenstra, Inklaar and Timmer, 2015). The colour coding presents the worst performing values as red and the best performing ones as blue. Although the years of schooling are a good estimate of human capital in general, the disadvantage of the HCI in PWT 9.1 is that it does not account for the quality of schooling and the experience (Feenstra, Inklaar and Timmer, 2015). This simple indicator is however enough, to compare the countries performance with each other.

Nearly all of the CEE countries started with a rather low level of human capital. In fact the index ranged in 1990 from 2.4 to 3.1 and the average during that year was around 2.8 points. Czechia, Slovakia and Slovenia had an HCI of 3.1 and can be considered as the top performers. Latvia, Albania and Lithuania were around 2.5, which is far less than the top performing countries. The situation however changed during the analysed periods and constant growths were observable everywhere. Every country had a better HCI in 2017 than in 1990. Czechia, Slovakia and Estonia were the best performing countries in 2017 reaching 3.7, 3.8 and 3.6 respectively. But which countries grew at most during the whole analysed periods? Surprisingly Croatia had the highest CAGR of around 1.02% and was followed by Estonia (0.95%) and Latvia (0.91%). Slovenia, Bulgaria and Albania had the lowest growth rates on average. At the end, in 2017, the HCI values ranged from 3.0 to 3.8, which results in a slightly lower difference than in 1990. Therefore, overall, no convergence trend can be found based on that table.

### 3.1.6 Qualitative analysis of the convergence effect

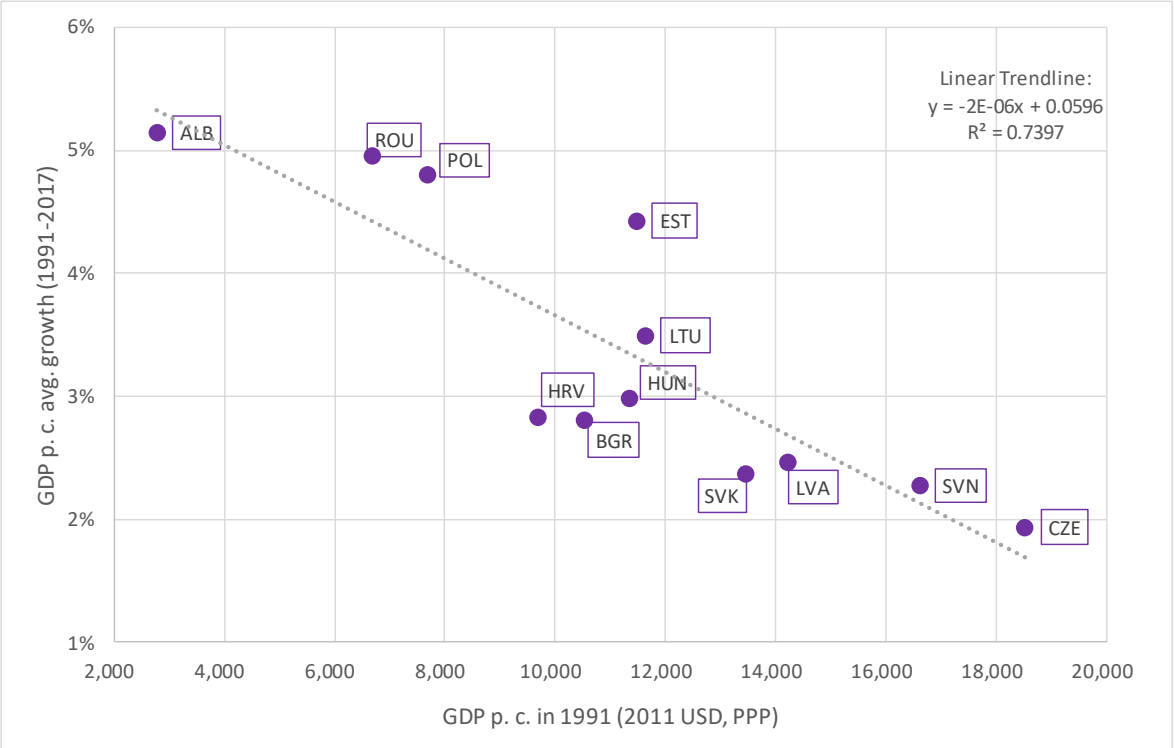
Prior to the application of the SURE model a simple convergence plot as depicted on the Figure 24 was analysed. The chart plots initial GDP p.c. level in 1991 (horizontal axis) against the average GDP p.c. growth rate during the period 1991-2017 (vertical axis). According to the convergence theory, countries with a lower initial GDP p.c. should have a higher growth rate in order to catch up with the richer ones. Therefore, the poorer countries are to be expected on the top-left side of the chart. Contrary to the poorest countries, the richest countries are expected to be on the bottom-right side having a lower GDP p.c. growth level. With this simple visualisation one may conclude whether a general convergence trend exists or not.

This idea matches perfectly with the best performing countries in 1991 and the worst performing ones. Albania, Romania and Poland having the lowest GDP p.c. levels had also the

best average growth rates around 5%. Czechia, Slovenia and Latvia had the highest GDP p.c. in 1991 and also a lowest average growth rate around 2%. Estonia and Slovakia can be considered as outliers for this rule, however the remaining ones having a moderate GDP p.c. level in 1991 were also subject to moderate growth rates around 3%.

Additionally, Figure 24 includes a general trendline and an automatic generated function based on the plot. The linear function has a rather low, but still negative value and a pretty solid $R^2$ magnitude of 0.74. A detailed and an in-depth analysis should be able to deliver more sophisticated and clear conclusions about the convergence. The next chapter will provide extensive insights about the variability of the catching-up speed (convergence heterogeneity).

*Figure 24:* Convergence plot in CEE




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

## 3.2 Results presentation and discussion

The CEE empirical convergence analysis involved a sample of 12 countries according to the OECD definition (Albania, Bulgaria, Czechia, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Slovenia and Slovakia), whereas the data ranges from 1992 to 2019. Due to data accuracy, the data range did not involve earlier periods. As per the methodology section, Equation (30) for convergence testing was applied. Seven parameters (despite the intercept) were tested to check the strength of the relationship between income dynamics and government spending, inflation, inflation square, gross capital formation (investment), human capital, time trend component and the initial income respectively. The endogenous variable was set as the growth of the GDP per worker. The analysis and discussion in this chapter involved purely the convergence parameters and the human capital relevance, however the reader may find all other results in the Appendix section (Table A *1* to Table A *8*).

Following the commonly accepted and used notations, the parameter next to the initial income is described as beta and accounts for the convergence strength. A negative value of beta estimates results in convergence. This means that the higher the initial income is, the lower GDP growth one may expect. If the beta parameter is positive, then no convergence was visible. Of course, the stronger the beta parameter is, the higher impact of the initial income on growth can be expected, which suggest stronger catching-up process. The theory behind this was described in detail in the first two chapters of this thesis.

In order to follow the main objective and hypothesis of this thesis, the focus in the results section was put on the visualisation of beta parameters. The analysis and empirical verification were done twofold. The Equation (30) was tested in both ways:

- **M0**: The model described here as M0 captures the convergence separately for each country. The error terms of the countries are not correlated. This is the classical way of estimating the convergence parameters country by country. Based on the literature review, other researchers usually tend to use the panel regression analysis making constancy of regression parameters across countries. In M0 it is possible to check cross country heterogeneity of convergence, but in the most primitive way by isolating estimates only to the dataset corresponding to a particular country.
- **M1**: The model named as M1 is the novel approach for convergence testing that treats the countries as a system. The error terms of the countries are correlated with each other. The estimation for the SURE model used the Zellner estimator (1962). This method for

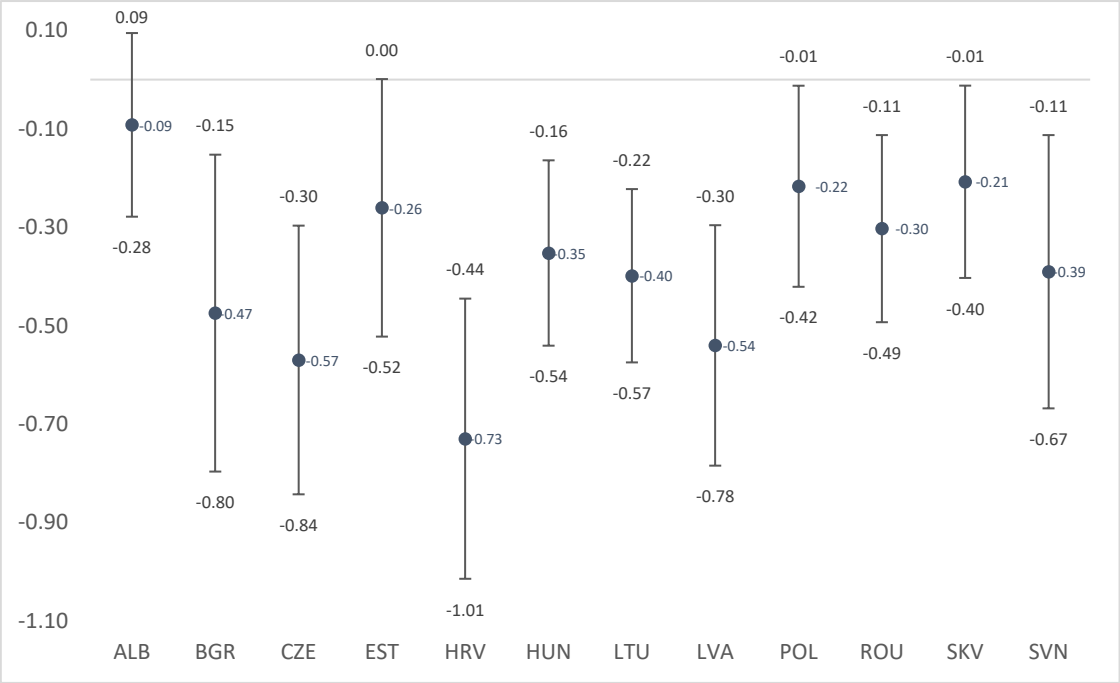
CEE convergence testing was introduced and discussed by Pipień and Roszkowska (2019). This paper will therefore also serve as a reference and comparison in this section.

An attempt to summarising and visualising the results involved a plot of the countries with beta values on the vertical axis and country labels on the horizontal axis. Further, it would be of high interest for the reader to see the statistical inferences of the analysis done. Therefore, bounds of the 95% confidence intervals were added to the visualization. M0 can be found when looking at Figure 25 below, while M1 was visualised in Figure 26.

Pipień and Roszkowska (2019) analysed 12 CEE countries from 1992-2015. The testing there also involved the same models, M0 (standard regression) and M1 (Zellner estimator). The calculation in this dissertation with an extended period and the additional variable in Equation (30) accounting for human capital, can therefore be considered as an extension of calculations by Pipień and Roszkowska (2019). For the sake of simplicity and to distinguish between the results from the dissertation and the paper, the models M0 and M1 from the paper will be named as PM0 and PM1 respectively.

Before moving into a more detailed results description it is worth to draw some first general conclusions about the CEE results obtained. Both, the model M0 from Figure 25 and model M1 from Figure 26 suggest a convergence process among all countries. All of the beta parameters are negative with very strong magnitudes. Nearly the same situation applies to the respective 95% confidence intervals. In fact, there is only one country among those two models that may – when considering the 95% intervals – be diverging, namely Albania. The betas for Albania are equal to -0.09 and -0.11 when looking at M0 and M1 respectively. Their confidence intervals range however between -0.28 - 0.09 for M0 and between -0.29 - 0.06 for M1. It is important to highlight, that this is the only country where the confidence intervals allow a positive beta magnitude. Also, the model M0 seems to have lower beta parameters than M1 when looking at the averages, -0.38 vs. -0.48 respectively. This means, that treating the CEE countries as one group and utilizing the Zellner estimator is suggesting a stronger convergence effect. This applies to the majority of the countries, but not to all. Croatia had the opposite situation with M0's beta reaching -0.73 and M1 -0.68. Furthermore, the beta parameters for some countries are different by couple percent (Albania, Romania) and for some of them by far (Poland, Estonia). This suggest for strong heterogeneity of the beta parameters between the two models. The next step will involve a more detailed analysis of each figure.

*Figure 25: $M_0$ C*onvergence parameters estimates for CEE countries together with bounds of the 95% confidence intervals, sample for 1992-2019.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

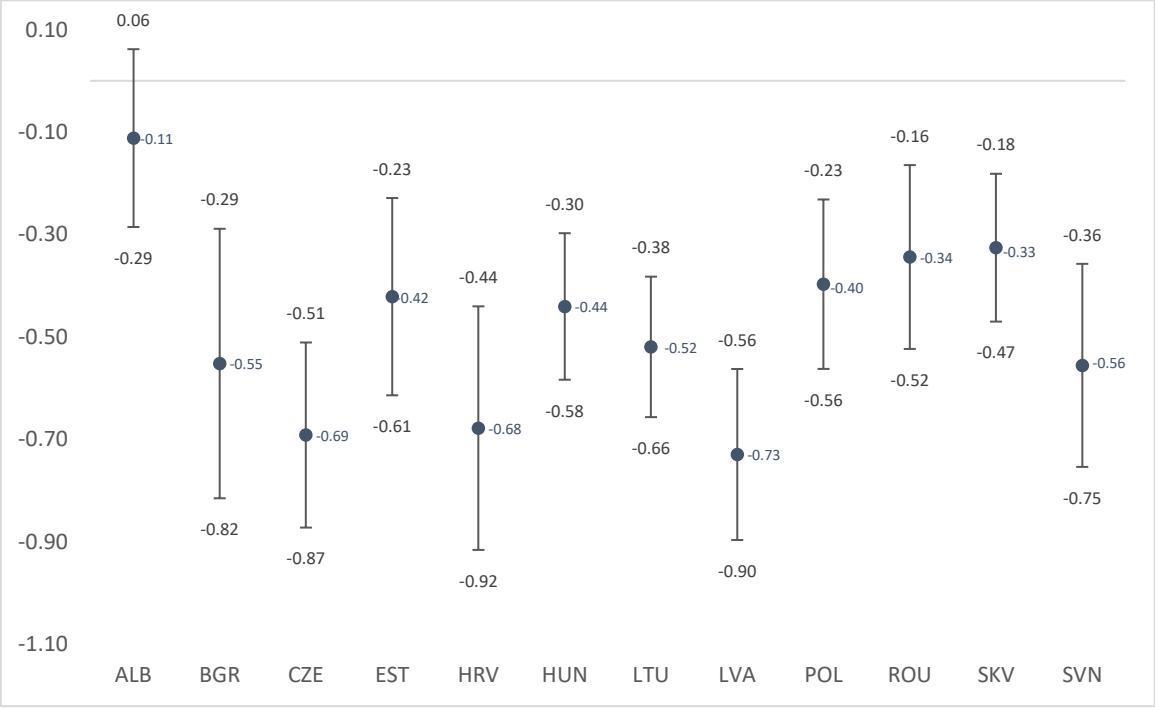
When looking at Figure 25, several interesting observations can be made. Overall, the beta parameters range between -0.73 (Croatia) and -0.09 (Albania) with an average beta value of -0.38. This indicates a very strong convergence effect among all of the countries. Top five countries with the strongest parameters included Croatia (-0.73), Czechia (-0.57), Latvia (-0.54), and Bulgaria (-0.47). The countries that had the bottom 5 lowest convergence rates were Albania (-0.09), Slovakia (-0.21), Poland (-0.22), Estonia (-0.26) and Romania (-0.30). Another observation is, that some countries tend to converge with a similar speed. To be more specific 2 groups may be identified. There are 5 countries that have beta parameters between -0.21 and -0.35, namely Estonia, Hungary, Poland, Romania and Slovakia. The second group involves countries that have much higher parameters, namely between -0.39 and -0.57. Those countries include Bulgaria, Czechia, Lithuania, Latvia and Slovenia. Finally, there are two outlying countries: Albania with a parameter of -0.09 and Croatia with a beta of -0.73. If those two countries are excluded from the set, the beta parameters are ranging between -0.21 and -0.57.

Albania and Bulgaria are currently the poorest countries in the sample when looking at the PPT GDP per worker values that reached 33,556 USD and 43,688 USD in 2019. The same applies to the GDP per capita which for 2019 is equal to 12,457 USD and 22,773 USD respectively. According to M0 however, Bulgaria is much better at catching up than Albania;

although it is (in 2019) and was a richer country (in 1992). The reason why Albania's economic growth is not so strongly correlated with initial income like for other countries may lay in other parameters. In fact, Konstandina and Gachino (2020) analysed the country's economic performance and indicated that foreign direct investment together with a solid infrastructure played a significant role in there. Hobbs, Paparas and AboElsound (2021) also indicate huge value of FDI and trade in Albania. Since the Equation (30) includes the investment parameter next to the beta, the case stated above may be valid, namely that Albania's growth was more correlated with the investment rate instead of the initial income.

When comparing the M0 results with the ones in PM0 obtained by Pipień and Roszkowska (2018) there is even a wider spread of the range with beta values between -0.93 (Slovenia) and -0.05 (Croatia). The average beta value is around -0.39 which is nearly on M0 level. Bulgaria, Lithuania and Latvia are in both models among the top 5 ones with the highest beta parameters suggesting strongest convergence. There are however major differences, especially when looking at Albania, Croatia and Czechia. Considering that the difference between M0 and PM0 includes the human capital variable and a time period, this variances indeed suggest the heterogeneity of convergence parameters.

*Figure 26: $M_1$ C*onvergence parameters estimates for CEE countries together with bounds of the 95% confidence intervals, sample for 1992-2019.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Analyses of Figure 26 that involved the Zellner estimator in a more deeper way can be started with the overall beta parameter values that range between -0.73 and -0.11, which is very similar to the OLS method from Figure 25. The same applies to the average size of the beta being on a -0.62 level. Top five countries are very similar as well and include Latvia, Czechia, Croatia, Slovenia and Bulgaria. Only Slovenia was not part of the top five countries when looking at M0 (-0.39), while it is now on the fourth place with a parameter of -0.56. The bottom countries with the lowest convergence rate are similar too and include among others Albania, Romania and Slovakia, which is in line with M0.

All countries except Croatia seem to catch up faster in the Zellner estimator when compared to M0. The biggest drivers include Estonia, Lithuania, Latvia, Poland and Slovenia. The average beta for those countries in M1 is equal to -0.52, while for M0 it was equal to -0.36 which is really a substantial difference.

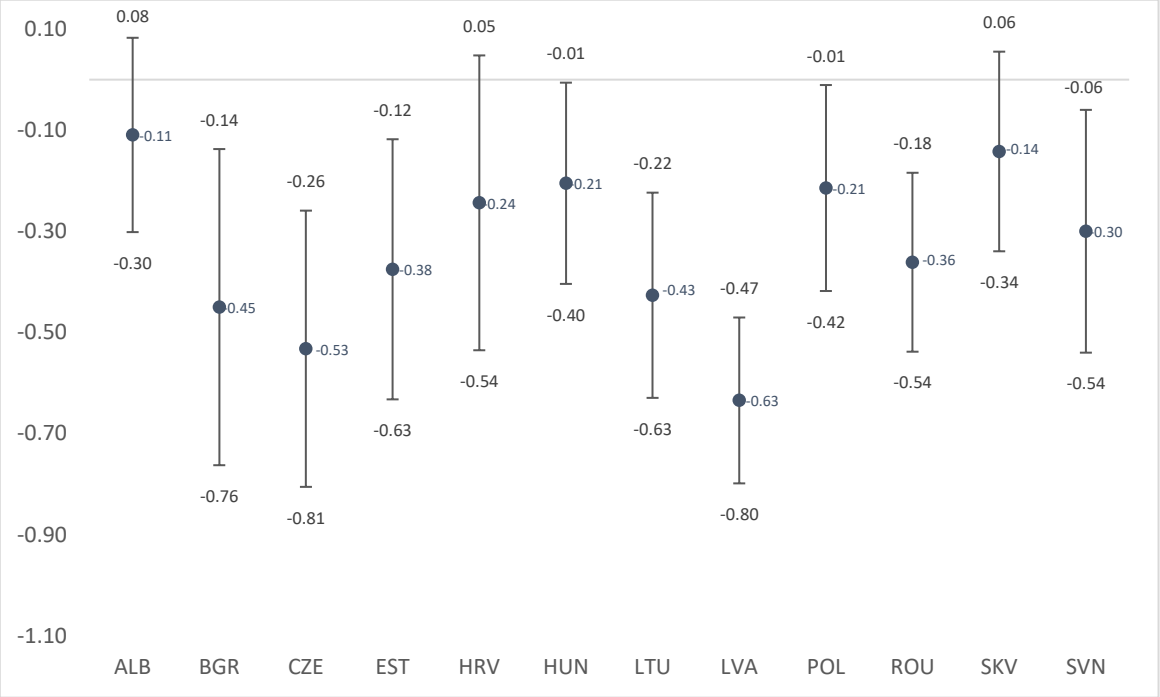
As previously, it is also at this point worth to compare the M1 results with the PM1 from Pipień and Roszkowska (2019). Both models used the Zellner estimator and thus treated the countries as a whole group. The average beta parameter for PM1 is equal to -0.42 which is pretty close the one from M1 (-0.48). The range for PM1 is between -0.99 and -0.15 which again suggests strong convergence effects. Three countries among the top 5 are the same for M1 and PM1, namely Bulgaria, Latvia and Slovenia. When looking at the bottom five countries, only Estonia and Poland are valid for both models. The biggest differences can be found for Albania, Czechia and Croatia. The differences may be related to the data source, extended period and of course the human capital inclusion in M1.

As a final remark for the main analysis of this thesis it should be highlighted, that the overall trend for the convergence is very similar when looking at the classical estimation method with the OLS technique and the Zellner estimator. However, some differences may be found among particular countries. Similar to Pipień and Roszkowska (2019), the Zellner estimator suggested for rather stronger convergence effects for some countries, but this did not apply for all of them. Heterogeneity of the convergence parameters is indeed visible at this point.

This is however still not the final point of the empirical analysis for CEE. In order to investigate the hypothesis about heterogeneity even deeper, two additional models were formulated. $M_{eh0}$ and $M_{eh1}$ are nearly the same as M0 and M1, but there is one particular difference – the models exclude the human capital variable from equation (30). The model $M_{eh0}$

calculates the parameters based on the classical approach and $M_{eh1}$ utilises the Zellner estimator are therefore in line with the PM0 and PM1 from Pipień and Roszkowska (2019). The further analysis in this dissertation can be therefore considered as a pure extension of the paper with a new period range and data source utilised. Following the structure at the beginning, Figure 27 and Figure 28 show the beta parameters with bounds of the 95% confidence intervals for $M_{eh0}$ and $M_{eh1}$ respectively. The next step will involve a detailed analysis of those results.

*Figure 27:$M_{eh0}$ C*onvergence parameters estimates without Human Capital for CEE countries together with bounds of the 95% confidence intervals, sample for 1992-2019.

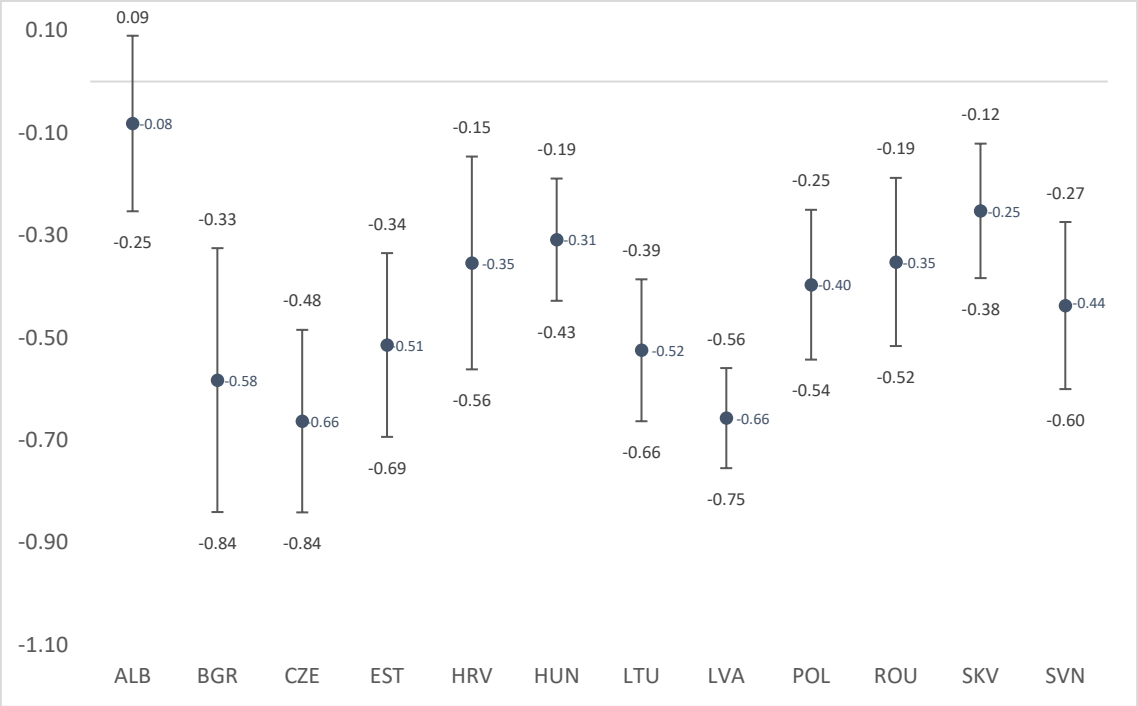



Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Similar to the results obtained previously, all of the countries in Figure 27 are converging. Excluding the human capital variable did not result in an observable trend. Some countries seem to converge faster and some lower when compared to the model M0 from Figure 25. In average, the beta parameter is equal to -0.33 which is slightly lower when compared to -0.38 from M0. The parameters range between -0.63 and -0.11, which is again slightly narrower than when looking at M0. The countries that converge faster in $M_{eh0}$ include Albania, Estonia, Lithuania, Latvia and Romania. The remaining ones, despite Poland, are converging lower. Poland seems to be one exception, where the beta parameters are nearly on the same level, namely -0.214 and -0.217 for $M_{eh0}$ and M0 respectively.

When comparing the results from $M_{eh0}$ with PM0 from Pipień and Roszkowska (2019) couple of similarities and differences may be found as well. The average beta rate is slightly lower at $M_{eh0}$ and equal to -0.33 vs -0.39 for PM0. The range is substantially narrower. Interestingly, the parameters stayed nearly exactly the same for 5 of the countries: Bulgaria, Hungary, Lithuania, Poland and Romania. The biggest and substantial difference is visible when looking at Albania, Czechia and Slovenia, which suggest some variances in the data source or the extended period, because it is in line with the difference between M0 and PM0.

*Figure 28:$M_{eh1}$* Convergence parameters estimates without Human Capital for CEE countries together with bounds of the 95% confidence intervals, sample for 1992-2019.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Figure 28 on the other hand represents the model $M_{eh1}$ that treats the countries as an entire group. Also, at this point all countries seem to be converging, with Albania having the lowest convergence rate. Beta parameters range in that case between -0.66 and -0.08, while the average equals -0.43. The top converging countries place equally: Czechia and Latvia with Bulgaria, Lithuania and Estonia following. The slowest converging country is once again Albania. The next few paragraphs compare the models with concluding remarks.

The first comparison will involve the $M_{eh0}$ OLS model from Figure 27. Two countries had a lower convergence rate in $M_{eh1}$ (Albania and Romania), the remaining 10 countries

converged faster. The biggest difference involved Poland which had a parameter of -0.40 when looking at $M_{eh1}$ and -0.21 when looking at $M_{eh0}$. The remaining parameters did not vary substantially, but one more time, the trend is still similar. For instance, when looking at the top five countries that converged very fast, all of them are in line between those two models.

The second comparison involves the $M_{eh1}$ and M1. It is worth to see what happens to the Zellner estimator after the human capital variable is excluded. The average beta value is slightly lower for $M_{eh1}$ (-0.43 vs. -0.48 for M1). The range of the parameters is very similar; between -0.66 to -0.08 for $M_{eh1}$ and -0.73 to -0.11 for M1. There are 3 top converging countries equal for both of the models. Looking at each individual country the parameters were stronger for 4 countries in the $M_{eh1}$ case, while 8 of them were weaker.

The third and final comparison will involve the PM1 model from Pipień and Roszkowska (2018). As indicated previously the only difference between $M_{eh1}$ and PM1 is the extended time period and the data source. The average beta parameters are very close to each other, namely -0.43 for $M_{eh1}$ and -0.42 for PM1. The range is narrower for the $M_{eh1}$ by a considerable margin. Three counties are in both of the models same, similar to a part of the top five converging ones. Looking in detail at the country specific parameters one may see that 9 countries are converging faster in $M_{eh1}$ and only 3 are for PM1. One more time the biggest differences relate to Albania, Czechia and Slovenia.

The Figure 29 below provides a summary of the models described above. It includes all of the beta parameters for each country based on the model and highlights the top 5 converging countries with a blue shadow. The heterogeneity is clearly visible.

*Figure 29:*Summary of all analysed beta parameters for the CEE countries based on the Model. $PM_0$ and $PM_1$ values extracted from Pipień and Roszkowska (2019).

| Model/Country | ALB | BGR | CZE | EST | HRV | HUN | LTU | LVA | POL | ROU | SKV | SVN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PM0** | -0.72 | -0.45 | -0.12 | -0.26 | -0.05 | -0.23 | -0.43 | -0.43 | -0.22 | -0.34 | -0.47 | -0.93 |
| **PM1** | -0.58 | -0.56 | -0.18 | -0.36 | -0.15 | -0.22 | -0.45 | -0.45 | -0.30 | -0.28 | -0.54 | -0.99 |
| **M0** | -0.09 | -0.47 | -0.57 | -0.26 | -0.73 | -0.35 | -0.40 | -0.54 | -0.22 | -0.30 | -0.21 | -0.39 |
| **M1** | -0.11 | -0.55 | -0.69 | -0.42 | -0.68 | -0.44 | -0.52 | -0.73 | -0.40 | -0.34 | -0.33 | -0.56 |
| **Meh0** | -0.11 | -0.45 | -0.53 | -0.38 | -0.24 | -0.21 | -0.43 | -0.63 | -0.21 | -0.36 | -0.14 | -0.30 |
| **Meh1** | -0.08 | -0.58 | -0.66 | -0.51 | -0.35 | -0.31 | -0.52 | -0.66 | -0.40 | -0.35 | -0.25 | -0.44 |

Source: Own elaboration.

*Blue coloured cells highlight top five countries with the highest beta magnitude within each model.

In order to test for statistical significance of some interesting restrictions imposed on model M1, the likelihood ratio test were performed. *Table 17* presents natural logarithms of the likelihood function that are calculated at ML estimates of parameters. When looking at the table's first row, it summarises all of the calculated models that were described previously. The first column shows M1 and M0 considering human capital and the second presents Meh1 and Meh0 that exclude it. The second row on the other hand shows the likelihood ratios of the respective models assuming that only the intercept is explanatory. This is why it is equal for M1 and Meh1 as well as for M0 and Meh0.

The case of unconstrained and, among all analysed specifications, of the most general model M1 having a score of 797 is subject to the greatest data support. As a reminder, this model takes into account the entire Equation (30), including human capital and utilises the Zellner estimator. The likelihood obtained in M1 is by far greater than the one attributed to the model M0 (equivalent to OLS regression) and reached a value of 666. This indicates that threating the regression equations as one system with the Zellner estimator has a much better statistical significance.

The second strongest data supporting model includes Meh1 with the value of the log likelihood around 773. This makes Meh0 with the value of the log likelihood 640 improbable from the view of the data. When excluding the human capital variable from convergence equations the more statistically relevant model is the one estimated with the Zellner method.

When comparing the cases that utilise the Human Capital Variable with the ones that do not, only a minor improvement can be found. M1's likelihood is higher than Meh1's and M0's is higher than Meh0's. Finally, the reader may consider the naïve specification when only the intercepts is taken into account (the second row of the table). This is similar to the explanation of the log GDP per capita with the average of the dataset – without any additional control variables or the convergence parameter. All analysed cases have by far stronger likelihood ratios when using the Equation (30) than when looking at the intercept only. This indicates that the theory behind the Equation (30) is correct and matches the empirical data.

Table 17: The value of the Log-likelihood function calculated at ML estimates of for models utilizing the CEE sample.

| CEE | | | | |
|---|---|---|---|---|
| | including Human Capital | | excluding Human Capital | |
| | M1 | M0 | Meh1 | Meh0 |
| **Model LH** | 797 | 666 | 773 | 640 |
| **Intercept only Model LH** | 624 | 536 | 624 | 536 |

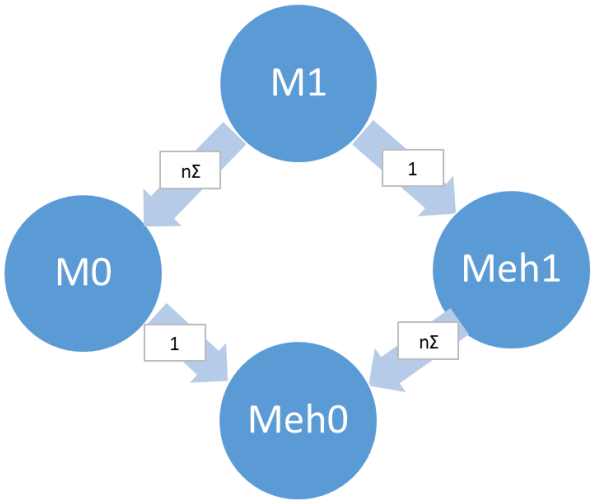
Source: Own elaboration.

Usually, when choosing between a less complicated model and a model with more complexity but with the same explanatory power, the easier one is preferred. In other words it would not make a lot of sense to use the Zellner estimator if a standard OLS regression can provide the same explanatory power. Similar logic relates to the variables utilised. It is not beneficial to include additional variables, like the human capital one, if they do not enhance the model.

In order to visualise the relationships between the respective models Figure 30 was created. It also shows all the possible restrictions among them. One may clearly see that model M1 can be treated as an extension of Meh1 or M0, while those two models are expansions of model Meh0. To keep it simple, Meh0 is the model with lowest complexity, while M1 with the biggest in the case of this dissertation.

*Table 18* sums up the LR tests performed for the possible restrictions. In fact, the p-values for all model-pairs have a magnitude far lower than the commonly accepted 0.025 level. It turns out that the model M1 that includes the human capital variable and treats the equations as one system, is the best solution for convergence testing among the ones tested in this dissertation. One would need to assume a very tough p-value criteria to see reasonability in using a different model than M1.

*Figure 30:*Graph presenting the relationships and restrictions of analysed models for CEE.




Note: Axes with arrows show the restrictions that may be imposed. Symbols in rectangles present the number of restrictions required to obtain less parametrised model. $n$ is the number of equations in (30), while $n\sum = \frac{1}{2}n(n+1) - n$.

Source: Own elaboration.

Table 18: Likelihood (LH) ratio test statistics for the CEE sample with P-Values obtained for the respective pairs of models together with the restrictions.

| | LH | Restrictions | P-Value |
|---|---|---|---|
| **M1 vs. M0** | 261 | 0.5*n*(n+1)-n | 4.89998E-25 |
| **M1 vs. Meh1** | 48 | 1 | 3.67622E-12 |
| **M0 vs. Meh0** | 52 | 1 | 5.30142E-13 |
| **Meh1 vs. Meh0** | 176 | 0.5*n*(n+1)-n | 6.34711E-12 |

Source: Own elaboration.

# Chapter 4: Empirical analysis of economic convergence in LA countries

## 4.1 An overview of economic performance of analysed LA region

### 4.1.1 LA countries as a suitable example for convergence testing

Contrary to the Central and Eastern European (CEE) countries described in the previous chapter, the Latin America (LA) region is more heterogenous, both in case of individual country performance and demography. These differences are empirically analysed in the next sections of this chapter. In this paragraph, the general question about the LA region as a suitable example for convergence testing will be specified.

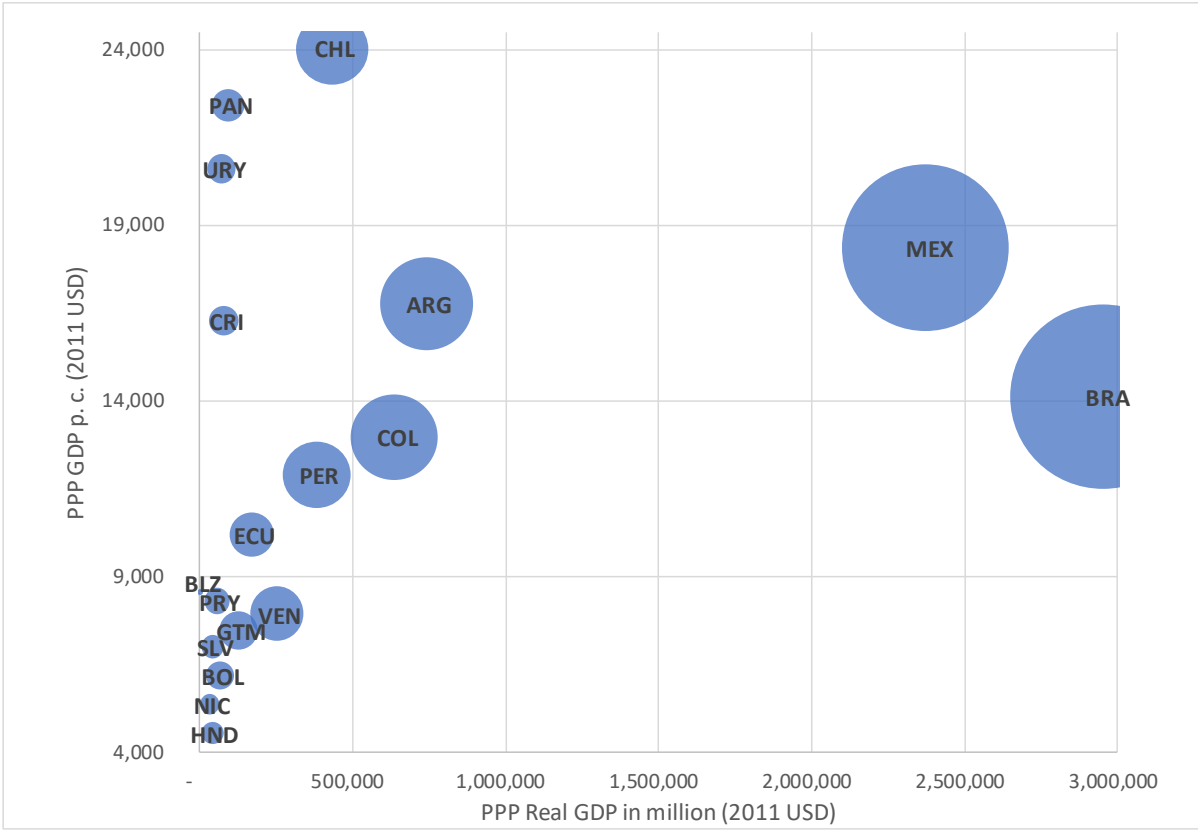
There are couple of reasons, why LA is an interesting topic for investigation. First of all, the lack, or rather the very little literature, that aims at testing the convergence in this region (Jarco and Pipień, 2020). Secondly, the mixed results within the authors who did analyse the LA region; this would even suggest the heterogeneity of convergence. And finally, when comparing the LA countries to the CEE ones, one may find sustainable differences in culture, history and of course geographical conditions including, but not limited to, natural resources.

To find an example for the first two reasons a brief literature review can serve as a good starting point. Looking at the papers with a meaningful citation index, they do not deliver a common conclusion for the convergence hypothesis, nor a suitable method for convergence testing. For instance, Ferreira (2000), Kuscevic (2014) and Dobson and Ramlogan (2002b) conducted a regression analysis for some countries or country groups within LA and found evidence for the convergence hypothesis. On the other hand, Dobson and Ramlogan (2002a) and Sutton et. all (2006) did not confirm the convergence hypothesis using the same regression analysis method. Another group of authors including Sanz-Villarroya (2005), Galvao and Gomez (2007), Escobari (2004) and King and Ramlogan (2008) used unit root testing to see whether LA countries are catching up with the richer ones. Most of them found evidence for convergence, but King and Ramlogan (2008) did not. The next sections in this chapter focus on the economic and demographic differences in LA countries, therefore, like in chapter 3, some Key Performance Indicators (KPIs) will be analysed.

### 4.1.2 GDP development and comparison throughout 1990-2017

*Figure 31* below - similar to the *Figure 16* for CEE - presents the chosen LA countries' real 2017 GDP p.c. on the vertical axis and the real 2017 GDP on the horizontal one. The heterogeneity can be visible here very well. In addition, the size of the bubble represents the size of the real GDP. This chart gives an overview of the 2017 situation in LA and can serve as a good initial comparison tool. It is clear that Chile, Panama and Uruguay achieved the best results while Honduras, Nicaragua and Bolivia were the three least performing countries when looking at GDP p.c. Brazil and Mexico on the other hand have the highest real GDP amounts making them the most powerful economies in LA. Their GDP p.c. values are also on an above-average level with 14,109 USD and 18,360 USD respectively. The difference between the real GDP of Mexico (2.3 tril. USD) and Argentina (0.7 tril. USD), which is the biggest economy among the remaining countries, is enormous and only confirms why Brazil and Mexico are very influential on the international market compared to other LA countries.

*Figure 31:* LA GDP p.c. and real GDP in 2017 (PPP, 2011 USD)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Figure 32 shows a more detailed development of the LA countries from 1990-2017. The GDP p.c. values are listed on the vertical axis and the years on the horizontal. In addition, the chart at the bottom presents the same information but considers the year's 1990 GDP as an index of 100. Although not a perfect visualisation due to many data labels, one can see straight away whether poorer countries are catching up with the richer ones or not. Further, the general time development can be seen here. Nearly all countries grew in some way between 1990 and 2017. Complementary to Figure 32, Table 19 presents the respective GDP p.c. growth rates for the same period and *Table 20* sums up the findings about the whole development. Several conclusions can be drawn.

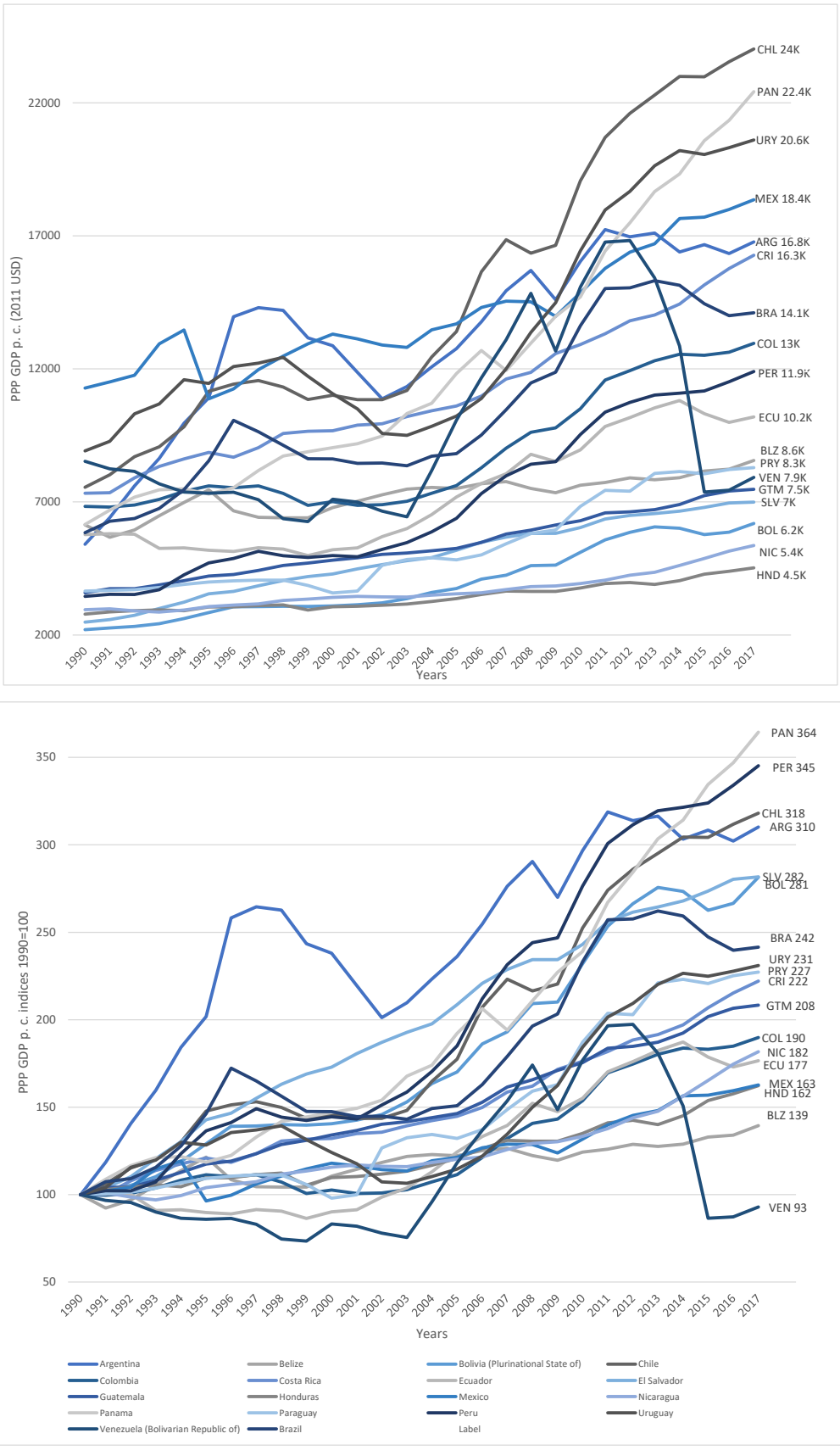
Let's start with the situation in 1990, when the average GDP p.c. was equal to only 5,603 USD. The poorest countries included Bolivia, El Salvador, Honduras, Nicaragua and Peru with 2,200 USD, 2,483 USD, 2,786 USD, 2,950 USD and 3,449 USD respectively. On the left top side of the chart one may find the richest countries including Mexico, Uruguay, Venezuela, Chile and Costa Rica, their GDP p.c. level reached respectively 11,283 USD, 8,919 USD, 8,528 USD, Chile 7,553 USD and 7,326 USD. In order to realise how big the differences among those countries were in 1990, one may take the GDP p.c. of the richest country, Mexico, and divide it with the one from the poorest – Bolivia. It turns out that Mexico's GPD p.c. was more than 5 times higher than the Bolivia's in 1990. Another interesting observation for this year includes something like a country GDP p.c. "club" with three groups. This is visible in Figure 32. The 7 poorest countries with the GDP p.c. ranging from 2,200 USD - 3,649 USD, 10 middle income countries with the GDP p.c. level between 5,406 USD – 8,919 USD and finally one high income country, Mexico with 11,283 USD. To explain the extraordinarily good situation of Mexico compared to other LA countries for this period one may refer to Moreno Brid, Rivas Valdivia and Santamaria (2005), who describe the role of North Atlantic Free Trade Agreement (NAFTA). Mexico implemented multiple reforms regarding the trade liberalisation and foreign direct investment in the late 80s in order to prepare for joining the NAFTA in January 1st, 1994. Also, already by 1990 Mexico was one of the developing economies, which were significantly open to foreign trade.

The overall situation in LA was completely different in 2017. When looking at Figure 32, the right 2017 area of the chart shows on the first place much higher differences with respect to GDP p.c. than the counterpart side on the left in 1990. As per *Table 20* the average GDP p.c. in the analysed LA region was equal to 12,386 USD, which is more than twice of the GDP p.c. from 1990. Hence the average yearly growth for the whole period was around 3.04%, which is slightly higher than the CAGR of 2.87%. When looking at the absolute GDP p.c. amount the

top five countries in 2017 included Chile with 24,024 USD, Panama with 22,422 USD, Uruguay with 20,607 USD, Mexico with 18,360 and Argentina reaching 16,771 USD. The worst performing countries in 2017 are Honduras 4,523 USD, Nicaragua 5,360 USD, Bolivia 6,192 USD, El Salvador 6,995 USD and Guatemala 7,473 USD.

Without a sophisticated convergence analysis, one may observe that the poorer countries in 1990 remained poor in 2017. Also, most of the richer ones from 1990 remained rich in 2017, which is contradictious to the analysed CEE sample in the previous chapter. However more information on this topic will be presented in the next section that deals with convergence in particular.

*Figure 32:* GDP p.c. development from 1990 - 2017 in LA and indices 1990=100 (PPP, 2011 USD)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Table 19: LA annual GDP p.c. growth rates with colour coding*.

| Country | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 19% | 19% | 14% | 15% | 10% | 28% | 2% | -1% | -7% | -2% | -8% | -8% | 4% | 6% | 6% | 8% | 8% | 5% | -7% | 10% | 7% | -2% | 1% | -4% | 2% | -2% | 3% |
| Belize | -8% | 5% | 9% | 8% | 7% | -11% | -4% | 0% | 0% | 6% | 4% | 3% | 3% | 1% | 0% | 2% | 1% | -3% | -2% | 4% | 1% | 2% | -1% | 1% | 3% | 1% | 4% |
| Bolivia | 3% | 2% | 5% | 8% | 9% | 8% | 0% | 1% | 0% | 1% | 1% | 2% | 5% | 7% | 4% | 9% | 4% | 8% | 0% | 10% | 9% | 5% | 3% | -1% | -4% | 2% | 6% |
| Brazil | 7% | 2% | 6% | 10% | 14% | 18% | -4% | -5% | -6% | 0% | -2% | 0% | -1% | 4% | 1% | 8% | 10% | 10% | 4% | 15% | 10% | 0% | 2% | -1% | -5% | -3% | 1% |
| Chile | 6% | 9% | 4% | 8% | 14% | 2% | 1% | -2% | -4% | 1% | -2% | 0% | 3% | 11% | 8% | 17% | 8% | -3% | 2% | 15% | 9% | 4% | 3% | 3% | 0% | 2% | 2% |
| Colombia | 0% | 1% | 3% | 4% | 3% | -1% | 1% | -4% | -6% | 2% | -2% | 0% | 2% | 4% | 4% | 9% | 9% | 7% | 2% | 7% | 10% | 3% | 3% | 2% | 0% | 1% | 3% |
| Costa Rica | 0% | 8% | 5% | 3% | 3% | -2% | 4% | 6% | 1% | 0% | 2% | 1% | 3% | 2% | 2% | 4% | 6% | 2% | 6% | 3% | 3% | 4% | 2% | 3% | 5% | 4% | 3% |
| Ecuador | 1% | 0% | -9% | 0% | -2% | -1% | 3% | -1% | -5% | 4% | 1% | 8% | 5% | 9% | 10% | 7% | 5% | 9% | -3% | 5% | 10% | 3% | 4% | 3% | -5% | -3% | 2% |
| El Salvador | 4% | 6% | 9% | 8% | 10% | 3% | 6% | 5% | 4% | 2% | 4% | 4% | 3% | 3% | 6% | 6% | 4% | 2% | 0% | 4% | 5% | 2% | 1% | 1% | 2% | 2% | 0% |
| Guatemala | 4% | 0% | 4% | 4% | 4% | 1% | 4% | 4% | 2% | 2% | 2% | 3% | 1% | 2% | 2% | 4% | 6% | 3% | 3% | 3% | 5% | 1% | 1% | 3% | 5% | 2% | 1% |
| Honduras | 3% | 2% | 1% | -1% | 5% | 0% | 2% | 1% | -6% | 4% | 1% | 1% | 2% | 3% | 3% | 5% | 4% | 0% | 0% | 3% | 4% | 1% | -2% | 4% | 6% | 3% | 3% |
| Mexico | 2% | 2% | 10% | 4% | -19% | 3% | 6% | 4% | 4% | 3% | -1% | -2% | -1% | 5% | 2% | 5% | 2% | 0% | -4% | 6% | 6% | 4% | 2% | 6% | 0% | 2% | 2% |
| Nicaragua | 1% | -2% | -2% | 3% | 5% | 2% | 2% | 4% | 2% | 2% | 1% | -1% | 0% | 2% | 2% | 1% | 3% | 3% | 1% | 2% | 3% | 4% | 3% | 6% | 6% | 6% | 4% |
| Panama | 9% | 7% | 4% | 1% | -3% | 3% | 9% | 7% | 2% | 2% | 2% | 3% | 9% | 4% | 10% | 7% | -6% | 9% | 8% | 5% | 12% | 6% | 7% | 4% | 6% | 4% | 5% |
| Paraguay | 1% | 1% | 2% | 3% | 2% | 1% | 1% | 0% | -5% | -7% | 2% | 27% | 5% | 1% | -2% | 4% | 8% | 7% | 2% | 15% | 9% | 0% | 9% | 1% | -1% | 2% | 1% |
| Peru | 2% | 0% | 5% | 15% | 11% | 4% | 6% | -3% | -1% | 1% | -1% | 6% | 5% | 7% | 9% | 15% | 9% | 5% | 1% | 12% | 9% | 4% | 3% | 1% | 1% | 3% | 3% |
| Uruguay | 4% | 11% | 4% | 9% | -1% | 6% | 1% | 2% | -6% | -6% | -5% | -9% | -1% | 4% | 4% | 6% | 10% | 11% | 8% | 13% | 9% | 4% | 5% | 3% | -1% | 1% | 1% |
| Venezuela | -3% | -1% | -6% | -4% | -1% | 1% | -4% | -10% | -2% | 13% | -2% | -5% | -3% | 27% | 23% | 16% | 12% | 13% | -15% | 19% | 11% | 0% | -8% | -17% | -43% | 1% | 6% |
| Average | 3% | 4% | 4% | 5% | 4% | 4% | 2% | 0% | -2% | 2% | 0% | 2% | 2% | 6% | 5% | 7% | 6% | 5% | 0% | 8% | 7% | 3% | 2% | 1% | 1% | 2% | 3% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

Table 20: LA annual GDP p.c. growth rate trend and growth KPIs.

| Country | Yearly GDP p.c. Growth trend (1991-2017) | 1990 GDP p.c. | 2017 GDP p.c. | Avg. growth | CAGR |
|---|---|---|---|---|---|
| Argentina |  | 5,406 | 16,771 | 4.70% | 4.13% |
| Belize |  | 6,138 | 8,562 | 1.70% | 1.20% |
| Bolivia |  | 2,200 | 6,192 | 4.00% | 3.76% |
| Brazil |  | 5,841 | 14,109 | 3.21% | 3.20% |
| Chile |  | 7,553 | 24,024 | 4.34% | 4.22% |
| Colombia |  | 6,830 | 12,964 | 2.44% | 2.32% |
| Costa Rica |  | 7,326 | 16,272 | 2.88% | 2.89% |
| Ecuador |  | 5,775 | 10,194 | 2.32% | 2.05% |
| El Salvador |  | 2,483 | 6,995 | 3.67% | 3.77% |
| Guatemala |  | 3,587 | 7,473 | 2.75% | 2.66% |
| Honduras |  | 2,786 | 4,523 | 1.69% | 1.75% |
| Mexico |  | 11,283 | 18,360 | 2.03% | 1.75% |
| Nicaragua |  | 2,950 | 5,360 | 2.24% | 2.16% |
| Panama |  | 6,152 | 22,422 | 4.91% | 4.73% |
| Paraguay |  | 3,649 | 8,292 | 3.17% | 2.97% |
| Peru |  | 3,449 | 11,905 | 4.59% | 4.52% |
| Uruguay |  | 8,919 | 20,607 | 3.10% | 3.04% |
| Venezuela |  | 8,528 | 7,925 | 1.06% | -0.26% |
| Average |  | 5,603 | 12,386 | 3.04% | 2.87% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

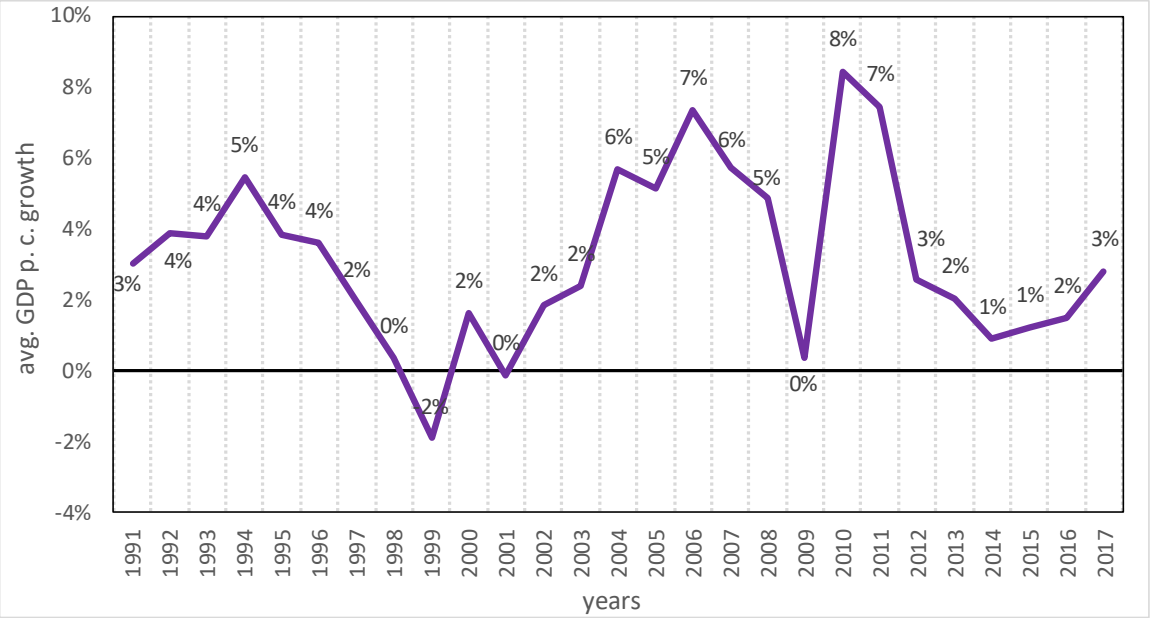
Table 19 and Figure 33 deal with the LA growth phenomenon in a more detailed way. *Table 20* on the other hand sums up the trend within the LA region. When looking at Table 19, the fastest growers may be easily identified and include Panama (avg. 4.9%), Argentina (avg. 4.7%), Peru (avg. 4.6%), Chile (avg. 4.3%) and Bolivia (avg. 4.0%). When looking at Panama, some authors argue that its success is due to their trade agreements including both export and import (Medina, Swiston, Barrot, 2012; Bakari, Mabrouki, 2017) and some authors see a big

role derived from the country's dollarisation (Edwards, 2001). Panama's growth in recent years was also positively affected by the infrastructure sector and the mining industry. On the other hand, the inequalities and corruption are the problems that the country is currently struggling with (Pérez, 2017). In case of Argentina and Chile the high level of human capital at the beginning of the 20$^{th}$ century can be seen as an explanation for solid long run performance, however the years 1990-2000 were the ones where export and international trade was booming (Della Paolera, Duran Amorocho and Musacchio, 2018).

Contrary to the fastest growing countries, Venezuela (avg. 1.1%), Honduras (avg. 1.7%), Belize (avg. 1.7%), Mexico (avg. 2.0%) and Ecuador (avg. 2.3%) did not manage to maintain high growth rates. However, one should note that Mexico should not be considered as a low performing country, because it's GDP p.c. is among the top five LA countries. This is rather related to its different development level when compared to the remaining 4 countries. Remarkable low performance can be seen when looking at Venezuela. In fact, it was the only country that faced an overall GDP decline in the analysed period from 8,528 USD in 1990 to 7,925 USD in 2017. The GDP p.c. in that country declined during most of the years with exception of the 2004-2011 period. Those were faced with huge GDP increases. After that, slowdowns occurred again and GDP dropped enormously in 2015 (-43%). The country's situation can be explained by large political instability and multiple populist regimes, which ultimately lead to hyper-inflation (Pittaluga, Seghezza and Morelli, 2020). Also, the oil dependent economy in Venezuela did not help in a sustainable growth approach, especially with the constantly low-level oil prices after the global financial crisis in 2008.

Looking at the overall growth trend, couple of periods may be defined. First of all, the peak between 1992-1995 where LA countries experienced 5% of average GDP p.c. growth. After this period, the turmoil related to oil shocks and the Dot Com crisis was visible, hence the growth circulated around -2% to +2% in average. Beginning with 2001, a huge boom was observable (similar to the countries in CEE), with a record high average growth of 7% in 2006. The slowdown occurred shortly before the 2008 financial crisis, in which the average minimum growth resulted in a stagnation of 0.3%. Right after the crisis, a V-shaped recovery was observable with growth rates of 8% and 7% in 2009 and 2010 respectively. After that, many countries were struggling and could not return to a sustainable growth path, which is visible on Table 19. Venezuela, Ecuador, Brazil and Bolivia faced negative growth rates between 2014 and 2016, thus resulting in a low average for the whole region. Ultimately the average growth for the whole analysed period was equal to 3.04% whereas the CAGR was equal to 2.87%.

*Figure 33:* LA average GDP p.c. annual growth from 1991 – 2017.



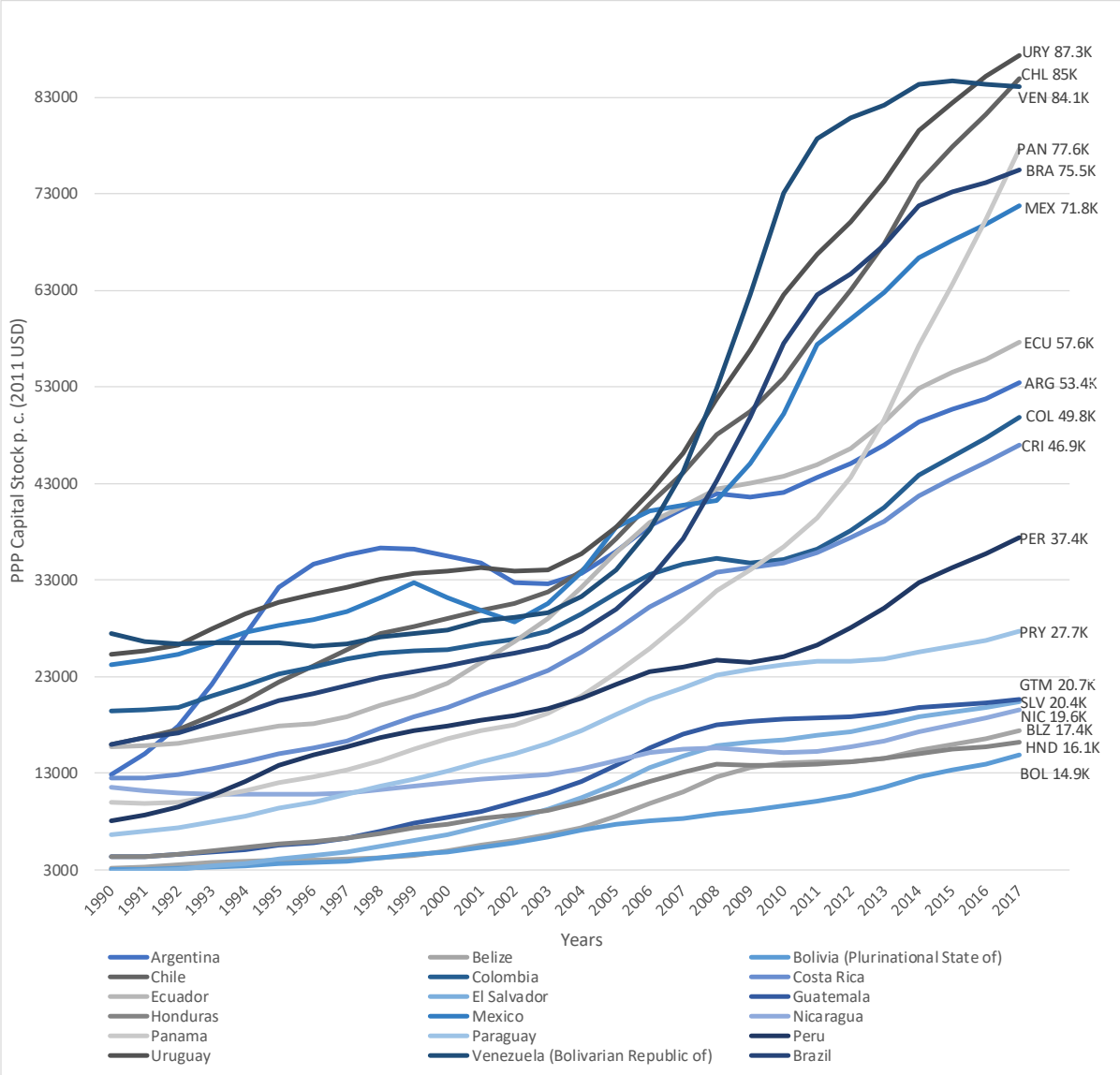

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

### 4.1.3 Capital Stock development and comparison throughout 1990-2017

The capital stock p.c. development can be found in Figure 34 below. On the first point of view a growth trend like for the GDP values is observable. Further, the countries with higher GDP p.c. amounts seem to be leading in capital stock p.c. as well. However, several major differences are visible. In general, the observed capital stock was subject to less fluctuations and "shocks" than the compared GDP p.c. For instance, the Dot Com crisis in 2001 moved only 3 countries to a lower capital stock p.c. level than during this year, namely Argentina, Mexico and Uruguay. Something like a sigma capital p.c. convergence was observable during that year. Others (although slower) were experiencing growth. Finally, the 2008 global financial crisis did not result in capital losses in general. In fact, the average capital stock p.c. level in 2008 was around 30,820 USD, whereas in 2009 the level increased by 5.8% to 32,606 USD. Table 21 provides more details on the growth and only confirms the observations from Figure 34.

Another observation relates to the starting level of capital stock p.c. It seems to be more evenly distributed than the GDP p.c. levels, although still with substantial differences. El Salvador had the lowest level of 2,829 USD in 1990, whereas the maximal 27,431 USD belonged to Venezuela.

*Figure 34:* Capital Stock p.c. development from 1990 - 2017 in LA (PPP, 2011 USD)




Sources: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

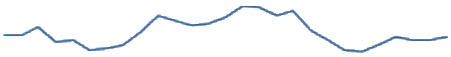
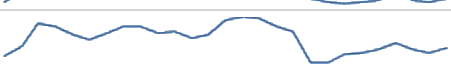
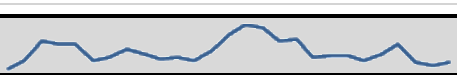
Looking at the Figure 34 and Table 21 one should pay a special attention to the years following the Dot Com crisis, between 2001-2006. Apparently several countries were able to jump to a high-level capital p.c. growth path. For Belize, Bolivia, Ecuador, El Salvador, Guatemala Honduras and finally Panama the capital p.c. growth levels were even higher than 10% annually. This phenomenon, where both poor and rich countries grew enormously, resulted somehow in a divergence effect. At the end of 2017 three "country clubs" – despite outlying Peru and Paraguay – can be easily observed.

Table 21: LA annual Capital Stock p.c. growth rates with colour coding*.

| Country | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 16% | 20% | 24% | 23% | 18% | 8% | 3% | 2% | 0% | -2% | -2% | -6% | -1% | 3% | 7% | 7% | 5% | 4% | -1% | 1% | 3% | 3% | 4% | 5% | 3% | 2% | 3% |
| Belize | 6% | 6% | 8% | 3% | 4% | 1% | 1% | 2% | 7% | 12% | 11% | 9% | 9% | 12% | 16% | 15% | 12% | 14% | 8% | 4% | 1% | 0% | 2% | 5% | 4% | 4% | 5% |
| Bolivia | 1% | 2% | 5% | 4% | 5% | 3% | 5% | 9% | 7% | 7% | 8% | 10% | 11% | 11% | 8% | 6% | 3% | 5% | 4% | 5% | 6% | 6% | 7% | 10% | 6% | 5% | 7% |
| Brazil | 4% | 3% | 6% | 6% | 6% | 4% | 4% | 4% | 3% | 2% | 3% | 2% | 3% | 6% | 8% | 11% | 13% | 16% | 15% | 15% | 9% | 4% | 5% | 6% | 2% | 1% | 2% |
| Chile | 4% | 5% | 8% | 8% | 9% | 7% | 7% | 6% | 3% | 3% | 3% | 2% | 4% | 7% | 10% | 10% | 8% | 9% | 5% | 7% | 9% | 7% | 8% | 9% | 5% | 4% | 5% |
| Colombia | 1% | 1% | 6% | 6% | 5% | 3% | 3% | 3% | 1% | 0% | 2% | 2% | 3% | 6% | 8% | 6% | 3% | 2% | -1% | 1% | 3% | 5% | 6% | 8% | 5% | 4% | 5% |
| Costa Rica | 0% | 2% | 5% | 5% | 6% | 3% | 5% | 8% | 7% | 6% | 6% | 6% | 6% | 8% | 9% | 9% | 6% | 5% | 2% | 1% | 3% | 4% | 5% | 7% | 4% | 4% | 4% |
| Ecuador | 1% | 1% | 4% | 3% | 4% | 2% | 4% | 6% | 5% | 7% | 9% | 9% | 9% | 11% | 11% | 9% | 4% | 4% | 2% | 2% | 3% | 4% | 6% | 7% | 3% | 2% | 3% |
| El Salvador | 3% | 5% | 9% | 10% | 12% | 8% | 10% | 12% | 11% | 11% | 11% | 11% | 12% | 13% | 14% | 14% | 10% | 7% | 2% | 2% | 2% | 2% | 4% | 5% | 2% | 2% | 3% |
| Guatemala | 1% | 4% | 6% | 6% | 7% | 6% | 8% | 11% | 11% | 9% | 7% | 10% | 10% | 11% | 13% | 13% | 9% | 6% | 2% | 1% | 1% | 1% | 2% | 4% | 1% | 1% | 2% |
| Honduras | 1% | 3% | 9% | 8% | 6% | 5% | 6% | 8% | 8% | 6% | 7% | 5% | 6% | 9% | 10% | 10% | 8% | 7% | -1% | -1% | 1% | 2% | 2% | 4% | 3% | 2% | 3% |
| Mexico | 2% | 3% | 4% | 5% | 3% | 2% | 3% | 5% | 5% | -5% | -4% | -4% | 7% | 11% | 14% | 4% | 2% | 1% | 9% | 11% | 14% | 5% | 5% | 6% | 3% | 2% | 3% |
| Nicaragua | -3% | -3% | -1% | 0% | 1% | 0% | 1% | 2% | 4% | 3% | 3% | 2% | 3% | 5% | 6% | 5% | 2% | 2% | -2% | -1% | 1% | 3% | 4% | 6% | 4% | 4% | 4% |
| Panama | -1% | 1% | 6% | 6% | 7% | 5% | 6% | 8% | 8% | 7% | 5% | 4% | 7% | 9% | 11% | 11% | 11% | 11% | 7% | 7% | 8% | 11% | 14% | 15% | 11% | 10% | 10% |
| Paraguay | 6% | 5% | 8% | 8% | 9% | 7% | 8% | 8% | 7% | 7% | 7% | 6% | 7% | 8% | 9% | 8% | 6% | 6% | 3% | 2% | 2% | 0% | 1% | 3% | 2% | 2% | 4% |
| Peru | 8% | 9% | 12% | 14% | 13% | 7% | 6% | 6% | 4% | 3% | 3% | 3% | 3% | 6% | 7% | 6% | 2% | 3% | -1% | 2% | 5% | 7% | 7% | 8% | 5% | 4% | 5% |
| Uruguay | 1% | 2% | 6% | 6% | 4% | 2% | 2% | 3% | 2% | 1% | 1% | -1% | 0% | 5% | 8% | 9% | 10% | 12% | 10% | 10% | 7% | 5% | 6% | 7% | 4% | 3% | 3% |
| Venezuela | -3% | -1% | 1% | 0% | 0% | -1% | 1% | 3% | 1% | 2% | 3% | 2% | 2% | 5% | 9% | 12% | 16% | 19% | 18% | 17% | 8% | 3% | 2% | 3% | 0% | 0% | 0% |
| Average | 3% | 4% | 7% | 7% | 7% | 4% | 5% | 6% | 5% | 4% | 5% | 4% | 6% | 8% | 10% | 9% | 7% | 7% | 4% | 5% | 5% | 4% | 5% | 7% | 4% | 3% | 4% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

Table 22: LA annual Capital Stock p.c. growth rate trend and growth KPIs.

| Country | Yearly Capital Stock p.c. growth trend (1991-2017) | 1990 Capital Stock p.c. | 2017 Capital Stock p.c | Avg. growth | CAGR |
|---|---|---|---|---|---|
| Argentina |  | 12,885 | 53,411 | 5.94% | 5.21% |
| Belize |  | 3,090 | 17,419 | 6.63% | 6.37% |
| Bolivia |  | 3,013 | 14,866 | 5.91% | 5.87% |
| Brazil |  | 15,976 | 75,479 | 5.94% | 5.70% |
| Chile |  | 16,003 | 84,975 | 6.35% | 6.14% |
| Colombia |  | 19,403 | 49,819 | 3.48% | 3.43% |
| Costa Rica |  | 12,450 | 46,922 | 4.97% | 4.85% |
| Ecuador |  | 15,686 | 57,619 | 4.85% | 4.76% |
| El Salvador |  | 2,829 | 20,357 | 7.47% | 7.30% |
| Guatemala |  | 4,324 | 20,676 | 5.92% | 5.75% |
| Honduras |  | 4,350 | 16,135 | 4.91% | 4.79% |
| Mexico |  | 24,191 | 71,786 | 4.13% | 3.96% |
| Nicaragua |  | 11,581 | 19,570 | 1.83% | 1.89% |
| Panama |  | 9,962 | 77,646 | 7.54% | 7.61% |
| Paraguay |  | 6,606 | 27,689 | 5.51% | 5.25% |
| Peru |  | 8,021 | 37,356 | 5.99% | 5.65% |
| Uruguay |  | 25,321 | 87,331 | 4.62% | 4.52% |
| Venezuela |  | 27,431 | 84,139 | 4.13% | 4.08% |
| Average |  | 12,396 | 47,955 | 5.34% | 4.95% |

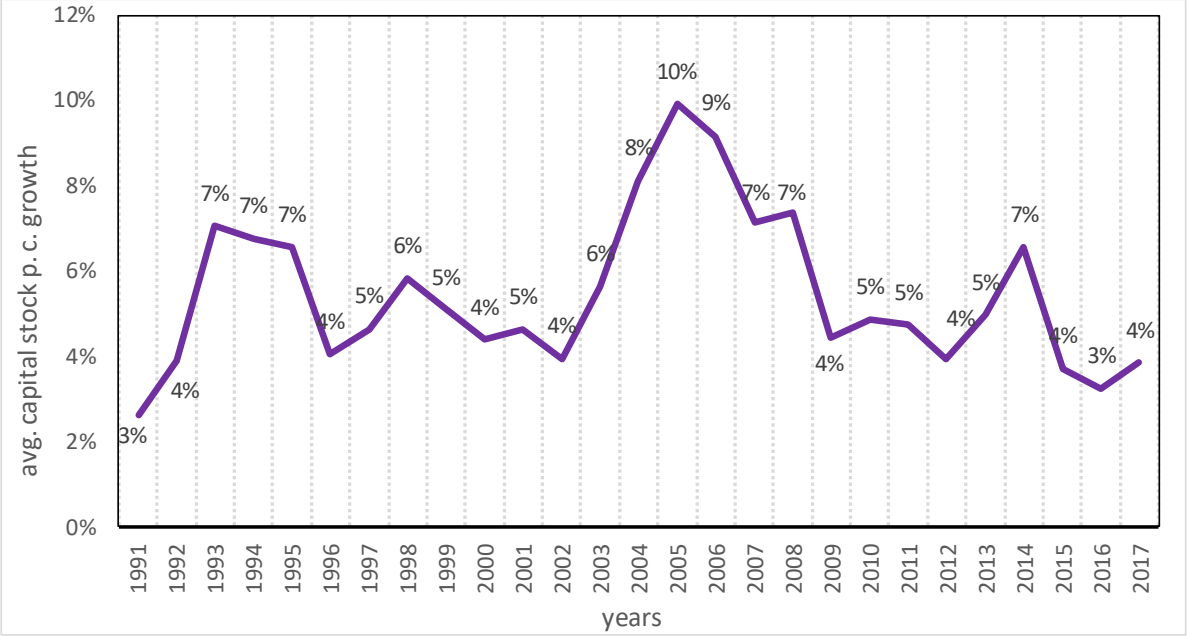
Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Table 22 sums up the findings made previously. When looking at the entire region, the average capital p.c. increased nearly 4 times from 12,396 USD in 1990 to 47,955 USD in 2017. This results in an average yearly growth rate of 5.34% and a CAGR of 4.95%. Top 5 countries in 1990 included Venezuela (27,431 USD), Uruguay (25,321 USD), Mexico (24,191 USD), Colombia (19,403 USD) and Chile (16,003 USD). The bottom 5 countries consisted of El Salvador (2,829 USD), Bolivia (3,013 USD), Belize (3,090 USD), Guatemala (4,324 USD) and Honduras (4,350 USD).

Although all countries were subject to a growth rate, the ones with higher capital stock p.c. remained rich, and the poorer ones still poor in 2017. Only minor movements were observable, especially Panama (jumped from place 11 to 4) and Colombia (felled from place 4 to 9).

Figure 35 does not deliver additional findings but confirms and generalises the observations made above. The average growth of the capital stock p.c. was more or less stable, despite the period after the Dot Com crisis where it peaked from 4% in 2001, to a record high of 10% in 2005, and then started to decrease constantly. In 2008, when the financial crisis began, the capital stock growth was stagnating between 4% and 5% until 2013 where a sudden increase to 7% was observable. After that, the capital returned to its standard growth and oscillated around 4% until the year 2017.

*Figure 35:* LA average Capital Stock p.c. annual growth from 1991 – 2017.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

### 4.1.4 Total Factor Productivity development and comparison throughout 1990-2017

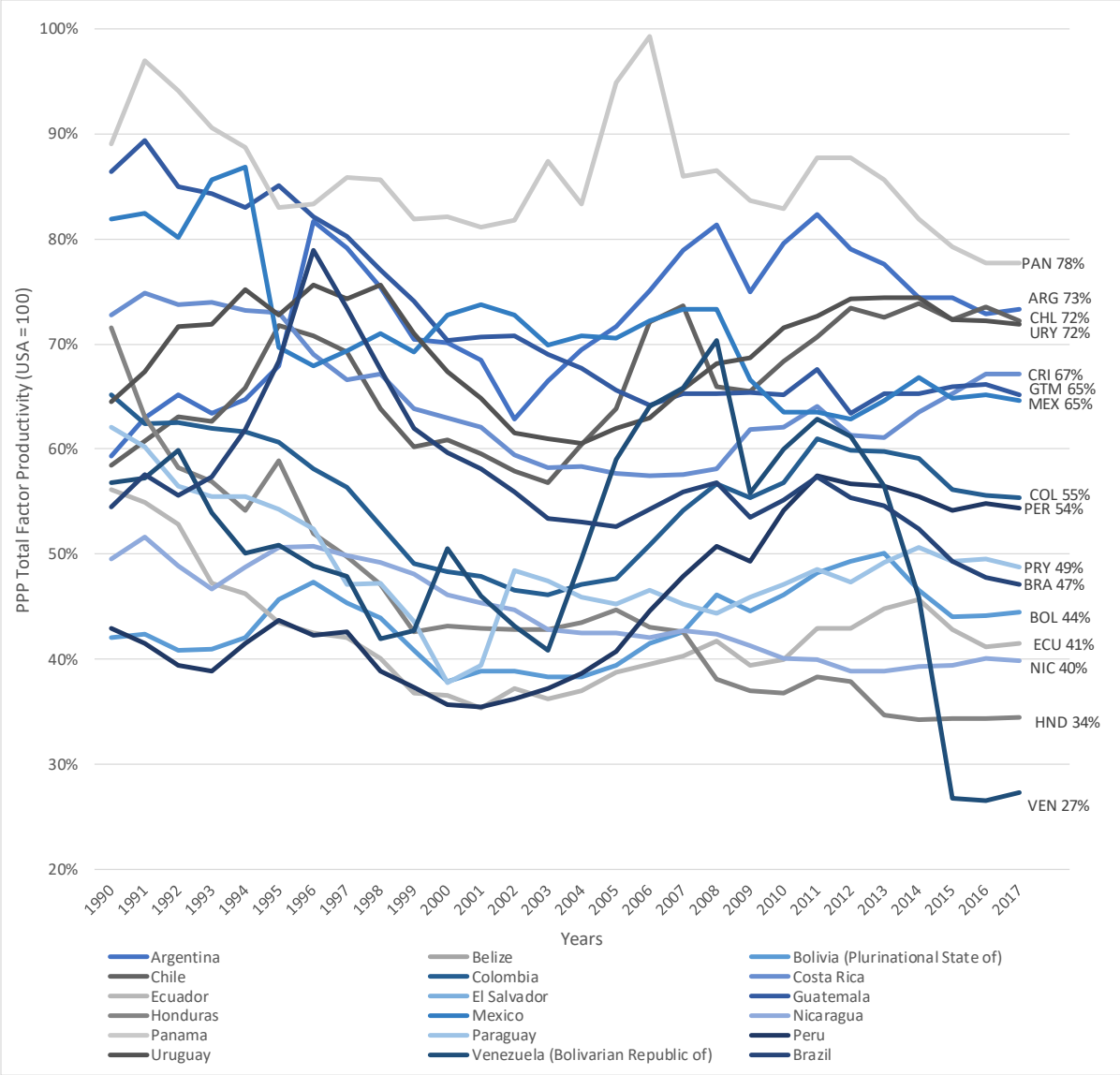
Taking the often-described lack of technological progress in Latin America into account, Ferreira, Pessoa and Veloso (2013) conducted an analysis of the total factor productivity in this region. The biggest long-term challenges in some LA countries related to TFP included the industrialisation of import-substitution together with international trade barriers and increasing government intervention. These factors contributed to the drops of the TFP levels that occurred after 1970, because until that time the LA TFP level had an average 82% of the US one. This is however only the case because the authors included the human capital related productivity increases into their model. If the human capital is excluded from the production function, the TFP for the years 1960-1980 decreases to 53%, which makes a substantial difference. The article concludes that the main reasons for low output between 1960-1980 corresponded to the factors of production (physical and human capital). After 1970 the TFP decline was indeed a reason for the stagnation in LA.

Figure 36 describes the TFP levels compared to those of the US from 1990 – 2017 and empirically confirms the "future orientated" findings from Ferreira, Pessoa and Veloso (2013). LA countries did not manage to stay on the same US TFP level in 2017 like they had in 1990. The TFP level declined in average from 64% to 55% over the analysed 27 years. As expected, some countries were luckier than others.

Supplementary to the Figure 36, the summary information can be found on Table 24, while the individual yearly values on *Table 23*. In 1990 the TFP level ranged from 43% to 89%. Top 5 countries included Panama (89%), Guatemala (86%), Mexico (82%), Costa Rica (73%) and Honduras (72%). The worst performing countries were Bolivia (42%), Peru (43%), Nicaragua (50%), Brazil (54%) and Ecuador (56%). After that the countries were facing constant changes and fluctuations. Since the beginning of the analysed period decrease were observable, but especially the years between 1994-1996 were followed by an overall decreasing trend of the TFP. The situation changed slightly after the 2002, right after the Dot Com crisis, where an increasing trend was partly observable. After small fluctuations in the following years, a V-shaped crisis and recover was visible in the years 2007-2011.

2017 resulted in a notable situation with a quite different set of leading/bottom countries than in 1990. From the best performing ones, only Panama and Costa Rica remained in the top five set, and Nicaragua, Brazil and Bolivia in the worst performing 5 countries. On the first point of view, it seems that convergence did not occur.

*Figure 36:* Total Factor Productivity (TFP) development from 1990 - 2017 in LA* (PPP, USA = 1)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

**Belize and El Salvador are not included in the dataset.*

Table 23: LA* annual TFP levels with colour coding** (PPP, USA = 1).

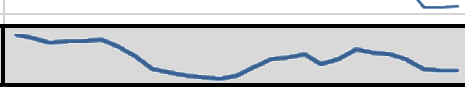
| Country | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 63% | 65% | 63% | 65% | 68% | 82% | 79% | 75% | 70% | 70% | 68% | 63% | 67% | 69% | 72% | 75% | 79% | 81% | 75% | 80% | 82% | 79% | 78% | 74% | 74% | 73% | 73% |
| Bolivia | 42% | 41% | 41% | 42% | 46% | 47% | 45% | 44% | 41% | 38% | 39% | 39% | 38% | 38% | 39% | 41% | 43% | 46% | 45% | 46% | 48% | 49% | 50% | 47% | 44% | 44% | 44% |
| Brazil | 58% | 56% | 57% | 62% | 68% | 79% | 73% | 68% | 62% | 60% | 58% | 56% | 53% | 53% | 53% | 54% | 56% | 57% | 54% | 55% | 57% | 55% | 55% | 52% | 49% | 48% | 47% |
| Chile | 61% | 63% | 63% | 66% | 72% | 71% | 69% | 64% | 60% | 61% | 60% | 58% | 57% | 60% | 64% | 72% | 74% | 66% | 66% | 68% | 71% | 73% | 73% | 74% | 72% | 74% | 72% |
| Colombia | 62% | 63% | 62% | 62% | 61% | 58% | 56% | 53% | 49% | 48% | 48% | 47% | 46% | 47% | 48% | 51% | 54% | 57% | 55% | 57% | 61% | 60% | 60% | 59% | 56% | 56% | 55% |
| Costa Rica | 75% | 74% | 74% | 73% | 73% | 69% | 67% | 67% | 64% | 63% | 62% | 59% | 58% | 58% | 58% | 58% | 58% | 58% | 62% | 62% | 64% | 61% | 61% | 63% | 65% | 67% | 67% |
| Ecuador | 55% | 53% | 47% | 46% | 44% | 42% | 42% | 40% | 37% | 37% | 35% | 37% | 36% | 37% | 39% | 40% | 40% | 42% | 39% | 40% | 43% | 43% | 45% | 46% | 43% | 41% | 41% |
| Guatemala | 89% | 85% | 84% | 83% | 85% | 82% | 80% | 77% | 74% | 70% | 71% | 71% | 69% | 68% | 66% | 64% | 65% | 65% | 65% | 65% | 68% | 63% | 65% | 65% | 66% | 66% | 65% |
| Honduras | 63% | 58% | 57% | 54% | 59% | 52% | 50% | 47% | 43% | 43% | 43% | 43% | 43% | 43% | 45% | 43% | 43% | 38% | 37% | 37% | 38% | 38% | 35% | 34% | 34% | 34% | 34% |
| Mexico | 83% | 80% | 86% | 87% | 70% | 68% | 69% | 71% | 69% | 73% | 74% | 73% | 70% | 71% | 71% | 72% | 73% | 73% | 67% | 63% | 64% | 63% | 65% | 67% | 65% | 65% | 65% |
| Nicaragua | 52% | 49% | 47% | 49% | 51% | 51% | 50% | 49% | 48% | 46% | 45% | 45% | 43% | 42% | 43% | 42% | 43% | 42% | 41% | 40% | 40% | 39% | 39% | 39% | 39% | 40% | 40% |
| Panama | 97% | 94% | 91% | 89% | 83% | 83% | 86% | 86% | 82% | 82% | 81% | 82% | 87% | 83% | 95% | 99% | 86% | 87% | 84% | 83% | 88% | 88% | 86% | 82% | 79% | 78% | 78% |
| Paraguay | 60% | 56% | 55% | 55% | 54% | 52% | 47% | 47% | 44% | 38% | 39% | 48% | 47% | 46% | 45% | 47% | 45% | 44% | 46% | 47% | 48% | 47% | 49% | 51% | 49% | 50% | 49% |
| Peru | 42% | 39% | 39% | 41% | 44% | 42% | 43% | 39% | 37% | 36% | 35% | 36% | 37% | 39% | 41% | 45% | 48% | 51% | 49% | 54% | 57% | 57% | 56% | 55% | 54% | 55% | 54% |
| Uruguay | 67% | 72% | 72% | 75% | 73% | 76% | 74% | 76% | 71% | 67% | 65% | 62% | 61% | 60% | 62% | 63% | 66% | 68% | 69% | 72% | 73% | 74% | 74% | 74% | 72% | 72% | 72% |
| Venezuela | 57% | 60% | 54% | 50% | 51% | 49% | 48% | 42% | 43% | 50% | 46% | 43% | 41% | 49% | 59% | 64% | 66% | 70% | 56% | 60% | 63% | 61% | 56% | 46% | 27% | 27% | 27% |
| Average | 64% | 63% | 62% | 62% | 62% | 63% | 61% | 59% | 56% | 55% | 54% | 54% | 53% | 54% | 56% | 58% | 59% | 59% | 57% | 58% | 60% | 59% | 59% | 58% | 56% | 56% | 55% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Belize and El Salvador are not included in the dataset.*
***Colour coding: blue = best performance, red = worse performance.*

A more detailed view can be obtained by Table 23 that shows the TFP levels for all of the LA countries and the whole analysed period. The table is characterised by red colour on the right and blue on the very left, which indicates that majority of the countries' TFP level decreased over time. The average rates on the bottom only confirm this visual effect.

Table 24 sums up the most important information and also shows the CAGR. When looking at this rate, only couple of the countries had a higher TFP level in 2017 than in 1990, namely Argentina, Bolivia, Chile, Peru and Uruguay. All remaining countries' TFP decreased.

Table 24: LA* annual TFP trend and growth KPIs.

| Country | Yearly Capital Stock p.c. growth trend (1991-2017) | 1990 TFP | 2017 TFP | CAGR |
|---|---|---|---|---|
| Argentina |  | 59% | 73% | 0.76% |
| Bolivia |  | 42% | 44% | 0.20% |
| Brazil |  | 54% | 47% | -0.51% |
| Chile |  | 58% | 72% | 0.76% |
| Colombia |  | 65% | 55% | -0.58% |
| Costa Rica |  | 73% | 67% | -0.29% |
| Ecuador |  | 56% | 41% | -1.08% |
| Guatemala |  | 86% | 65% | -1.00% |
| Honduras |  | 72% | 34% | -2.58% |
| Mexico |  | 82% | 65% | -0.84% |
| Nicaragua |  | 50% | 40% | -0.78% |
| Panama |  | 89% | 78% | -0.49% |
| Paraguay |  | 62% | 49% | -0.86% |
| Peru |  | 43% | 54% | 0.85% |
| Uruguay |  | 65% | 72% | 0.38% |
| Venezuela |  | 57% | 27% | -2.59% |
| Average |  | 63% | 55% | -0.48% |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Belize and El Salvador are not included in the dataset.*

### 4.1.5 Labour force and human capital in LA

Human capital and the resulting from it labour force seem to have played a significant role in Latin America. There are hardly any articles about the labour patterns visible in LA, but multiple authors deal with the female participation in those regions (Busso and Fonseca, 2015; Psacharopoulos and Winter, 1992; Jelin, 1977). The shift from an agriculturally leading region to a modern state with dominating services sector is challenging and leads to multiple structural changes. The changes in LA in the past, similar to other developing countries, caused a deeper involvement of men in the industry sector and changed the traditional family significance with respect to the economic sector. Women were more involved in consumption and ultimately able to participate in the services sector job market, especially when considering lower level white collar employment (Safa, 1977). Also, the income differences between men and women played a significant role in LA, which lead to motivational and finally performance problems (Psacharopoulos and Winter, 1992). Ultimately good progress has been made in this area when considering the latest development. From 1990 to 2010 the female labour participation increased by 10%. This was particularly due to changes in education, family structure, fertility and in the socioeconomic environment (Busso and Fonseca, 2015).

The majority of those changes involve human capital in general. An interesting paper from Brown and Hunter (2004) investigated the spending on human capital in LA between 1980 and 1997 and tried to connect it with the World Bank recommendation to spend more resources on primary education in developing economies. Unfortunately, the analysed period did not show a substantial improvement in the education sector, nor a correlation between such one and the World Bank suggestions. The biggest reasons and challenges to overcome the problem were related to the policymakers, who had a rather lobbying-like form of government spending's distribution. Thus, according to the authors, the LA countries needed to overcome the money allocation problem and restructure higher education, whereas the money lending institutions play a significant role and promote primary education instead (i.e. International Monetary Fund).

Another problem is, that multiple countries in LA are still dependent on agriculture and natural resources. According to Blanco and Grier (2012) these dependencies lead to negative effects on human and partly on physical capital. The natural dependency enhances the physical capital, but in the long run perspective lowers the human capital. Similarly to the agricultural sector, which one has a negative effect on both human and physical capital.

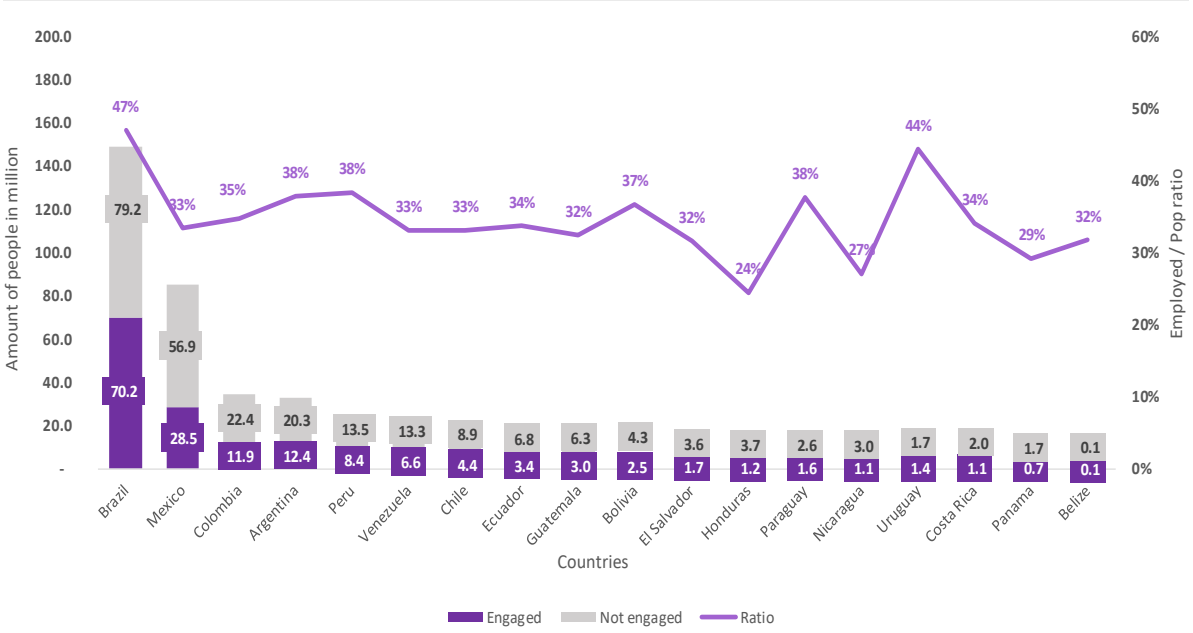
When looking at the empirical data, Figure 37 and Figure 38 below show all of the analysed LA countries and their respective population amounts. The purple bar indicates the engaged labour force and the grey one the people not employed. The line above on the secondary axis shows the employment rate. Looking at Figure 37 and the year 1990 one may find that there are two major economies with nearly 100 million inhabitants – Brazil and Mexico. There are several middle-sized countries like Colombia, Argentina, Peru, Venezuela and Chile and 11 of remaining ones which substantial smaller, especially beginning with Ecuador and ending with Belize. In general, Brazil, Argentina, Peru, Paraguay and Uruguay faced the best employment situation in 1990 with a ratio of 47%, 38%, 38%, 38% and 44% respectively. Only 3 countries had a lower employment ratio than 30%, namely Honduras (24%), Nicaragua (27%) and Panama (29%). The remaining ones oscillated around 32-37%.

The population of the whole Latin America region grew in the analysed period enormously by 46.2% from 410 million in 1990 to 600 million in 2017. The employment ratio went up to 47% (from 39% in 1990) as well, because the amount of people engaged grew much faster (75%) than the amount of people unemployed (28%). Most interesting is that the population growth was observable in all of the countries and none of those had a growth lower than 30% for the analysed period. Belize, Honduras and Paraguay nearly doubled their population.

The rank of the respective countries based on the population size did not change much, which was expected for this period. One must say however, that all of the countries managed to increase their employment ratio. Honduras was the best performer when looking at the increases in labour force for the analysed period, namely achieving +20%. It was followed by Nicaragua achieving +18%, Panama +17%, Ecuador +14% and Peru +14%. The countries with an already high employment ratio in 1990 did not increase it very much. One may definitely see some convergence effect here, which could be correlated with migration.

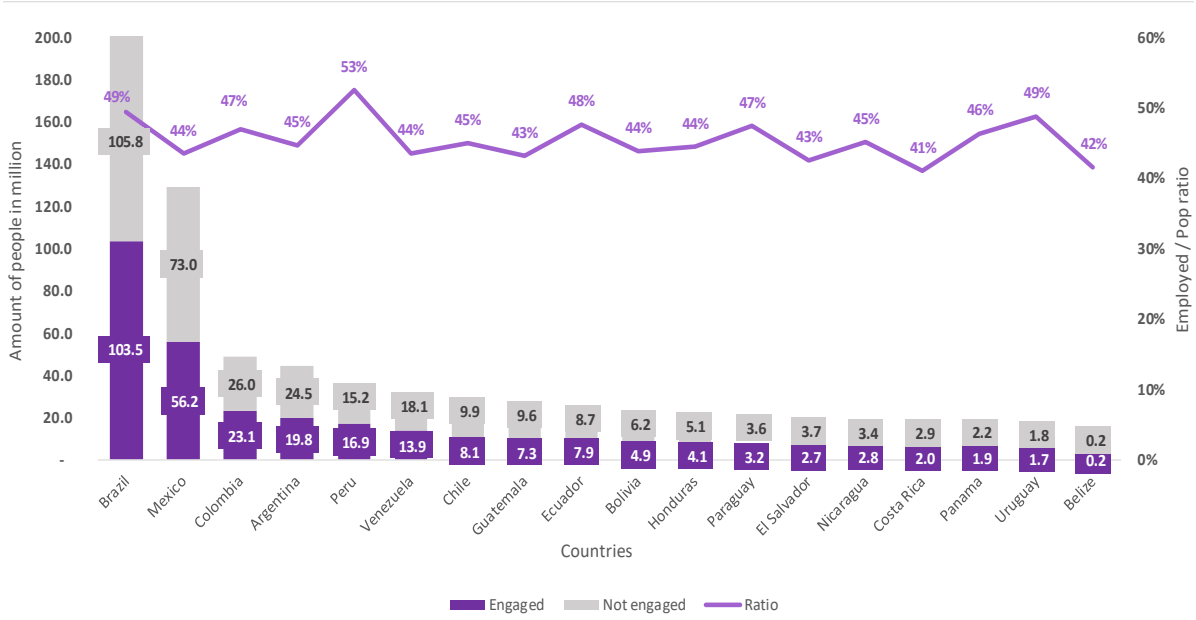
Table 25 shows the Human Capital (HC) values based on education and years of schooling. First observation is, that HC increased in every single country (unlike the TFP). The leaders in HC were in 1990 Chile, Belize, Argentina, Panama and Uruguay. The bottom 5 performers included Guatemala, El Salvador, Brazil, Nicaragua and Honduras. In 2017 two countries managed to catch up the best performing ones, namely Brazil and Bolivia. Panama remained in 6th place but Uruguay fell to 11th place. In average, the HC increased from 2.09 in 1990 to 2.71 in 2017 which results in a CAGR of 0.93% slightly below the CEE sample.

*Figure 37:* Labour Force and Population Indicators during 1990 in LA (in million and %)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

*Figure 38:* Labour Force and Population Indicators during 2017 in LA (in million and %)




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Table 25: LA annual Human Capital Index based on years of schooling and returns to education with colour coding*.

| Country | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 |
| Belize | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.2 | 3.2 | 3.2 | 3.3 | 3.3 | 3.3 | 3.4 | 3.4 | 3.4 | 3.5 | 3.5 |
| Bolivia | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 |
| Brazil | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.5 | 2.6 | 2.6 | 2.7 | 2.7 | 2.8 | 2.9 | 2.9 |
| Chile | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 | 2.9 | 2.9 | 2.9 | 2.9 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.1 | 3.1 | 3.1 | 3.1 |
| Colombia | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 |
| Costa Rica | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 |
| Ecuador | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| El Salvador | 1.6 | 1.7 | 1.7 | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 |
| Guatemala | 1.5 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.7 | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 |
| Honduras | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 |
| Mexico | 2.2 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 |
| Nicaragua | 1.7 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| Panama | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 2.9 |
| Paraguay | 2.0 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 |
| Peru | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 | 2.8 |
| Uruguay | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.7 |
| Venezuela | 1.8 | 1.8 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.5 | 2.5 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 | 2.8 | 2.8 | 2.8 |
| Average | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.3 | 2.3 | 2.3 | 2.3 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.6 | 2.6 | 2.6 | 2.7 | 2.7 | 2.7 |

Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.
**Colour coding: blue = best performance, red = worse performance.*

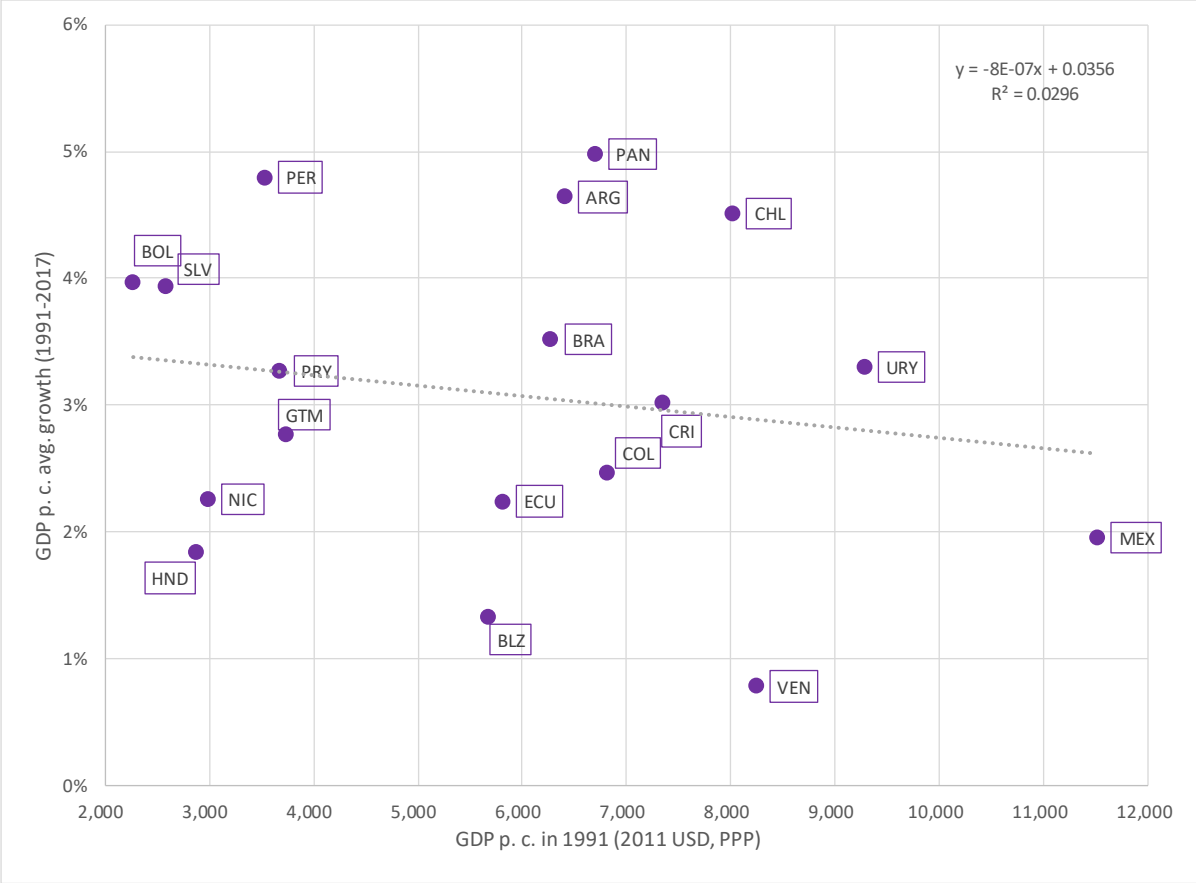
### 4.1.6 Qualitative analysis of the convergence effect

Before continuing with the SURE model results for LA, it is important to analyse how the initial GDP p.c. plots with the average growth rate. As discussed previously, the plot on Figure 39 gives a general overview and feeling of the convergence situation. Because of the catching up process one would expect to see the poorer countries on the top left side of the chart and the richer ones on the right bottom. This would result in a situation where poorer LA countries with a lower initial GDP p.c. in 1990 were subject to high growth, and the richer ones to lower growth. Yet, this trend is not clearly visible here. Some of the poorest countries like Bolivia, El Salvador and Peru indeed grew faster on average, but some of them like Honduras and Nicaragua had a growth rate below the average. From the richer countries only Mexico and Venezuela are where one would expect. Although the situation in Mexico could make sense when looking at the neoclassical theory of growth, Venezuela's low growth is mainly driven by poor political stability and choices after 2012, as described in the previous chapter. To visualise how big this effect is, one needs to consider that, when excluding the growth rates in Venezuela after 2012, the average would move to 3.9% instead of 1.1% and moving the country up to the top.

Another remarkable observation is related to some clubs. Especially when considering multiple middle-income countries that are placed either above the average growth, or below. Brazil, Argentina, Panama and Chile are the ones having substantial growth development. Belize, Ecuador, Colombia, and Costa Rica are below the average growth line, although having the similar initial GDP p.c. level like the 4 middle-income countries on the top.

The linear function on the top suggest a negative slope and a convergence effect on the first view, but the intercept is on a very low level, indicating insignificance. Similar for the $R^2$, which does not confirm any explanation power of this function to reality at all. Further and more sophisticated calculations are needed here, which will be presented in the next sub-chapter.

*Figure 39:* Convergence plot in LA




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

## 4.2 Results presentation and discussion

Due to data availability and accuracy, the sample including 10 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay, and Venezuela) in the period 1953-2019 was analysed. Equation (30), described in detail in the methodology section, is utilised here. Despite the intercept, the equation includes in total seven parameters that measure the strength of the annual GDP per worker growth, namely: government spending, inflation, inflation square, gross capital formation (investment), human capital, time trend component and finally the initial income. Following the standard notations in the reviewed theory, the parameter standing next to the initial income and thus accounting for the convergence effect, is named as beta. Once the beta parameter is negative, then the initial income affects the economic growth negatively and we speak about the catching up process or the beta convergence. The further below zero the beta parameter is, the stronger this effect.

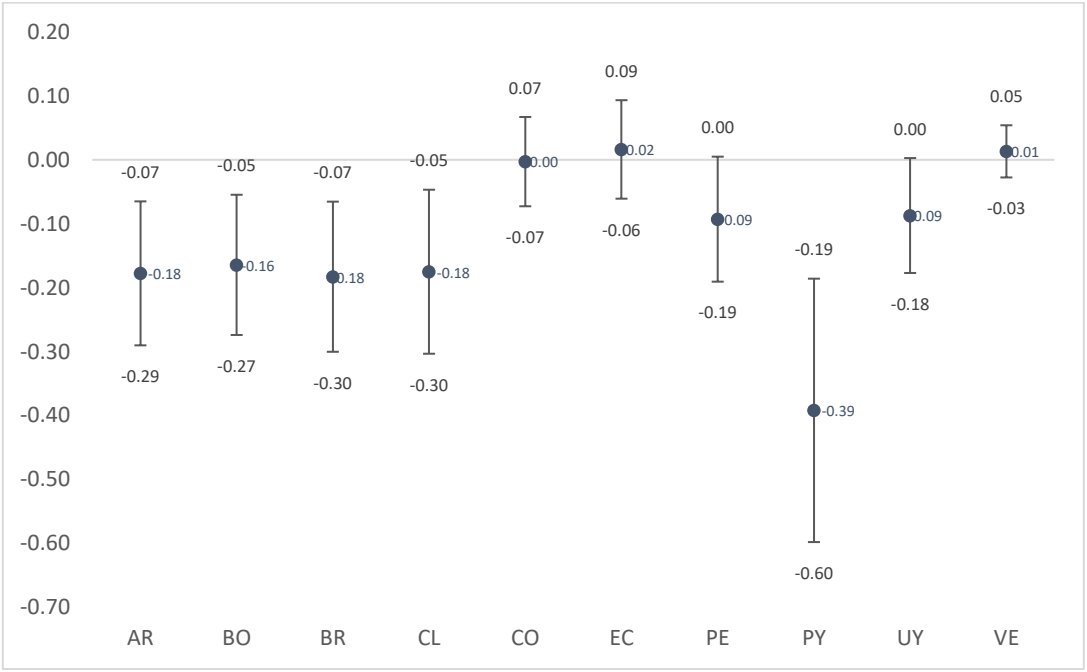
All results for the LA analysis are available in the appendix section (Table A *9* to Table A *16*) but considering the main objectives and hypotheses of this thesis, it is more than necessary to analyse those beta parameters in a detailed way (and the human capital impact). This is done with the Figure 40 and Figure 41 below that describe their magnitudes together with the 95% confidence intervals. The difference between those two is the model's case that was utilised. As per the methodology and CEE chapters already noted, the SURE framework delivers flexibility in the way the data is calculated. For the purpose of empirical analysis, two special cases were established: M0 and M1. The cases vary based on the correlation of the error term. M0 treats the Equation (30) for each country in a separate way (independent country regressions), while M1 treats them as a system and the error term is correlated (SURE model, Zellner estimator). Case M0 is visible on Figure 40, while case M1 is shown on Figure 41.

As per the methodology and the literature review section, the analysis performed for the Latin America (LA) region can be considered as a more detailed follow-up of the paper Jarco and Pipień (2020). It is therefore also interesting to compare the results obtained in this thesis with the ones from the paper. Jarco and Pipień (2020) analysed the same group of 10 LA countries from 1953 to 2014. The dissertation is expanding this period with new values that range from 1953 to 2019. Also, a similar set of variables was utilised; the paper did not consider Human Capital, besides that, equation 30 stated the same. Furthermore, the paper investigated multiple and slightly different cases/constrains of the SURE model. The closest model from the paper to compare with is the M1. To avoid confusion when comparing the models from Jarco

and Pipień (2020) and the ones from the dissertation, the models from the paper will have a "P" indicator added, for instance PM1 to describe the M1 from Jarco and Pipień (2020).

Looking at the overall LA results from the dissertation and the convergence process itself, M0 did not confirm convergence for three countries (Colombia, Ecuador and Venezuela) while M1 did not confirm it only for one of them (Venezuela). Although the trend within those two figures is similar and convergence is visible nearly for each country, there are substantial differences when looking at the variability of the beta parameters itself and even of its confidence intervals. The biggest differences are visible for Argentina, Ecuador, and Bolivia with beta parameters for M0 of - 0.18, 0.02 and -0.16, while M1 showed -0.11, -0.03 and -0,20 respectively. More interesting, the differences between the two models are not homogenous. For some countries M0 had higher beta parameters, and for some it was M1. To be exact out of the 10 analysed countries M1 estimated higher beta parameters that indicate stronger convergence for 6 of them (Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela), than model M0 and vice versa. Considering that the two models had exactly the same sample confirms the main objective - O0 - of the thesis: the convergence is a heterogenous process. In this case, the chosen calculation method, or rather the version of the model, was decisive and confirmed the variability of the parameters. Convergence trends for the particular countries can be seen between Figure 40 to Figure 43 below.

*Figure 40: $M_0$ C*onvergence parameters estimates for LA countries together with bounds of the 95% confidence intervals, sample for 1953-2019.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

When looking at Figure 40 one may see that convergence can be confirmed for almost all of the countries. The beta magnitudes range between 0.02 (Ecuador) and -0.39 (Paraguay). The average beta value for all analysed LA countries is equal to -0.12. Further, there are three groups of countries with very similar beta parameters: four countries that catch up fast, three countries that do not converge at all, and two countries that catch up on a moderate level. The four countries with a strong beta parameter include Argentina (-0.18), Bolivia (-0.16), Brazil (-0.18) and Chile (-0.18). While Argentina, Brazil and Chile are on a similar economic performance level (2019 PPP GDP p.c. between 14,638 USD and 23,596 USD), Bolivia is far behind and can be considered as an emerging country (2019 PPP GDP p.c. of 8,629 USD). It is however not a surprise. Bolivia was subject to an economic transformation, where human capital and mobility played a significant role (McKay, 2018). After recovering from the debt-crisis Bolivia resumed its growth in 1986 with later small disruptions such as the Dot Com bubble and global financial crisis. The fiscal and monetary policy, which was reliant on external financing, also played a major role in the country's performance (Kehoe, Machicado and Peres-Cajías, 2019).

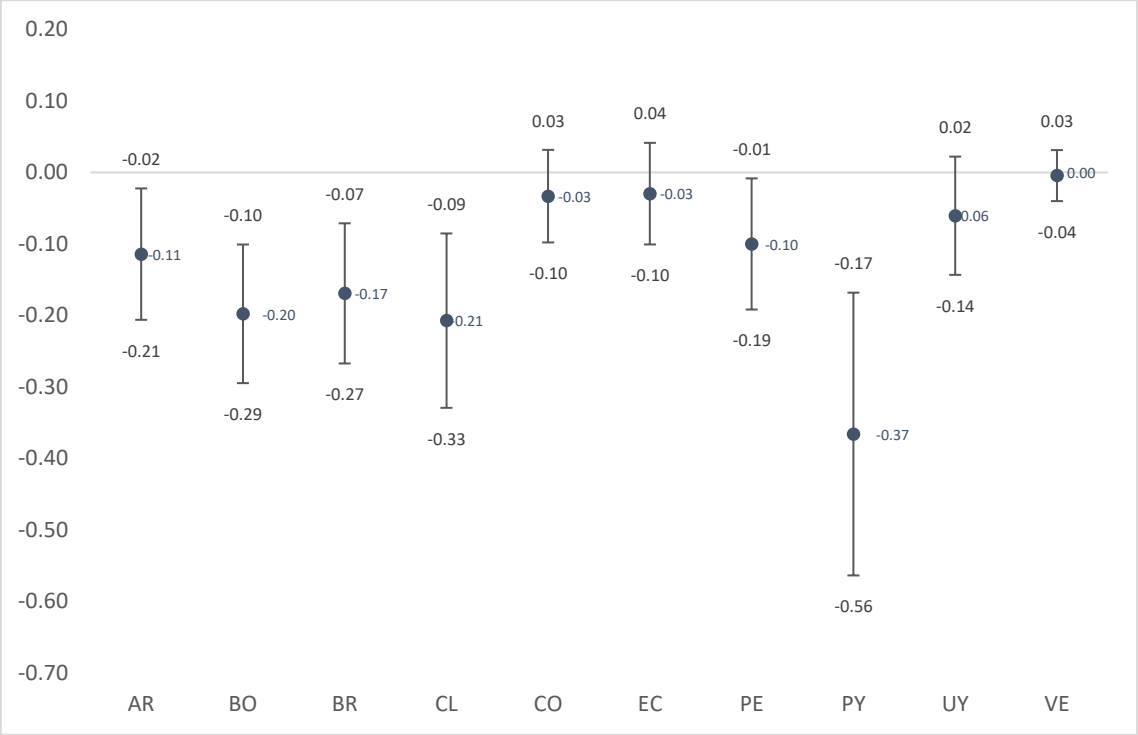
The three countries that do not seem to be converging at all have a beta parameter between 0 and 0.02 and include Colombia, Ecuador and Venezuela. Both Colombia and Ecuador had a similar starting level of the PPP GDP p.c. in 1951 of 3,374 USD and 3,316 USD. They also grew on average during that period in similar manner, in 2019, at the end of the analysed period their PPP GDP p.c. levels reached 13,820 USD and 11,238 USD respectively. The big outlier is Venezuela. The negative impact of Maduro's autocratic regime policy (Corrales, 2020) is clearly visible in the PPP GDP p.c., which was in 1951 twice that of Columbia or Ecuador on a level of 6,808 USD, but in 2019 it reached the lowest level of 251 USD. High inflation rate in this country drives the PPP GDP down from its nominal value. This ending value of Venezuela is what drives the convergence parameter to suggest no convergence at all. To overcome this outcome, researchers could calculate the convergence for a specific period in Venezuela before Maduro's reforms, but to analyse each country's convergence on a separate level is beyond the scope of this thesis.

Finally, there is one outlier with an incredible high beta parameter suggesting for a fast catching up process – Paraguay. Unfortunately, the convergence or economic performance literature for this particular country (similar to other LA countries) is very limited. One paper suggests that it is difficult to correlate Paraguay's sustainable economic growth with a specific

determinant, and that the 20th century had non-standard growth-challenges, like the infrastructure or corruption (Hausmann and Klinger, 2007). Those reasons may suggest why the beta parameter related to initial income is that high.

Comparing the M0 results with the PM1 from Jarco and Pipień (2020), the PM1 beta values range between -0.24 (Bolivia) to -0.05 (Uruguay), which is narrower than M0 (-0.30 to 0.06). All countries were subject to convergence, which is not surprising because the dataset did not include years after 2014, where multiple GDP slowdowns for some countries occurred, for instance Venezuela or Ecuador, which do not suggest a convergence in Figure 40. PM1 has similar top 5 countries with respect to convergence (Bolivia, Paraguay, Peru, Brazil and Argentina), as M0 above (Paraguay, Brazil, Argentina, Chile, Bolivia) with 1 difference (Peru for PM1 and Chile for M1). The general trend is therefore very similar.

*Figure 41: $M_1$ C*onvergence parameters estimates for LA countries together with bounds of the 95% confidence intervals, sample for 1953-2019.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

The next step will be the detailed investigation of Figure 41, which looks at the Zellner estimator. Similarly to Figure 40, some country groups with close beta parameters may be identified: Bolivia, Brazil and Chile have a parameter between -0.17 and -0.21. This is more or less in line with Figure 41, although the countries seem to catch up a little bit faster within the

Zellner estimator than when looking at the OLS regression. Also, the first group does not include Argentina. With a beta parameter of -0.11 the convergence effect seemed to be lower.

Further, Argentina is this time much closer to Peru (-0.10) and Uruguay (-0.06), which formulate a second group of countries with similar rates. Their economic performance varies however widely when looking at the GDP p.c. levels.

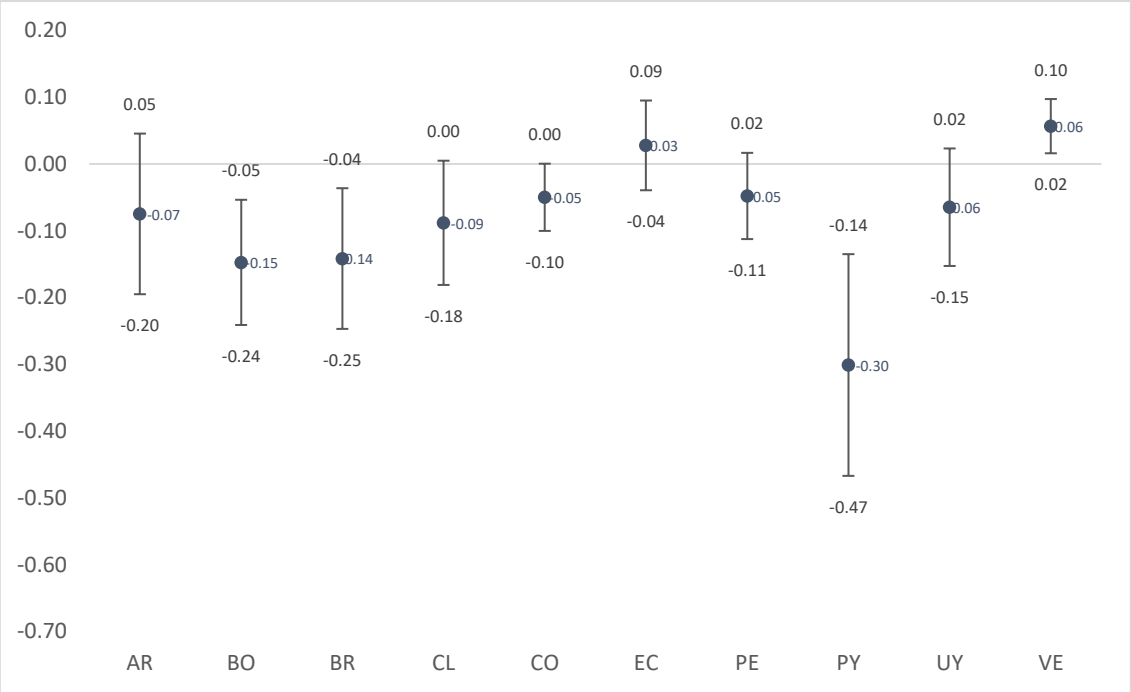
As previously, also at this point Colombia (-0.03), Ecuador (-0.03) and Venezuela (0.00) are the countries with the lowest beta parameter, which suggests little convergence, whereas Paraguay has the biggest one, suggesting a strong convergence effect (-0.37).

Comparing the M1 case with the PM1 from Jarco and Pipień (2020) should give even closer values, because in contrary to M0, the same version of the model is used here. The overall convergence result is much closer, because all countries converged at PM1 (despite Venezuela), as they do when looking at Figure 41 above. The beta parameters range is closer too (M1: -0.37 to 0.00 vs PM1: -0.24 to -0.05). The top five countries within M1 are also similar and differ because of Chile only.

To conclude, treating the countries as a whole group within the Zellner estimator resulted in different parameter magnitudes than the OLS regression, but with a similar trend. Some countries seemed to catch up faster and some longer than in the OLS regression.

Comparison of Figure 40 and Figure 41 already suggested the heterogeneity of convergence, but in order to verify the hypothesis even deeper, another series of analyses was performed. This time, the analysis can be really considered as an extension of the paper by Jarco and Pipień (2020) because it does not include the Human Capital KPI. So in the case of Figure 42 and Figure 43, the equation 30 excludes the fifth variable, described as h, like Jarco and Pipień (2020). Hence, we will refer to those models as $M_{eh0}$ and $M_{eh1}$ that suggest for the human capital to be excluded. It is clear that the convergence parameters differ from the original equation and analysis done previously.

*Figure 42:$M_{eh0}$ C*onvergence parameters estimates without Human Capital for LA countries together with bounds of the 95% confidence intervals, sample for 1953-2019.

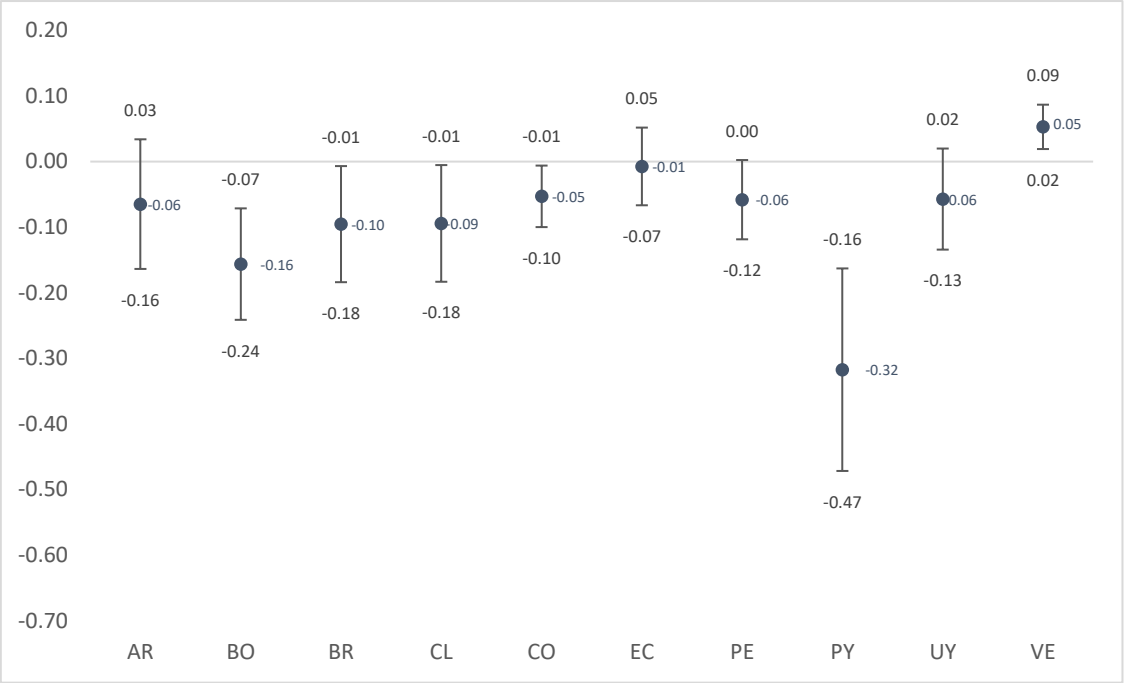



Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Figure 42 describes the $M_{eh0}$ results. All of the beta parameters, despite Colombia, suggested a lower convergence effect when excluding the human capital variable and comparing the classical methods with each other (M0). The beta parameters for $M_{eh0}$ were weaker by around 0.04 in average. The range of the country specific beta parameters is between -0.30 and 0.06, which is slightly narrower than for M0 including HC (-0.39 and 0.02). The biggest difference came from Argentina (-0.18 vs -0.07), Paraguay (-0.39 vs -0.30) and Chile (-0.018 vs. -0.09). Colombia was the only exception, as the country did not converge when HC was included at all (0.00) and converged when looking at $M_{eh0}$ (-0.05). Further, there are two countries that are not converging when looking at Figure 42, namely Ecuador and Venezuela. Both of them have weaker beta parameters when HC was excluded than they had originally.

When comparing the $M_{eh0}$ results with the PM1 model from Jarco and Pipień (2020) one may still find the similar trend with some differences suggesting for heterogeneity. The range of the parameters is still very similar, for $M_{eh0}$ between -0.30 and 0.06 and for PM1 -0.24 to -0.05. Again, the expansion of the dataset affected the countries which lowered the GDP level in recent years. The average beta value for $M_{eh0}$ is equal to -0.08 while it is -0.11 for PM1. The biggest differences come, as expected, from Venezuela ($M_{eh0}$ 0.06 and PM1 -0.08).

*Figure 43:$M_{eh1}$ C*onvergence parameters estimates without Human Capital for LA countries together with bounds of the 95% confidence intervals, sample for 1953-2019.




Source: Own elaboration based on Feenstra, R. C., Inklaar, R., & Timmer, M. P. (2015). The next generation of the Penn World Table. *American Economic Review*, *105*(10), 3150-82.

Looking at Figure 43 that presents the $M_{eh1}$ beta parameters, it can be observed that there is only one country not converging, namely Venezuela. The range of the beta parameters for this model is between 0.05 and -0.32. The top country with the highest convergence rate, Paraguay, is in line with models M0, M1 and $M_{eh0}$. Similar to the one with the lowest (Venezuela), which was only not the case when looking at M0.

When comparing the two models that exclude the human capital, $M_{eh1}$ to $M_{eh0}$, the differences between the beta parameters are within the 0.01 magnitude despite two exceptions: Brazil and Ecuador. Interestingly enough, the betas for those countries did change into one direction. In case of $M_{eh0}$ the beta parameters were equal to -0.14 and 0.03, while in case of $M_{eh1}$ they were equal to -0.10 and -0.01 for Brazil and Ecuador respectively.

Checking for differences between the Zellner estimator that includes Human Capital and excludes it, M1 and $M_{eh1}$, one may note that the average beta parameter is much higher for M1 on a -0.13 level, while it is -0.09 in case of $M_{eh1}$. The range is different too and indicates stronger convergences when including the human capital variable. All of the countries had a lower beta parameter for the model $M_{eh1}$ when comparing to M1, in spite of Colombia.

The final comparison of the LA analysis involves $M_{eh1}$ and PM1 from Jarco and Pipień (2020). It is important to highlight one more time, that the only difference between those two models is the sample that expands the years from 2014-2019 for $M_{eh0}$. With this modification, the beta parameters vary for 5 countries by a lot (>0.05), but very minor for the remaining ones. The biggest differences come from Paraguay, Venezuela, Bolivia, Ecuador and Peru.

In summary, Figure 44 below contains all the beta parameters from the models described previously. Further, top five countries suggesting for strongest beta convergence within each model are highlighted in blue.

*Figure 44:* Summary of all analysed beta parameters for the LA countries based on the Model. $PM_1$ values extracted from Jarco and Pipień (2020).

| Model/Country | AR | BO | BR | CL | CO | EC | PE | PY | UY | VE |
|---|---|---|---|---|---|---|---|---|---|---|
| **PM1** | -0.10 | -0.24 | -0.10 | -0.08 | -0.07 | -0.08 | -0.13 | -0.17 | -0.05 | -0.08 |
| **M0** | -0.18 | -0.16 | -0.18 | -0.18 | 0.00 | 0.02 | -0.09 | -0.39 | -0.09 | 0.01 |
| **M1** | -0.11 | -0.20 | -0.17 | -0.21 | -0.03 | -0.03 | -0.10 | -0.37 | -0.06 | 0.00 |
| **Meh0** | -0.07 | -0.15 | -0.14 | -0.09 | -0.05 | 0.03 | -0.05 | -0.30 | -0.06 | 0.06 |
| **Meh1** | -0.06 | -0.16 | -0.10 | -0.09 | -0.05 | -0.01 | -0.06 | -0.32 | -0.06 | 0.05 |

Source: Own elaboration.

*Blue coloured cells highlight top five countries with the highest beta magnitude within each model.

Similar to the CEE group, the likelihood ratio tests were conducted also for Latin America, in order to verify the statistical significance of some restrictions imposed on the most general model M1. *Table 26* presents the natural logarithms of the likelihood function that are calculated at parameters' ML estimates. The first row of the table sums up all of the models, that were described for LA previously. First column indicates the models M1 and M0 which include human capital and the second the models Meh1 and Meh0 that exclude the human capital variable. Looking at the second row of the table one may find likelihood ratios of the respective models for which only the intercept would be the existing variable. Same values for M1 and Meh1 as well as for M0 and Meh0 can be considered as "proof" of this case.

Just like in case of CEE countries, the model with the greatest likelihood is M1 and has the value of 1218. The M1 likelihood ratio is also higher than the corresponding OLS model M0 (1140). Similar to the case of CEE, this highlights that treating the countries as a whole and utilizing the Zellner estimator has more statistical support than when utilizing the most common approach in the literature – OLS estimation.

The second observation confirms the above statement: Meh1 reached a value of 1193, which is higher than its equivalent Meh0 (1114). Also when excluding the human capital variable, the statistical relevance increases when estimated with Zellner.

When looking at the columns that utilise the Human Capital Variable with the ones that exclude it, an improvement can be found, but of a small size. M1's likelihood is slightly higher than that of Meh1 and M0's is slightly greater than Meh0. Ultimately one may ask whether the whole analysis makes sense and what would have happened, if only an average of the dataset is estimated instead of all the parameters in Equation (30). This can be found in the second row of the table. All analysed models have stronger likelihood ratios when using the parameters from Equation (30) instead of the intercept only. Similar to the Central and Eastern European sample, this confirms that the theory behind the parameters from Equation (30) is in line with the empirical data.

Table 26: The value of the Log-likelihood function calculated at ML estimates for models utilizing the LA sample.

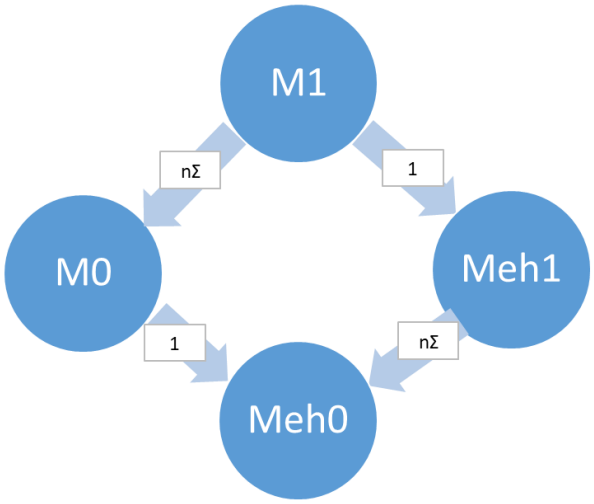
| LA | | | | | |
|---|---|---|---|---|---|
| | **including Human Capital** | | | **excluding Human Capital** | |
| | M1 | M0 | | Meh1 | Meh0 |
| **Model LH** | 1218 | 1140 | | 1193 | 1114 |
| **Intercept only Model LH** | 1075 | 979 | | 1075 | 979 |

Source: Own elaboration.

Similar to the CEE chapter, the relationships between the respective models for the LA sample was presented on Figure 45. The reader may also fine the possible restrictions in the rectangles. Hence M1 is an augmentation for Meh1 or M0, while Meh0 is a reduction of those two.

*Table 27* shows the LR tests for all possible restrictions. Similar to the CEE example, the p-values for all model-pairs are close to 0. Model M1 with the Zellner estimator and the human capital variable is superior when compared to the remaining ones utilised in this chapter. Only a very strict p-value criteria could lead to reasonability for other models.

*Figure 45:*Graph presenting the relationships and restrictions of analysed models for LA.




Note: Axes with arrows show the restrictions that may be imposed. Symbols in rectangles present the number of restrictions required to obtain less parametrised model. $n$ is the number of equations in (30), while $n\sum = \frac{1}{2}n(n+1) - n$.

Source: Own elaboration.

Table 27: Likelihood (LH) ratio test statistics for the LA sample with P-Values obtained for the respective pairs of models together with the restrictions.

| | LH | Restrictions | P-Value |
|---|---|---|---|
| **M1 vs. M0** | 157 | 0.5*n*(n+1)-n | 2.82595E-14 |
| **M1 vs. Meh1** | 51 | 1 | 7.96805E-13 |
| **M0 vs. Meh0** | 52 | 1 | 5.92996E-13 |
| **Meh1 vs. Meh0** | 192 | 0.5*n*(n+1)-n | 4.17586E-20 |

Source: Own elaboration.

In conclusion of this section, a comparison between the LA results obtained above and the CEE ones provided in the previous chapter can deliver interesting value added. Before starting, it is important to note that those groups varied considerably in the observation size. The LA set included a very long term perspective covering the period from 1952 to 2019 while, due to limited data availability, the CEE analysis was based on much shorter series (1992 – 2019). But regardless of this difference, both of the time periods are considered in literature as a long term. Firstly, it is important to seek whether a common pattern for those two emerging

country groups can be identified. All of the analysed countries from CEE and LA, with 3 exceptions, suggested strong convergence. The average beta values were stronger for CEE than for LA by far when considering each model. This suggests, that CEE countries tend to catch up much faster. The reader may think about geographical, geopolitical and cultural differences as described in the theoretical chapter.

In all of the cases the average beta parameter for the analysed countries was higher for the Zellner estimation than for the classical OLS. However, the differences between the respective models were narrower for LA than they were for CEE. To be more specific, although the parameters between M0 and M1 changed, the difference for the LA countries was barely visible, which was not the case for CEE, where it was substantial.

When excluding the human capital variable, thus when comparing the M0 and M1 to $M_{eh0}$ and $M_{eh1}$ for both country groups, the average beta parameters were in all of the cases lower. Of course, the absolute magnitudes varied for the CEE group more than for the LA group, but when looking at the percentual change of the individual countries, the LA countries' beta values were rather strongly affect by the human capital variable than the ones from CEE.

In general, stronger convergence in CEE may also suggest that those countries are more homogenous with respect to economic growth and economic performance, which in fact is the case when considering the economic indicators presented previously. 11 out of the 12 CEE countries are part of the European Union, where LA does not have such an institution that enhances the convergence effects, for instance through cohesion policy. Those differences do not only suggest the heterogeneity of convergence, but also indicate how broad the term "emerging economy" can be.

# Conclusions

Overall, the dissertation utilised a nonstandard econometric framework SURE (Seemingly Unrelated Regression Equations) to analyse the income convergence across two different emerging economy country groups: Central and Eastern European (CEE) and Latin American countries (LA). Multiple models were formulated, and the variety of results suggests the heterogeneity of convergence. The results obtained are in line with the theory and the critical literature review where such a heterogeneity was already observable.

The first chapter of this thesis, which covered the majority of the theoretical part, sets the foundations towards the objectives and hypotheses of the dissertation. Hence it resulted in being a foundation for the remaining and main empirical part. The theoretical findings can be summarised as follows:

1. First interest in the economic growth analysis was already observable in the 18$^{th}$ century (Smith, 1776 or Malthus, 1798), but focused on broad economic issues rather than looking at the determinants of cross-country differences.
2. The breakthrough in the economic growth theory occurred with the paper published by Solow (1956). Solow's paper can be classified as a neoclassical one. This is because the Solow model implies a neoclassical condition – the diminishing returns to capital.
3. The endogenous growth theory on the other hand, highlights the possibility of increasing returns to capital when considering the knowledge, innovation and the human capital in general. The view became popular in the 1980s (Romer, 1986; Lucas 1988). A debate between the neoclassical and the endogenous school of economic though occurred.
4. The convergence debate was raised as a need for verification of the diminishing returns to capital concept. Hence it was also a result of the discussion between the neoclassical and endogenous growth theory. The most popular framework for testing the income convergence was presented by Barro and involved a panel regression analysis (i.e. Barro 1986, 1990, 1991). Barro introduced the beta and sigma convergence terminology, which may be defined as higher income growth of the poorer countries vs. the richer ones and a decreasing income gap between them over time respectively.
5. The methodology of the papers that dealt with the convergence topic was mostly based on the model introduced by Barro, however the variety of the samples and variables (conditional convergence) lead to multiple and uncommon results that lead to more questions. The debate about the existence of convergence and its speed was present

more or less until the end of the 20th century, where something like an unformal consensus indicating a convergence speed of around 3% was established.

6. After the 2008 global financial crisis, the convergence topic became popular again. Multiple papers in high impact economic journals dealt with this issue. The last part of the first chapter dealt partly with the impact of the financial crisis on economic performance. When looking at the convergence literature, the research question was mostly related to the nature of the global financial crisis: did it increase or decrease the income gaps? Many studies and papers analysed various samples with dividing it between the pre-crisis and after-crisis period. Also, some novel methods to convergence testing became visible (i.e. unit-root tests, Markov Chain). However, similarly to the convergence debate prior to the 2008 global financial crisis, no common conclusion about the results was observable. This fact suggested the heterogeneity of convergence.

The reintroduction of the convergence debate after the 2008 global financial crisis and the analysed literature that delivered multiple results, led in a natural way towards the formulation of the thesis' research questions, objectives and hypotheses. In fact, the main hypothesis of this thesis that suggests the convergence to be a country specific phenomenon may already be confirmed with the critical literature review. But the main objective of the thesis was to utilise the SURE model as the verification tool, which can be considered as a novel approach. This brings the reader to the second part of the thesis.

The second chapter presents the methodology for convergence testing, which is based on the Seemingly Unrelated Regression Equations (SURE). The SURE model was estimated with the framework proposed by Zellner (1962). The SURE model is yet another method, or rather an enhancement, of the Generalised Linear Regression Model (GLRM). One of the advantages of the GLRM is the assumption about heteroscedasticity for cross sectional data and the assumption about autocorrelation for time series. Those assumptions make indeed sense when analysing cross-sectional data or time series separately. But when analysing those jointly and having to do with panel data both heteroscedasticity and autocorrelation can reflect the reality. Those assumptions can be combined with the SURE framework, because its multi-equations are allowed to be linked by disturbances. Therefore, the advantage of the SURE model over the GLRM depends on the nature of the data. When looking at the convergence hypothesis and the panel data utilised, the assumptions of the SURE model suggest that it can indeed be a good alternative to the GLRM or even to the Classical Linear Regression Model (CLRM). Statistical significance tests done in this thesis involved the log-likelihood ratios. In

all of the analysed cases the SURE model exhibited higher likelihood ratios than the OLS equivalents. The statements mentioned above confirm the first detailed hypothesis H1.

The structure of chapters three and four was very similar and had an empirical nature. There was however one difference: Chapter three dealt with the Central and Eastern European (CEE) sample and chapter four with the Latin American (LA) sample. When analysing the convergence, and especially its heterogeneity, it was more than important to carefully select the sample and also to justify the selection. Based on the literature and the idea behind the income convergence, it should be more visible for countries that are poorer. Emerging economies seem therefore to be a perfect example for convergence testing. In this case, the more "classical" sample containing 12 CEE countries (as per the OECD definition) was chosen and the rather non-standard one that contained 10 selected LA countries (based on data-availability). With those two country groups the reader may see two different aspects of emerging economies that vary not only by some economic indicators, but also by geography, political situation, and other social aspects. When investigating the heterogeneity of convergence, this sample may be suitable indeed. In addition, the income convergence literature on LA countries is very limited, therefore including this group in the dissertation gives also a novelty aspect with a broader contribution to the research than the "classical" CEE sample.

When looking in more detail at chapters three and four, they were split into two parts. The first part investigated the economic performance of the individual CEE and LA countries. Some most commonly used indicators applied to economic-growth analysis were utilised, i.e. the GDP p.c. together with its growth rates, capital stock development, total fact productivity and the labour force. The second part dealt with the results of the SURE model, statistical inference, and offered discussion of results. The dataset utilised for chapters three and four were the Penn World Tables: PWT 9.1 for (economic performance) and its latest version PWT 10 (convergence testing).

In general, for both country groups four different models were created to test for convergence heterogeneity:

1. M0 capturing the convergence parameter for each country separately without correlation of the error terms (classical way).
2. M1 treating all countries as one system and correlating the error terms (novel approach).
3. Meh0 same as M0 but with 1 restriction excluding the human capital variable.
4. Meh1 same as M1 but with 1 restriction excluding the human capital variable.

Across the analysed samples, both the existence of convergence and its huge variability of the parameters were confirmed. Overall, the CEE countries were subject to higher convergence rates than the LA ones. In fact, nearly all of the countries were subject of convergence in all models, despite two: Ecuador and Venezuela indicated a divergence when looking at M0 and Meh0. The variability was present in both samples, but when looking at the ranges of the convergence parameters across all models CEE countries were between -0.73 to -0.08 and the LA ones between -0.39 and +0.06. The trends of the results are in line with the analysed literature.

The objectives set for the thesis were nearly fully realised. The SURE model was applied to test the income convergence on the CEE and LA sample, which was set as the main objective O0. The framework was also described and introduced according to what was set as O1. O2 involving the verification of convergence parameters across CEE and LA countries was realised as well. Regarding O3 all models with the human capital variable showed higher likelihood ratios, then the ones without it, indicating that it is important to include human capital measures when analysing the economic growth and the convergence process. Finally, the literature review presented the mainstream trends and the CEE results are in line with those. Because of a lack of literature for the LA countries it was not able to present multiple results there, but overall, the trend seems to be in line. Hence O4 was realised partly because of the limited literature for LA. This could be for sure a point for further investigation as there is clearly a research gap.

The main hypothesis H0 of the thesis can be confirmed. Huge variability of results obtained for all analysed countries within both groups indicates that convergence should be seen as a country specific phenomenon, rather than a single absolute rate for all countries or even for a country group. The likelihood ratio tests, and their p-values confirmed the differences to be statistically significant. H1 was confirmed in the second chapter when the SURE model was derived; it is indeed a generalization of the panel regression and can be treated as an empirically important alternative. H2 about the convergence parameters magnitudes is true as well; the beta parameters are different for both the country groups and the individual countries. The heterogeneity of convergence was analysed when comparing two models, one that included human capital and one that did not. The results were different and hence H3 can be confirmed as well. When looking at the statistical inference of the models and i.e. the likelihood ratio tests, the human capital regressor is relevant for convergence testing; H4 is true.

There were limitations when working on the dissertation and can be categorised into two categories: literature and dataset. The first limitation relates to the limited availability of

English-lingual literature on income convergence for the Latin American countries. Also when searching for some key words among articles published in Spanish language that had English abstracts hardly any results were found. More literature was found for individual countries than for the LA region as a whole. The convergence tests for the LA region can therefore be a solid starting point for further research. The second limitation is not something special and it was visible when working on the research plan. The data for Central and Eastern European countries becomes unreliable when looking at periods before 1991/1992. This relates to the central reporting done by the former socialist government in many of the CEE countries. Also couple of years after the transformation may not be reliable at all. Many datasets try to extrapolate the data, which can be done with more accuracy over time, but it is still a substantial problem for long-run tests. This is the reason why the CEE countries have a different time frame in the analysis than the LA ones.

The main contribution of this thesis relates to the results and the way how they were calculated. The results and the hypothesis about the heterogeneity of the convergence process throw a new light on the whole convergence debate. The convergence debate may shift from the main hypothesis about its existence and speed towards the statement that it is a country specific phenomenon. Looking at the individual regressors and each country on individual basis, the research may be able to find more ways that lead to the steady state or rather a sustainable growth path. The importance of the human capital variable for convergence testing was confirmed too. Also, the SURE model that was already introduced in 1962 by Zellner, can serve as a suitable and empirically relevant method for panel regression tests that involve cross-country analyses.

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# Appendix

Table A 1: $M_0$ OLS estimates of parameters of the system of convergence equations covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| ALB | 2.481 | 0.062 | -0.043 | 0.363 | 0.713 | -0.630 | 0.006 | -0.092 |
| BGR | 1.132 | 0.391 | -0.075 | 0.583 | 0.159 | 1.252 | -0.006 | -0.474 |
| CZE | 6.301 | 0.178 | 0.097 | -0.665 | 1.075 | -0.163 | 0.012 | -0.570 |
| EST | 0.848 | 0.649 | -0.094 | -0.553 | 0.784 | 0.474 | -0.001 | -0.261 |
| HRV | 11.399 | 0.647 | 0.032 | -0.260 | 0.346 | -1.598 | 0.077 | -0.730 |
| HUN | 0.270 | -0.427 | 0.072 | -0.664 | 0.600 | 1.251 | -0.026 | -0.352 |
| LTU | 1.577 | 0.106 | -0.041 | -1.057 | 0.513 | 0.858 | -0.003 | -0.399 |
| LVA | 4.228 | 0.142 | -0.024 | 0.012 | 0.056 | 0.416 | 0.015 | -0.540 |
| POL | 1.603 | 0.837 | -0.063 | -0.599 | 0.239 | 0.151 | 0.004 | -0.217 |
| ROU | 7.555 | 0.644 | 0.110 | -0.591 | 0.717 | -1.774 | 0.047 | -0.303 |
| SKV | 1.021 | -1.190 | -0.149 | 0.350 | -0.026 | 0.516 | -0.013 | -0.208 |
| SVN | 6.036 | -0.015 | -0.028 | 0.159 | 0.195 | -0.609 | 0.016 | -0.390 |

Table A 2: P-Values of $M_0$ parameters for the OLS estimates of the system of convergence equations covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| ALB | **0.042** | 0.849 | 0.709 | 0.507 | **0.041** | 0.140 | 0.387 | 0.332 |
| BGR | 0.845 | 0.667 | 0.629 | 0.470 | 0.718 | 0.564 | 0.837 | **0.004** |
| CZE | **0.000** | 0.683 | 0.057 | 0.072 | **0.002** | 0.222 | **0.000** | **0.000** |
| EST | 0.629 | **0.045** | 0.517 | 0.528 | **0.009** | **0.035** | 0.865 | 0.051 |
| HRV | **0.000** | **0.021** | 0.626 | 0.603 | **0.035** | **0.000** | **0.000** | **0.000** |
| HUN | 0.814 | 0.417 | 0.386 | 0.220 | 0.169 | **0.001** | **0.005** | **0.000** |
| LTU | 0.213 | 0.638 | 0.679 | 0.194 | **0.036** | **0.002** | 0.657 | **0.000** |
| LVA | 0.054 | 0.702 | 0.807 | 0.981 | 0.812 | 0.312 | 0.186 | **0.000** |
| POL | 0.418 | 0.236 | 0.200 | 0.131 | 0.428 | 0.797 | 0.772 | **0.038** |
| ROU | **0.021** | 0.270 | 0.061 | 0.073 | **0.031** | 0.165 | **0.030** | **0.002** |
| SKV | 0.362 | **0.001** | 0.141 | 0.376 | 0.923 | **0.045** | 0.051 | **0.037** |
| SVN | **0.032** | 0.984 | 0.738 | 0.622 | 0.452 | 0.233 | 0.135 | **0.006** |

Table A 3: $M_1$ Zellner estimates of parameters of the system of convergence equations covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| ALB | 3.656 | 0.361 | -0.054 | 0.339 | 0.932 | -1.059 | 0.014 | -0.112 |
| BGR | 3.853 | 0.345 | -0.063 | 0.571 | -0.031 | 0.559 | 0.007 | -0.552 |
| CZE | 7.843 | 0.176 | 0.050 | -0.518 | 1.240 | -0.248 | 0.015 | -0.692 |
| EST | 3.002 | 0.568 | -0.154 | -0.825 | 0.973 | 0.286 | 0.009 | -0.421 |
| HRV | 10.206 | 0.651 | -0.019 | -0.278 | 0.470 | -1.349 | 0.066 | -0.678 |
| HUN | 3.085 | -0.473 | -0.011 | -0.337 | 0.412 | 0.585 | -0.007 | -0.441 |
| LTU | 4.124 | -0.137 | -0.030 | -0.376 | 0.413 | 0.392 | 0.012 | -0.519 |
| LVA | 8.294 | -0.221 | -0.018 | 0.102 | -0.018 | -0.351 | 0.035 | -0.730 |
| POL | 1.570 | 0.026 | -0.088 | -0.611 | 0.081 | 0.901 | -0.007 | -0.397 |
| ROU | 6.088 | 0.481 | 0.098 | -0.717 | 0.845 | -1.093 | 0.036 | -0.344 |
| SKV | 2.566 | -0.989 | -0.158 | 0.419 | 0.231 | 0.380 | -0.007 | -0.326 |
| SVN | 6.974 | -0.644 | 0.021 | -0.220 | 0.152 | -0.307 | 0.016 | -0.556 |

Table A 4: P-Values of $M_1$ parameters for the Zellner estimates of the system of convergence equations covering the CEE countries from 1992 to 2019

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| ALB | **0.001** | 0.221 | 0.604 | 0.485 | **0.004** | **0.007** | **0.037** | 0.206 |
| BGR | 0.443 | 0.610 | 0.602 | 0.365 | 0.932 | 0.763 | 0.790 | **0.000** |
| CZE | **0.000** | 0.566 | 0.172 | **0.022** | **0.000** | **0.011** | **0.000** | **0.000** |
| EST | **0.022** | **0.014** | 0.127 | 0.151 | **0.000** | 0.104 | 0.175 | **0.000** |
| HRV | **0.000** | **0.010** | 0.740 | 0.506 | **0.001** | **0.000** | **0.000** | **0.000** |
| HUN | **0.001** | 0.190 | 0.855 | 0.359 | 0.169 | **0.039** | 0.316 | **0.000** |
| LTU | **0.000** | 0.421 | 0.674 | 0.501 | **0.014** | 0.072 | **0.031** | **0.000** |
| LVA | **0.000** | 0.343 | 0.759 | 0.746 | 0.898 | 0.246 | **0.000** | **0.000** |
| POL | 0.282 | 0.959 | **0.016** | **0.021** | 0.706 | **0.049** | 0.470 | **0.000** |
| ROU | 0.052 | 0.378 | 0.082 | **0.024** | **0.007** | 0.369 | 0.080 | **0.000** |
| SKV | **0.004** | **0.000** | **0.035** | 0.137 | 0.211 | **0.042** | 0.172 | **0.000** |
| SVN | **0.000** | 0.245 | 0.746 | 0.358 | 0.406 | 0.413 | **0.031** | **0.000** |

Table A 5: $M_{eh0}$ OLS estimates of parameters of the system of convergence equations excluding the human capital variable (α5) covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| ALB | 1.187 | -0.326 | -0.056 | 0.355 | 0.255 | -0.001 | -0.109 |
| BGR | 4.338 | 0.393 | -0.093 | 0.603 | 0.340 | 0.011 | -0.450 |
| CZE | 5.235 | 0.592 | 0.104 | -0.773 | 1.070 | 0.010 | -0.532 |
| EST | 3.459 | 0.382 | -0.213 | -0.495 | 1.001 | 0.013 | -0.375 |
| HRV | 2.422 | 0.010 | -0.082 | 0.845 | 0.477 | 0.006 | -0.244 |
| HUN | 2.281 | -0.265 | 0.100 | -0.645 | -0.066 | 0.003 | -0.205 |
| LTU | 4.250 | -0.214 | -0.017 | -0.724 | 0.774 | 0.015 | -0.427 |
| LVA | 6.303 | 0.029 | -0.028 | -0.028 | 0.133 | 0.025 | -0.635 |
| POL | 2.010 | 0.796 | -0.064 | -0.616 | 0.252 | 0.007 | -0.214 |
| ROU | 3.157 | 0.571 | 0.113 | -0.480 | 1.018 | 0.018 | -0.361 |
| SKV | 1.858 | -1.058 | -0.078 | 0.195 | 0.080 | -0.001 | -0.142 |
| SVN | 3.079 | 0.310 | -0.003 | 0.075 | 0.354 | 0.004 | -0.300 |

Table A 6: P-Values of $M_{eh0}$ parameters for the OLS estimates of the system of convergence equations excluding the human capital variable (α5) covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| ALB | 0.176 | 0.113 | 0.639 | 0.533 | 0.122 | 0.799 | 0.263 |
| BGR | **0.010** | 0.667 | 0.543 | 0.457 | 0.274 | **0.024** | **0.005** |
| CZE | **0.000** | **0.035** | **0.046** | **0.036** | **0.002** | **0.000** | **0.000** |
| EST | **0.010** | 0.233 | 0.141 | 0.599 | **0.001** | **0.018** | **0.004** |
| HRV | 0.113 | 0.977 | 0.335 | 0.173 | **0.033** | 0.231 | 0.101 |
| HUN | 0.051 | 0.670 | 0.308 | 0.316 | 0.886 | 0.376 | **0.044** |
| LTU | **0.000** | 0.357 | 0.879 | 0.438 | **0.004** | **0.001** | **0.000** |
| LVA | **0.000** | 0.936 | 0.780 | 0.958 | 0.559 | **0.000** | **0.000** |
| POL | 0.089 | 0.247 | 0.198 | 0.116 | 0.399 | **0.044** | **0.039** |
| ROU | **0.000** | 0.342 | 0.062 | 0.146 | **0.000** | **0.001** | **0.000** |
| SKV | 0.095 | **0.005** | 0.440 | 0.639 | 0.780 | 0.804 | 0.158 |
| SVN | **0.025** | 0.661 | 0.973 | 0.817 | 0.123 | 0.267 | **0.015** |

Table A 7: $M_{eh1}$ Zellner estimates of parameters of the system of convergence equations excluding the human capital variable (α5) covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| ALB | 0.949 | -0.338 | -0.024 | 0.216 | 0.166 | -0.002 | -0.082 |
| BGR | 5.836 | -0.097 | -0.067 | 0.891 | 0.019 | 0.016 | -0.583 |
| CZE | 6.513 | 0.772 | 0.065 | -0.812 | 1.310 | 0.013 | -0.663 |
| EST | 4.968 | 0.084 | -0.127 | -0.674 | 0.825 | 0.020 | -0.514 |
| HRV | 3.503 | 0.060 | -0.100 | 0.325 | 0.690 | 0.008 | -0.354 |
| HUN | 3.371 | -0.366 | 0.028 | -0.429 | 0.044 | 0.005 | -0.309 |
| LTU | 5.329 | -0.410 | -0.001 | -0.084 | 0.447 | 0.020 | -0.525 |
| LVA | 6.588 | -0.067 | -0.022 | 0.118 | -0.037 | 0.026 | -0.657 |
| POL | 4.166 | -0.274 | -0.084 | -0.775 | 0.065 | 0.013 | -0.397 |
| ROU | 3.177 | 0.261 | 0.087 | -0.602 | 0.943 | 0.017 | -0.352 |
| SKV | 2.947 | -0.925 | -0.120 | 0.322 | 0.236 | 0.002 | -0.253 |
| SVN | 4.672 | -0.238 | 0.029 | -0.112 | 0.212 | 0.008 | -0.437 |

Table A 8: P-Values of $M_{eh1}$ parameters for the Zellner estimates of the system of convergence equations excluding the human capital variable (α5) covering the CEE countries from 1992 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| ALB | 0.224 | 0.066 | 0.825 | 0.663 | 0.284 | 0.643 | 0.347 |
| BGR | **0.000** | 0.888 | 0.582 | 0.166 | 0.942 | **0.000** | **0.000** |
| CZE | **0.000** | **0.000** | 0.086 | **0.000** | **0.000** | **0.000** | **0.000** |
| EST | **0.000** | 0.697 | 0.198 | 0.261 | **0.000** | **0.000** | **0.000** |
| HRV | **0.001** | 0.810 | 0.154 | 0.466 | **0.000** | **0.017** | **0.001** |
| HUN | **0.000** | 0.287 | 0.649 | 0.227 | 0.867 | **0.020** | **0.000** |
| LTU | **0.000** | **0.012** | 0.988 | 0.887 | **0.011** | **0.000** | **0.000** |
| LVA | **0.000** | 0.723 | 0.690 | 0.663 | 0.757 | **0.000** | **0.000** |
| POL | **0.000** | 0.586 | **0.024** | **0.004** | 0.761 | **0.000** | **0.000** |
| ROU | **0.000** | 0.633 | 0.125 | 0.052 | **0.000** | **0.001** | **0.000** |
| SKV | **0.000** | **0.000** | 0.071 | 0.209 | 0.153 | 0.365 | **0.000** |
| SVN | **0.000** | 0.640 | 0.637 | 0.633 | 0.196 | **0.002** | **0.000** |

Table A 9: $M_0$ OLS estimates of parameters of the system of convergence equations covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| AR | -0.802 | 0.010 | 0.103 | -0.005 | 1.636 | 1.219 | -0.018 | -0.178 |
| BO | 1.436 | -0.305 | -0.003 | 0.217 | 0.568 | -0.102 | 0.007 | -0.164 |
| BR | 1.567 | 0.423 | 0.114 | -0.227 | 0.467 | -0.055 | 0.005 | -0.183 |
| CL | 2.636 | -0.313 | 0.188 | -0.374 | -0.033 | -0.474 | 0.013 | -0.175 |
| CO | -0.325 | -0.068 | 0.128 | -0.345 | 0.204 | 0.234 | -0.004 | -0.003 |
| EC | 0.244 | -0.579 | 0.149 | 0.000 | -0.330 | -0.124 | 0.002 | 0.016 |
| PE | 1.091 | -0.319 | 0.233 | -0.613 | 0.246 | -0.151 | 0.004 | -0.093 |
| PY | 2.975 | 0.178 | 0.006 | 0.092 | 0.275 | 0.254 | 0.005 | -0.392 |
| UY | 1.265 | -0.109 | 0.174 | -0.249 | 0.087 | -0.238 | 0.005 | -0.087 |
| VE | 1.187 | -1.563 | -0.220 | 0.015 | -0.063 | -0.774 | 0.015 | 0.013 |

Table A 10: P-Values of $M_0$ parameters for the OLS estimates of the system of convergence equations covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| AR | 0.130 | 0.962 | **0.044** | 0.969 | **0.000** | **0.000** | **0.000** | **0.002** |
| BO | **0.018** | 0.060 | 0.981 | 0.428 | **0.015** | 0.560 | 0.205 | **0.003** |
| BR | **0.003** | **0.001** | **0.008** | 0.292 | **0.044** | 0.142 | **0.016** | **0.002** |
| CL | **0.008** | 0.059 | **0.000** | **0.004** | 0.887 | 0.060 | **0.035** | **0.008** |
| CO | 0.486 | 0.806 | **0.000** | 0.067 | 0.151 | 0.063 | 0.080 | 0.935 |
| EC | 0.680 | **0.002** | **0.008** | 1.000 | 0.189 | 0.550 | 0.698 | 0.680 |
| PE | 0.063 | **0.041** | **0.000** | **0.007** | 0.263 | 0.233 | 0.232 | 0.063 |
| PY | **0.000** | 0.505 | 0.898 | 0.688 | **0.029** | 0.154 | 0.088 | **0.000** |
| UY | **0.022** | 0.531 | **0.000** | **0.039** | 0.440 | 0.087 | **0.045** | 0.057 |
| VE | **0.002** | **0.000** | **0.000** | 0.429 | 0.732 | **0.000** | **0.001** | 0.526 |

Table A 11: $M_1$ Zellner estimates of parameters of the system of convergence equations covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| AR | -1.139 | -0.156 | 0.116 | 0.110 | 1.182 | 1.133 | -0.018 | -0.114 |
| BO | 1.732 | -0.383 | -0.060 | 0.260 | 0.700 | -0.126 | 0.008 | -0.198 |
| BR | 1.487 | 0.310 | 0.048 | -0.115 | 0.321 | -0.055 | 0.005 | -0.169 |
| CL | 3.067 | -0.335 | 0.129 | -0.329 | -0.076 | -0.536 | 0.014 | -0.207 |
| CO | 0.154 | 0.195 | 0.077 | -0.359 | 0.217 | 0.088 | -0.001 | -0.033 |
| EC | 0.819 | -0.459 | 0.110 | 0.175 | -0.246 | -0.246 | 0.005 | -0.030 |
| PE | 1.063 | -0.228 | 0.175 | -0.468 | 0.259 | -0.093 | 0.003 | -0.100 |
| PY | 2.805 | 0.166 | -0.013 | 0.158 | 0.258 | 0.216 | 0.005 | -0.366 |
| UY | 0.717 | -0.253 | 0.174 | -0.256 | 0.004 | -0.045 | 0.001 | -0.061 |
| VE | 1.372 | -1.609 | -0.190 | 0.003 | -0.025 | -0.779 | 0.015 | -0.004 |

Table A 12: P-Values of $M_1$ parameters for the Zellner estimates of the system of convergence equations covering the LA countries from 1953 to 2019

| Country | α0 | α1 | α2 | α3 | α4 | α5 | α6 | β |
|---|---|---|---|---|---|---|---|---|
| AR | **0.016** | 0.380 | **0.003** | 0.251 | **0.000** | **0.000** | **0.000** | **0.015** |
| BO | **0.001** | **0.008** | 0.512 | 0.268 | **0.000** | 0.442 | 0.101 | **0.000** |
| BR | **0.001** | **0.006** | 0.145 | 0.490 | 0.081 | 0.094 | **0.007** | **0.001** |
| CL | **0.001** | **0.034** | **0.004** | **0.006** | 0.727 | **0.024** | **0.010** | **0.001** |
| CO | 0.722 | 0.436 | **0.015** | **0.030** | 0.082 | 0.449 | 0.502 | 0.314 |
| EC | 0.135 | **0.005** | **0.025** | 0.451 | 0.271 | 0.198 | 0.257 | 0.412 |
| PE | 0.053 | 0.129 | **0.002** | **0.027** | 0.207 | 0.432 | 0.380 | **0.033** |
| PY | **0.000** | 0.524 | 0.761 | 0.468 | **0.035** | 0.206 | 0.072 | **0.000** |
| UY | 0.148 | 0.117 | **0.000** | **0.015** | 0.969 | 0.720 | 0.500 | 0.151 |
| VE | **0.000** | **0.000** | **0.000** | 0.823 | 0.869 | **0.000** | **0.000** | 0.808 |

Table A 13: $M_{eh0}$ OLS estimates of parameters of the system of convergence equations excluding the human capital variable (α5) covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| AR | 0.622 | -0.073 | 0.101 | -0.110 | 0.483 | 0.002 | -0.075 |
| BO | 1.163 | -0.233 | 0.014 | 0.194 | 0.554 | 0.004 | -0.147 |
| BR | 1.168 | 0.373 | 0.127 | -0.199 | 0.390 | 0.003 | -0.142 |
| CL | 0.964 | -0.388 | 0.194 | -0.385 | -0.116 | 0.002 | -0.088 |
| CO | 0.406 | 0.377 | 0.122 | -0.296 | 0.289 | 0.000 | -0.050 |
| EC | -0.068 | -0.523 | 0.147 | 0.031 | -0.296 | -0.001 | 0.028 |
| PE | 0.488 | -0.250 | 0.247 | -0.647 | 0.158 | 0.000 | -0.048 |
| PY | 2.533 | 0.311 | 0.002 | 0.165 | 0.168 | 0.007 | -0.301 |
| UY | 0.666 | -0.176 | 0.195 | -0.228 | 0.022 | 0.001 | -0.065 |
| VE | -0.136 | -0.833 | -0.300 | 0.025 | -0.348 | -0.004 | 0.057 |

Table A 14: P-Values of $M_{eh0}$ parameters for the OLS estimates of the system of convergence equations excluding the human capital variable (α5) covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| AR | 0.215 | 0.763 | 0.085 | 0.441 | 0.238 | 0.158 | 0.222 |
| BO | **0.003** | **0.027** | 0.892 | 0.475 | **0.017** | **0.000** | **0.002** |
| BR | **0.010** | **0.004** | **0.003** | 0.363 | 0.088 | 0.054 | **0.008** |
| CL | **0.035** | **0.019** | **0.000** | **0.004** | 0.618 | 0.136 | 0.063 |
| CO | 0.115 | **0.009** | **0.001** | 0.122 | **0.036** | 0.708 | 0.052 |
| EC | 0.807 | **0.001** | **0.009** | 0.905 | 0.228 | 0.053 | 0.417 |
| PE | 0.103 | 0.088 | **0.000** | **0.004** | 0.449 | 0.898 | 0.145 |
| PY | **0.000** | 0.221 | 0.965 | 0.468 | 0.102 | **0.001** | **0.000** |
| UY | 0.128 | 0.307 | **0.000** | 0.062 | 0.842 | 0.121 | 0.149 |
| VE | 0.601 | **0.001** | **0.000** | 0.241 | 0.072 | **0.006** | **0.006** |

Table A 15: $M_{eh1}$ Zellner estimates of parameters of the system of convergence equations excluding the human capital variable (α5) covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| AR | 0.563 | 0.066 | 0.124 | 0.053 | 0.213 | 0.002 | -0.065 |
| BO | 1.216 | -0.243 | -0.072 | 0.321 | 0.720 | 0.004 | -0.156 |
| BR | 0.809 | 0.220 | 0.062 | -0.131 | 0.242 | 0.002 | -0.095 |
| CL | 1.033 | -0.399 | 0.139 | -0.366 | -0.197 | 0.002 | -0.094 |
| CO | 0.436 | 0.334 | 0.077 | -0.301 | 0.298 | 0.000 | -0.053 |
| EC | 0.184 | -0.324 | 0.101 | 0.164 | -0.113 | -0.001 | -0.007 |
| PE | 0.564 | -0.206 | 0.169 | -0.439 | 0.223 | 0.000 | -0.058 |
| PY | 2.685 | 0.200 | -0.002 | 0.205 | 0.183 | 0.008 | -0.317 |
| UY | 0.610 | -0.241 | 0.170 | -0.231 | -0.018 | 0.001 | -0.057 |
| VE | -0.170 | -0.834 | -0.268 | 0.014 | -0.199 | -0.003 | 0.053 |

Table A 16: P-Values of $M_{eh1}$ parameters for the Zellner estimates of the system of convergence equations excluding the human capital variable (α5) covering the LA countries from 1953 to 2019.

| Country | α0 | α1 | α2 | α3 | α4 | α6 | β |
|---|---|---|---|---|---|---|---|
| AR | 0.172 | 0.731 | **0.005** | 0.620 | 0.516 | 0.204 | 0.198 |
| BO | **0.001** | **0.013** | 0.423 | 0.180 | **0.000** | **0.000** | **0.000** |
| BR | **0.034** | **0.044** | 0.071 | 0.453 | 0.198 | 0.147 | **0.035** |
| CL | **0.018** | **0.012** | **0.002** | **0.003** | 0.370 | 0.057 | **0.038** |
| CO | 0.067 | **0.009** | **0.013** | 0.058 | **0.010** | 0.452 | **0.027** |
| EC | 0.458 | **0.020** | **0.034** | 0.460 | 0.598 | 0.229 | 0.806 |
| PE | **0.044** | 0.135 | **0.002** | **0.034** | 0.245 | 0.855 | 0.060 |
| PY | **0.000** | 0.408 | 0.952 | 0.328 | 0.063 | **0.000** | **0.000** |
| UY | 0.110 | 0.114 | **0.000** | **0.021** | 0.843 | 0.118 | 0.145 |
| VE | 0.430 | **0.000** | **0.000** | 0.410 | 0.214 | **0.010** | **0.002** |

# ABSTRACT

This PhD thesis evaluates the economic convergence hypothesis utilizing the Seemingly Unrelated Regression Equations framework (SURE) based on Central and Eastern European (CEE) and Latin American (LA) countries. The income convergence is defined as a catching up process between poorer and richer countries. The convergence magnitudes found through the literature review were subject to huge variability of the convergence parameters. Also, the leading methodology among other researchers for convergence testing involved the classical linear regression model. Those findings led to formulating the main hypothesis of this thesis saying that the convergence is a country specific phenomenon. The methodology for verifying this hypothesis involved the SURE model, which on the other hand can be treated as an extension of the General Linear Regression Model (GLRM). Although the convergence was present nearly among the whole sample, the findings showed substantial differences among the convergence parameters for both, the selected country groups, and the individual countries among a group, confirming the main hypothesis. The thesis shades therefore new light on the calculation of the income convergence with the SURE methodology. It also may shift the most frequently asked research question about the overall existence of convergence towards one related to some individual convergence magnitudes on country basis.

## Streszczenie rozprawy doktorskiej w j. polskim
## (Summary of the doctoral thesis in polish language)

Tytuł pracy: Badanie konwergencji gospodarczej: Zastosowanie modelu SURE na przykładzie państw ameryki łacińskiej oraz europy środkowo-wschodniej

Głównym celem rozprawy doktorskiej było zbadanie zmienności konwergencji dochodowej korzystając z niestandardowego narzędzia do tego typu badań jakim był model SURE (Seemingly Unrelated Regression Systems, pl.: System Regresji Równań Pozornie Niepowiązanych). Praca miała charakter teoreytczno-empiryczny i była podzielona na cztery części. Część pierwsza opisała teorię wzrostu gospodarczego i założenia, które prowadzą do hipotezy konwergencji dochodowej. Część druga miała charakter metodologiczny i zaprezentowała model SURE jako roszerzoną wersję modelu GLRM (General Linear Regression Model, pl.: Uogólniony Model Regresji Liniowej). Część trzecia skupiała się na analizie empirycznej i opisie wyników oraz wniosków grupy krajów Europy Wschodniej i Centralej (CEE). Część czwarta analogicznie do cześci trzeciej opisała wyniki i wnioski, jednak dla krajów Ameryki Łacińskiej (LA). Po wnikliwej analizie piśmiennictwa zdefinionwano konwegergencję gospodarczą jako proces, w którym kraje biedniejsze doganiają kraje bogatsze. Hipoteza ta jest spodowodowana założeniem neoklasycznej szkoły ekonomii dotyczącym malejących przychodów z kapitału. W kontrze do tejże szkoły są teorie, które zakładają stałe lub nawet rosnące przychody z kapitału uwarunkowane przykładowo kapitałem ludzkim. Liczne badania empiryczne opisane w pierwszym rozdziale starały się potwierdzić hipotezę konwergencji lub ją odrzucić, aby zweryfikować słuszność danej szkoły. Głównym narzędzie stosowanym do analiz konwergencji był model regresji liniowej. Wyniki tychże opracowań były bardzo różnorodne. Wnioski te prowadziły do sformuowania głównej hipotezy badawczej, wg. której konwergencja dochodowa jest fenomenem specyficznym dla danego kraju i jej wielkość może się znacząco różnić. Model SURE okazał się dobrym narzędziem, a wyniki potwierdziły zmienność konwergencji dla analizowanych krajów CEE oraz LA. Niniejsza praca rzuca nowe światło na analizę konwergencji pod względem metodologicznym. Może też przyczynić się do zmiany pytań badawczych z punktu czy konwergencja istnieje, w kierunku iż jest ona zmienna i różna dla poszczególnych krajów.