CONVERGENCE IN ECONOMIC GROWTH AND ITS DETERMINANTS: AN EMPIRICAL ANALYSIS

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To My Dearest Mother; Shahla Bohloul Kheibari,

My Dearest Brother; Behrooz Sabaghpour fard and

My Dearest Husband; Hamed Merati.

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Abstract

For decades economic growth and its determinants have been the centre of attention among both theoretical and development economists. Theoretical economists have built models of economic growth while development economists are concerned as to how low-income countries can catch up with the rich ones, or, worse, become caught in a low-income trap. The persistence of poverty in some countries in the world and the failure to catch up has caused social scientists to not only review and debate the sources of economic growth but also to take the debate of convergence more seriously and try to provide different explanations.

Neoclassical growth (NCGM) and new growth (NGM) theories, currently the main contending schools of thought, try to explain growth sources, and, by extension, convergence by focusing on capital accumulation and technological change, respectively. However, empirical studies using either model largely ignore the importance of institutions, on which there is increasing focus and discussion of economic performance, and globalization, which affects the economic welfare of countries. Therefore, in this research we try to reopen the debate of convergence incorporating these factors in re-estimating the above models. We do this by examining convergence for three groups of countries, which are classified by income according to the World Bank classification method, and by applying the GMM method to estimate the growth models.

The results of this research show that the income level of countries is material when it comes to both the sources of growth and the speed of convergence. The debate over which model (NCGM or NGM) is appropriate is not that meaningful. Each model is appropriate for countries at particular levels of income, but not for the entire income range. The NCGM, which is believed to be obsolete by many economists, especially those who espouse the NGM, continues to be relevant for many countries of the world.

Testing the convergence hypothesis in terms of GDP per capita shows that middle-income countries converge with high-income ones in both models. However, this only occurs very slowly in low-income countries. Therefore, we can conclude that income convergence is not monotonic and that an income threshold may need to be reached before convergence occurs. This shows the existence of a poverty trap.

Investigating the role of institutions and globalization and innovation factors shows that these factors are the most important drivers of growth for middle-income and high-income countries but not for low-income countries. However, the effects of these variables were greatest across middle-income countries compared to high-income countries, which makes sense for the convergence hypothesis in both classes.

Capital accumulation and secondary schooling are the most important drivers for low-income countries. This result again alerts us to the existence of an income threshold. Being more globalized and having stronger institutions does not work for these groups of countries unless they reach a certain level of income. This is consistent with the results of other researchers who find that 'the tide of globalization does not lift all boats'.

Abstrak

Selama berdekad, pertumbuhan ekonomi dan penentunya menjadi tumpuan di antara ahli teori ekonomi dan ahli ekonomi pembangunan. Ahli teori ekonomi telah membina model pertumbuhan ekonomi manakala ahli ekonomi pembangunan pula prihatin tentang mengapa negara-negara yang berpendapatan rendah boleh mengejar golongan yang kaya atau lebih teruk lagi terperangkap dalam perangkap penduduk berpendapatan rendah. Kegigihan daripada belenggu kemiskinan di beberapa negara di dunia dan kegagalan untuk bersaing telah menyebabkan saintis sosial bukan sahaja untuk mengkaji dan membahaskan sumber pertumbuhan ekonomi bahkan turut memberi tumpuan yang lebih serius mengenai perdebatan tentang perubahan itu dan cuba untuk memberikan penjelasan yang berbeza.

Pertumbuhan neoklasik (NCGM) dan pertumbuhan teori baru (NGM), aliran pemikiran yang utama pada masa kini adalah, berusaha untuk menjelaskan sumber pertumbuhan dan mengikut perubahan lanjutan dengan masing-masing memberi tumpuan kepada pengumpulan modal dan perubahan teknologi. Walau bagaimanapun, kajian empirikal yang menggunakan kedua-dua model sebahagian besarnya mengabaikan kepentingan institusi, di mana terdapat tumpuan yang semakin meningkat dalam perbincangan prestasi ekonomi, dan globalisasi, yang menjejaskan kebajikan ekonomi negara. Oleh itu, di dalam kajian ini kami berusaha untuk membuka semula perdebatan tentang perubahan itu dengan menggabungkan faktor-faktor ini dan menganggarkan semula model-model di atas. Kami berbuat demikian dengan memeriksa perubahan untuk tiga kumpulan negara-negara yang diklasifikasikan oleh pendapatan mengikut kaedah klasifikasi Bank Dunia, menggunakan kaedah GMM untuk menganggarkan pertumbuhan model.

Keputusan kajian ini menunjukkan bahawa tahap pendapatan negara adalah penting apabila ia datang kepada kedua-duanya iaitu sumber pertumbuhan dan kelajuan perubahan tersebut. Perdebatan ke atas model mana (NCGM atau NGM) yang lebih sesuai adalah tidak begitu bermakna. Setiap model adalah bersesuaian bagi setiap negara pada peringkat pendapatan tertentu, tetapi bukan untuk keseluruhan julat pendapatan. NCGM, yang dipercayai oleh kebanyakan ahli ekonomi, terutama mereka yang menyokong NGM, menjadi usang, terus menjadi relevan untuk kebanyakan negara di dunia.

Ujian hipotesis perubahan dari segi KDNK per kapita menunjukkan negara-negara berpendapatan sederhana akan berubah menjadi orang yang berpendapatan tinggi dalam kedua-dua model. Walau bagaimanapun, perkara ini berlaku amat perlahan di negara-negara yang berpendapatan rendah. Oleh itu, kita boleh menyimpulkan bahawa perubahan pendapatan adalah tidak ekanada dan ambang pendapatan mungkin perlu dicapai sebelum perubahan berlaku. Ia menunjukkan kewujudan perangkap kemiskinan.

Penyiasatan tentang peranan institusi dan globalisasi dan faktor inovasi menunjukkan bahawa faktor-faktor ini adalah yang paling penting untuk memacu pertumbuhan negara berpendapatan sederhana dan berpendapatan tinggi dan bukannya negara-negara berpendapatan rendah. Walau bagaimanapun, kesan daripada pembolehubah ini adalah yang terbesar di seluruh negara-negara berpendapatan sederhana berbanding dengan negara-negara berpendapatan tinggi bagi hipotesis perubahan yang masuk akal dalam kedua-dua kelas ini.

Pengumpulan modal dan persekolahan menengah adalah perkara yang paling penting bagi negara-negara berpendapatan rendah. Keputusan ini sekali lagi mengingatkan kita kepada kewujudan ambang pendapatan. Menjadi lebih global dan mempunyai institusi yang kuat juga tidak akan berhasil untuk kumpulan negara-negara sebegini melainkan jika mereka mencapai paras pendapatan tertentu. Ini adalah konsisten dengan hasil penyelidikan lain yang mendapati bahawa 'arus globalisasi tidak boleh mengangkat semua bot'.

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Introduction

1.1 Introduction and Background

The question of whether poorer countries are converging to the richer ones is an important issue in development economics, in general, and growth literature, in particular (P Aghion & Howitt, 1998; P. Aghion & P. Howitt, 2006; R. J. Barro, 1991; Phelps, 1966; Raiser, Di Tommaso, & Weeks, 2001; J.D. Sachs, 2003). Convergence is important for developing countries because of the already wide gap between rich and poor countries and because for some of the latter, this gap is increasing. This process is also occurring in most of the development that has global significance. Such development includes increasing the globalization of goods, services, finance, people and ideas, as well as accelerating technological change. For a better understanding about the debate of convergence it is helpful to have an initial definition of this term from the growth literature.

1.1.1 What Does Convergence Mean?

"Poorer countries can grow at a faster rate than rich countries in terms of GDP per capita and reach to the same steady state" provides a general definition for the term unconditional convergence from the neoclassical growth theory. In this theory, developing countries should grow faster because of the diminishing return to scale, especially for capital. However, later on, during the twentieth century, following the second industrial revolution, 1860-1865, technological revolution economists started thinking about catching up in terms of technology and not GDP per capita, and, therefore, the concepts of frontiers or distance and proximity to frontiers became important in the new growth theories.

1.1.2 History of Convergence and the Convergence Debate

Around 300 hundred years ago, about 1750, the industrial revolution happened in England and income started to increase. The pattern spread among European countries, the US, Canada, Australia and New Zealand, and for two hundred years economic growth was sustained and increased in these areas. The source of this growth was technology, science, communication, institutions and governance. This increase in income affected the lives of around 15 per cent of the people in the world (Spence, 2011). Outside this circle, the other countries remained poor, and, therefore, great divergence happened. However, after World War II, 1945, this growth also started in developing countries. Of course, at first, it was not massive and it only happened in some isolated countries, however, after a while, it spread to other countries. Furthermore, the growth rate became even greater, 7 per cent, compared to industrial countries that were around 2 per cent during those 200 years. It seems that after two-hundred years of what has come to be called “the great divergence”(Pomeranz, 2001), convergence has taken over. What caused this shift to occur? Which factors accelerated the growth rate in these groups of countries? The interesting part is that, notwithstanding the shift, some countries are still trapped at the low-income level, and cannot even catch up with the middle-income countries.

According to the new growth theories developed by P. Aghion and P. Howitt (2006), and C. Jones (1998), technology plays an important role in explaining the growth rate of advanced countries and a large proportion of their growth is explained by technological change. Furthermore, these classes of theoretical models, which were inspired by Schumpeter, argue that being farther away from technology leaders or advanced countries could be a benefit for the developing and undeveloped countries to take advantage of this backwardness and grow faster. However, as can be seen in the reality, this idea of technology catching up is not working for some low-income countries. They are far away from the technology leaders and even though they have such an advantage to grow faster they are still in the trap of a low level of income.

1.2 Problem Statement

The persistence of poverty in several countries in the world, and, therefore, the failure of technological catching up and convergence hypothesis, has led to social scientists taking the debate of convergence more seriously and encouraged them to provide different explanations for this behaviour. While some economists, like Bloom, Sachs, Collier, and Udry (1998), explain the failure using geographical reasons, others, like R. Nelson (2007) and D. Dollar and Kraay (2004) use the role of institutions and globalization, respectively. These explanations can be grouped under different theories of economic growth.

The neoclassical and new growth theories try to explain these differences by focusing on capital accumulation and technological change, respectively. However, empirical studies in this area, technological catching up and convergence hypothesis, largely ignore the importance of institutions and globalization. Therefore, in this research we try to reopen the debate of convergence according to these shortcomings in empirical studies, and, by applying a new method of estimation, generalized method of moments (GMM), re-estimate the models across three different groups of countries that are classified by their level of income according to the world classification method.

1.2.1 The Importance of Convergence in Economic Development

The growth rate of countries is one of the most important concerns of economists in recent decades, because it is not only about the welfare and level of standard of living of people, but it is also about having better political and social positions across different countries (Milanovic & Squire, 2005). Taking a look at the United States of America (US) could be a good example. Since 1870, the US GDP per capita increased almost tenfold until 1990. In contrast, the GDP per capita of Africa for the same period only increased threefold. This rapid growth made the US a superpower among countries. Recently we can see this kind of rapid growth rate for China and some other countries and the political movement among them. Indeed, the growth of latecomers like Korea and Taiwan has excited development economists eager to identify development "models". Indeed, the rise of China, India and other members of the BRICs (Brazil and Russia) are shifting the economic balance of power from the so-called G7. Therefore, understanding the driving forces of growth is always interesting for economists. At the same time, these gaps among developed, undeveloped and developing countries have attracted the attention of economists. Studies have attempted to determine why some countries are rich while others are poor, and which factors can accelerate the growth rate of countries to converge to the development level. Such questions raise the concept of convergence.

Actually, the debate on convergence came into sharp focus when P.M. Romer (1986) questioned the neoclassical growth models (NCGM) introduced by Solow (1956). Solow's models raised the convergence concept. He believed that since there is a diminishing return to capital and labour, an economy is converging to a unique steady state, whether it is higher or lower than the equilibrium capital level. Of course, initially it was all about convergence within a country and later it was extended to across countries. Since this NCGM could not explain the long-run growth path and at the same time come to a bigger sample, because of different structures, convergence is not happening or in other words countries are heterogeneous in some aspects and so their steady state determinants are different. P. Romer (1991) claimed that this class of model is not accurate and he introduced the new growth theory (NGM): endogenous growth model. In this new model, P.M. Romer (1986) questioned two main assumptions of the NCGM: first, diminishing returns to capital and labour, and, second, exogeneity of technology. By avoiding these two assumptions he could explain the endogenous long-run growth of economies. In this model, technology is endogenous, countries can grow in the long-run, and, therefore, there is no convergence across countries.

However, empirical evidence in the world shows that convergence is happening and those developing countries are accelerating their growth rate and catching up with the richer ones. Therefore, Romer’s model also seems to be inadequate. This point is helpful to understand the interactions across countries among other dimensions like human capital, institutions and so on. At the same time, Solow’s assumption that countries with similar economic structures should converge to the same steady state has also not been borne out in the real world. This was the beginning of the convergence debate, which created different concepts, methodologies and factors.

One area of development is to refine the specification of models through the inclusion of new variables in growth models to control the steady state growth path of different countries. Thus, N. G. Mankiw, D. Romer, and D. N. Weil (1992) introduced the augmented Solow model to the literature, and, by adding human capital to the growth model, claimed that 80% of cross country income differences can be explained by this model. Meanwhile, economists like Redek and Sušjan (2005), F. Caselli, G.

Esquivel, and F. Lefort (1996); Easterly and Levine (1997); Nandakumar, Batavia, and Wague (2004) , and Pomeranz (2001) argue that capital per capita (physical and human) can only account for a proportion of differences in output per worker, and, instead, changes in total factor productivity or technological changes can explain the huge difference. Therefore, total factor productivity (TFP) became the engine behind long-run growth across countries.

In addition, the endogenous growth model makes it possible to explain these differences by endogenizing technology, stock of knowledge, through different channels. Economists have conducted much research in this area concerning through which channels technology can affect TFP, and, finally, growth. Human capital is one of the important channels through which technology can affect growth. Economists like Lucas (1988), pioneered applying human capital in a different way than just investment in education, like the effect of learning by doing through human capital on growth. By introducing these spillover effects, other economists tried to contribute to the growth literature by incorporating other factors that can effect growth through human capital, such as R&D, technology transfers or imitation, trade and innovation (Eberhardt & Teal, 2010; J. Ha & P. Howitt, 2007; Harris, 2011; Madsen, 2008).

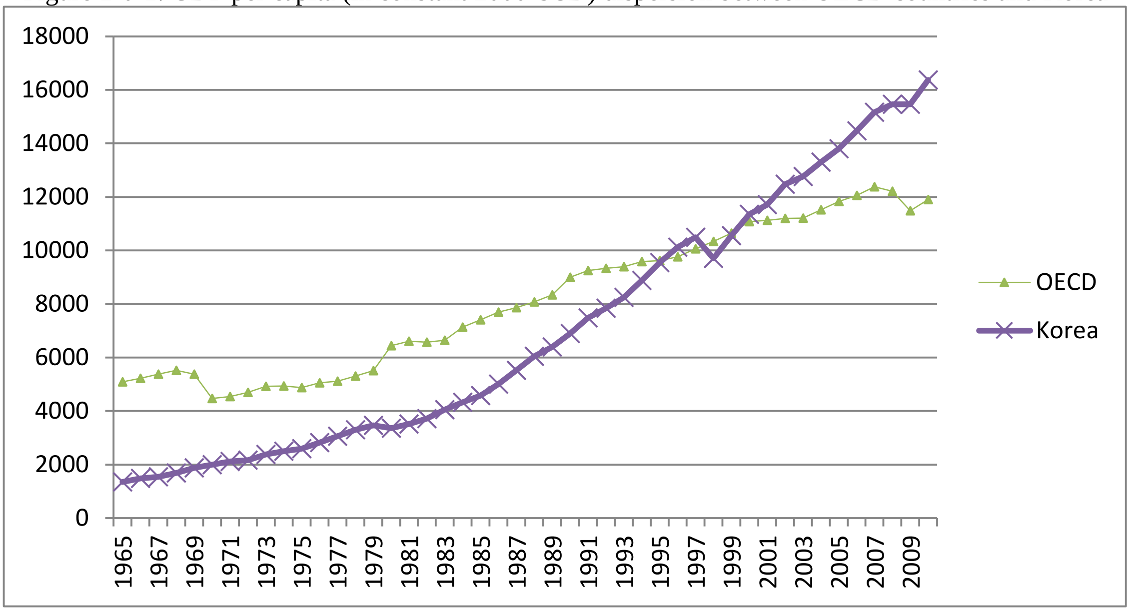
As can be seen, studies about conditional convergence produced different important issues that can be important for growth literature. First, by studying conditional convergence, new stylized facts about growth across several countries can be produced. Second, undertaking research about convergence highlights the significance of changing technology across countries, and, therefore, develops new methodologies and also factors for quantification of these differences. The results of such quantification are very important since they create different technology based models, and, like the current study, can also be a motivation to contribute to the literature by applying them in different theories like the neoclassical model. Furthermore, choosing convergence as the criterion to give validity to growth models makes this debate more important. Researchers have argued that by testing the convergence hypothesis the validity of the model can be approved. This argument has introduced many different methods, models, and concepts, to the growth literature.

1.2.2 Cases of Successful Convergence and the Debate on Causes

To make the concept of convergence clear, first we take a look at some successful countries in this process and explain how they have escaped from the low-income trap and catch up with the rich ones. Later we extend it across other countries and test the convergence hypotheses based on two-definitions highlighted in this study by employing two growth models.

One good example is Korea, which joined the OECD countries in 1996 (Figure 1-1). In 1965, its GDP per capita was around USD1,351 and although during 18 years this amount doubled and reached USD3,709 the distinction between OECD and Korea remained.

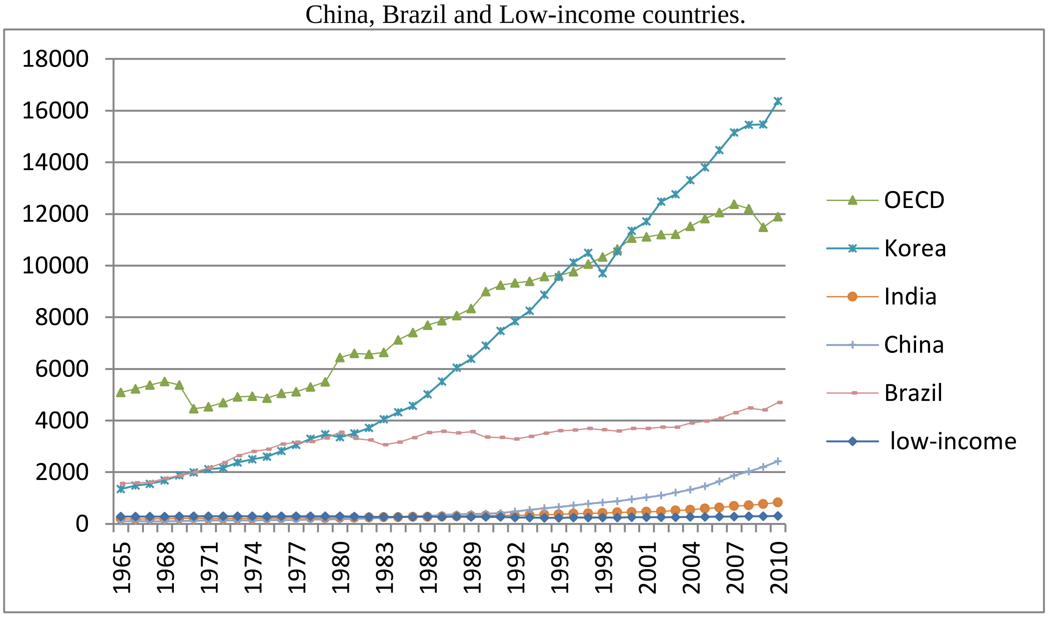
Figure 1-0-1: GDP per capita (in constant 2000 USD) dispersion between OECD countries and Korea



Note: Author's calculations

However, around 1996, its GDP per capita accelerated and rose to USD10,119 and, therefore, caught up with the OECD countries, and, finally, Korea joined this group. Other countries that can also be named as successful in the process of catching up include China and India.

Figure 1-0-2: GDP per capita (in constant 2000 USD) dispersion across OECD countries, Korea, India, China, Brazil and Low-income countries.



Note: Author's calculations

The interesting thing about China is that, around 1965, its GDP per capita was approximately USD100 lower than India, which was around USD192 (Figure 1-2). However, by late 1980, when some countries agreed to have more liberalized economies in order to became more prosperous, as figure 1-2 shows, China accelerated its growth rate and it rose to USD2,425 in 2010 even with the Asian crisis in 1997-98. However, India could not catch up with the developed countries as fast as China or Korea.

We can extend this question to other countries in the middle-income and low-income groups as well. Why do these countries not accelerate their growth rate to catch up and converge with the developed one? Why does poverty persist in some low-income countries? For instance, in the case of Africa, during the period 1965-1990, on average, the growth rate of GDP per capita was 0.2 per cent while, in East Asia and the Pacific the growth rate of GDP per capita was around five per cent (Easterly & Levine, 1997). This poverty persists in African countries in the sense that the levels of income in the 1990s were the same as in 1970. This empirical evidence of persistence of poverty in poor countries, on the one hand, and the catching up of some countries with the developed ones, on the other hand, attracted the attention of economists to investigate the factors and policies that can affect growth in these countries. This evidence raises many questions about convergence. Were those countries that were more successful endowed with better conditions in the beginning? Were there factors special to these countries that could grow fast? Was it luck? Was it history? Were there factors that were favourable to growth? Of course, we can say that a part of this debate is ideological, whether it is the market or the state? However, since this is not the concern of this study we open this part for further research.

1.2.3 Analysis of Convergence through Growth Models

Convergence has been analysed from both a qualitative and quantitative perspective. Qualitative discussions are framed in terms of poverty and overcoming barriers to its reduction. Quantitative analysis has been largely based on growth models. Yet, from the perspective of growth models, convergence is an important but not the primary objective of investigation, which is to explain why and how economic growth occurs. Researchers use growth models to examine the convergence hypothesis, classifying them by type as a basis for comparison, such as unconditional convergence vs. conditional convergence, income convergence vs. total factor productivity (TFP) convergence, and global convergence vs. club convergence, etc. Therefore, estimating convergence equations and the factors that contribute to convergence has become increasingly popular and convergence or the ability to catch up economically became the criterion to assess which class of growth models is valid. One of the purposes of this research is to test whether these different growth model types are mutually exclusive, and, hence, whether the existing judgment of their validity, convergence hypothesis, is appropriate. To do so, different growth models and the determinants of growth should be explained.

Growth models have developed over time. The neoclassical exogenous growth model (NCGM), which was introduced by Solow (1956) and Swan (1956), was pioneered in testing the convergence hypothesis. However, subsequently, because of the shortcomings of this model according to empirical evidence, P.M. Romer (1986) talked about the endogenous growth model (NGM), which consists of a newer version of the NCGM as well as the evolutionary growth model of Schumpeter and others. The NGM was expanded by C. Jones (1998) in the R&D based model, and P Aghion and Howitt (1998) who talked about the importance of R&D intensity instead of inputs and distance to frontiers. However, at the same time, the Schumpeterian framework ran parallel to the neoclassical models.

In each of these classes, the channel that brings growth is different. The NGM studies focused more on catch up technologically, by working more on factors that can increase total factor productivity as a source of growth rather than factor accumulation, which is important in NCGM. This is because researchers recognize the limits of factor accumulation in the efforts of countries to achieve catch-up growth. At the same time, economists like Redek and Sušjan (2005) supported that most of the differences in growth rates across countries could be explained by total factor productivity. In these models, innovation and R&D play a crucial role on productivity growth (J. Ha & P. Howitt, 2007; Kortum, 1998; Madsen, 2008; Segerstrom, 1998).

In addition, economists like N. G. Mankiw et al. (1992), in their augmented Solow model, explained the cross country income variations by physical and human capital accumulation, and not technology change, which was supported by Pääkkönen (2010) .

How and through which channels technology and factor accumulation can affect growth in the new growth model and neoclassical model, respectively, are two important questions in growth literature.

One of the variables that play a crucial role in both NCGM and NGM literature is human capital. However, the way that these two theories look at this factor is different. In the neoclassical growth models, human capital is entered into the production function as another advantage of capital, which can affect growth, while in the new growth theories it is a source of technological change and technology transfer, which can effect growth through different channels, such as innovation, imitation, R&D activities and international trade.

In this research, since in the new growth literature, the existing literature emphasizes innovation and imitation as sources of growth, we try to look at the neoclassical growth model by reopening the debate of the accumulation of human capital through these channels.

In addition, we argue that even with a proper definition for the human capital variable, existing explanations in NGM ignore several important factors. We postulate that globalization and institutions are accelerators of innovation and imitation rate that need to be included into the new growth model. Without having proper institutions in a country, people do not feel secure to innovate. In addition, we should not ignore the role of globalization as a factor that helps to transfer technology to countries far from technology leaders. Because trade is not only the flow of goods but also the flow of ideas, it can be very important for improving the imitation rate in developing and undeveloped countries. Similarly, the NCGM omit important variables. We contribute to the literature by deriving the neoclassical regression equation by incorporating new aspects of growth, imitation and innovation through human capital into the neoclassic growth model.

This research explores the convergence hypothesis by focusing on the two types of growth model mentioned above by applying a panel dataset. One is allocated to the new growth model and the other is for the neoclassical growth model (NCGM).

By pursuing the above approach, we want to answer two questions simultaneously. First, which class of growth model can explain the different growth rates across countries and for which did the convergence occur. Second, as two important factors, what are the roles of institutions and globalization, for which, according to the literature, their effect is still not clear. This research contributes to the literature by looking at these factors in both the neoclassical and new growth models, and shows the effect of these factors by considering the assumptions that are important for each of the classes.

1.3 Research Questions

The above broad review of economic growth raises several research questions that this study will try to answer:

1. Do countries with a low and middle level of income converge to the income level of high-income countries in terms of GDP per capita?
2. Is convergence the criterion to show the validity of different growth models?
3. Which class of model is accurate to explain the different growth rates across low-income, middle-income and high-income countries? Neoclassical or endogenous models? Factor accumulation (neoclassical view) or technology change (endogenous view)?
4. Does globalization speed up the process of convergence in poor countries?
5. Do institutional factors affect the growth rate and accelerate the convergence process? (Governance indicators)

To answer the foregoing questions, the research will study the theoretical and empirical aspects of growth and convergence theories. For testing the convergence hypothesis we have to briefly discuss the theories of economic growth that form the foundation of convergence. Therefore, the thesis will study different theories of growth including the neoclassical and endogenous models.

1.4 Research Objectives

Given the questions posited above, the research objectives of this study will be:

1. To examine which class of growth model can better explain the different growth rates across these three groups of countries.

2. To measure the speed of convergence based on the factor accumulation (neoclassical model) and technology change (endogenous model) models in three groups of countries (conditional β- convergence).

3. To measure the speed of convergence in each dimension of technology based on the new growth model (φ convergence).

4. To examine the effect of globalization in the three groups of countries using two different growth models, through human capital accumulation and technology spillovers.

5. To test the effect of institutions in three groups of countries using two different growth models, through human capital accumulation and technology spillovers.

1.5 Structure of Thesis

The structure of the thesis is organized as follows. The next chapter will explain the theoretical background of economic growth and convergence, focussing on the models used in the study and a review of previous literature about different growth theories and different convergence concepts. The third chapter reopens the debate of technology spillovers from the innovation and imitation perspectives and builds the models that are going to be tested in the current study. The fourth chapter reviews the empirical studies that have been conducted to test convergence based on the method that they used. Chapter five discusses the role of human capital, institutions and globalization on the growth and convergence process in greater detail by reviewing the empirical studies that have been done in these fields. The sixth chapter addresses the definitions and measurements, controlling variables, research hypothesis, sample, model specifications and the method used for testing the model. Chapter seven presents the results of convergence in each group. Finally, the conclusions, limitations and possible contributions will be presented.

Chapter 2

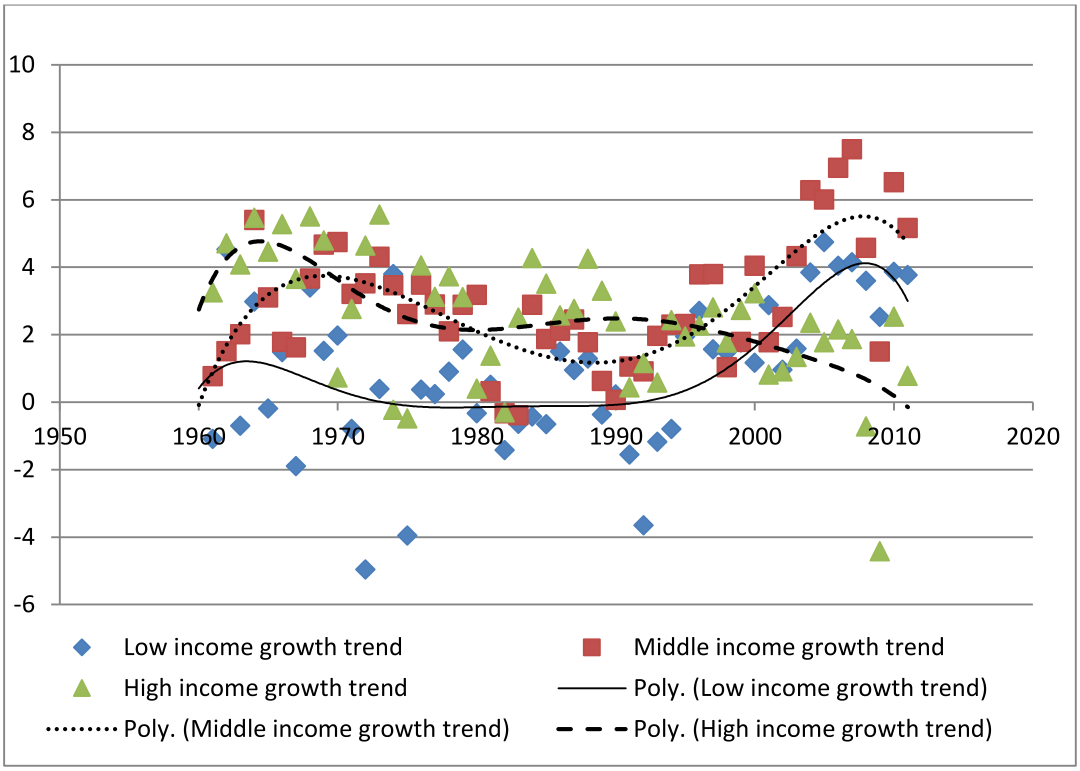
Theoretical Background of Growth Models

2.1 Introduction

A key question for many developing countries is: do developing countries tend to converge with the developed ones? Does the growth in high-income countries affect the growth in low-income countries in an affirmative way? Does growth in high-income countries eventually slow down? What are the sources affecting lung-run growth in countries? What does history have to say about convergence and growth?

As we can see in figure 2-1, the gap between high-income countries and middle and low-income countries was at its highest point in the late 1980s, which was not unexpected because of the oil shock, which happened during 1970, followed by global recession in the early 1980s. However after this period, the growth rate was boosted, especially in middle-income countries, and of course, in low-income countries, albeit at a lower rate, and this growth rate passed even from high-income countries growth rate in late 1990s. What causes these differences in growth rate across countries to occur? Is it an automatic force or does it depend on several variables like institutions, the policies implemented in each economy, their level of human capital and so on? Why could middle-income countries catch up with the rich ones while low-income countries could not?

Figure 2-1: The growth trend of low-income, middle-income and high-income economies



Note: GDP per capita growth rate, (1950-2011): The growth trend in low-, middle- and high-income economies. Author's calculation from World Bank database (2011).

To answer the foregoing questions, the next section describes the concepts of convergence in their general form. Section 3 is about the history of growth models and the implications of convergence based on these different classes of growth model. Section 4 is the summary and conclusion.

2.2 General concepts of convergence

Hume and Tucker (1974) were the economists who pioneered the debate of convergence from the mid-eighteenth century. They had two different views; Hume believed that there is a tendency across countries to converge with rich ones, while Tucker believed in the persistence of disparity among countries. After 1820, economists became more interested in these disparities because of the great divergence that happened around the world. described the main contention of the "convergence hypothesis": 'Under certain conditions, being behind gives a productivity laggard the ability to grow faster than the early leader'Krueger and Berg (2003).

Later economists divided the concept of convergence into two categories: Micro and Macro convergence. R. J. Barro (1991), Rassekh and Thompson (1993), and O'Rourke, Taylor, and Williamson (1996) defined the concept of micro convergence as "income of identical factors across countries will equalize based on the factor price equalization theory under the Heckscher-Ohlin model". The second concept is macro convergence, which focused on aggregate factors like per capita income and productivity. Of course, since these aggregate variables are the weighted average of factor price, there is a relationship between the micro and macro concepts. The macro convergence supporters argued that economies tend to converge in terms of per capita income and productivity over time. These theoretical concepts of convergence need to be operationally defined:

2.2.1 β Convergence and δ Convergence

There are two concepts of convergence – "β convergence" and "σ convergence" – which were introduced by R. J. Barro and X. Sala-i-Martin (1995). β convergence applies when the speed of convergence is faster across poor countries (R. J. Barro & X. Sala-i-Martin, 1995). Further, they subdivided the "β convergence" concept into conditional and absolute β convergence. In absolute β-convergence, it assumes that the only difference in growth rates amongst countries is reliant on their initial levels of capital. However, in conditional β-convergence some variables are added to the model to control the differences among economies and, therefore, convergence appear under some conditions.

The other concept is "δ convergence". If the differences between incomes per capita of countries decrease over time it indicates δ convergence. One way to test δ convergence is to measure the standard deviation of GDP per capita amongst countries over a specific period. If the value of standard deviation in a sample becomes smaller it means that countries decreased the gap that existed among their income per capita. Otherwise, there is no convergence.

2.2.2 Club Convergence versus Global Convergence

The other concept is club convergence versus global convergence. The pioneer who focused on this concept was Baumol (1986), who argued the concept of "club convergence". In this concept countries are divided into two groups based on their growth rate: countries that have lower and countries that have higher growth rates. Those countries that have middle ranges are going to merge with each of these groups depending on the rate of the immigrants that they have in each group. Therefore, countries in each group experience growth or stagnation (Boldrin & Canova, 2001). Quah (1996), and Ben-David and Papell (1994), in their research also supported the existence of club convergence.

2.2.3 Income Convergence versus TFP Convergence

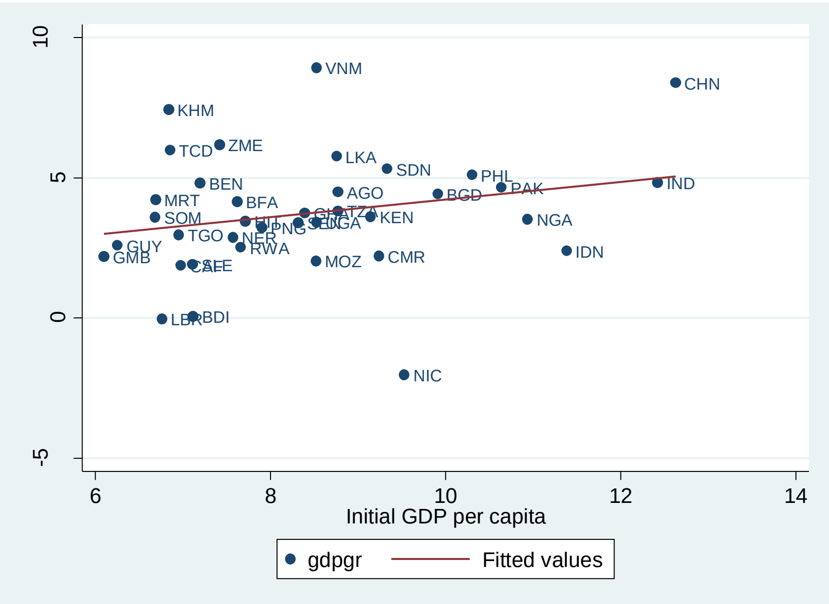
The initial studies based on the neoclassical growth models focused more on the concept of convergence in terms of income, because the important matter in those classes of models was capital deepening and nothing else. However, with the emergence of new growth theories, economies started thinking about catching up in terms of technology, and, since total factor productivity (TFP) was the closest measure for technology, the economies started studying whether or not countries are closing their gap in terms of the level of TFP.

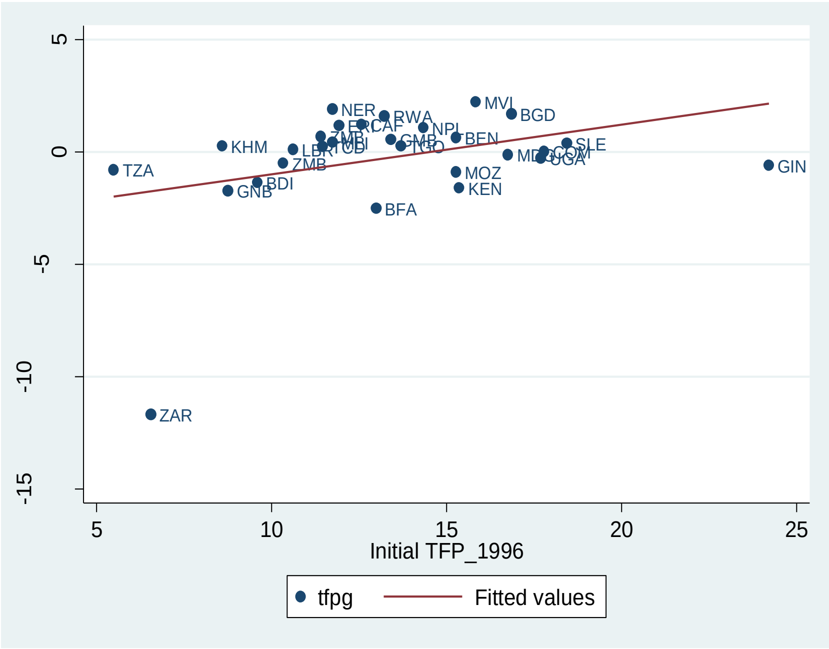
To have a better understanding of the concept of convergence, here we test the absolute or unconditional convergence in terms of GDP per capita and productivity for the sample of low-income, middle-income and high-income countries.

Figures 2-2, 2-3 and 2-4 indicate the result of absolute β convergence across low-income, middle-income and high-income countries, respectively, for the period 1996 and 2010.

Figure 2-2 shows that there is a positive relationship between the growth rate and initial level of GDP per capita and also productivity across low-income countries during the period, and, therefore, there is no convergence. However, the slope of fitted value is sharper in testing convergence in terms of productivity.

Figure 2-2: Convergence across low-income Countries in terms of GDP per capita and productivity, 1996–2010.

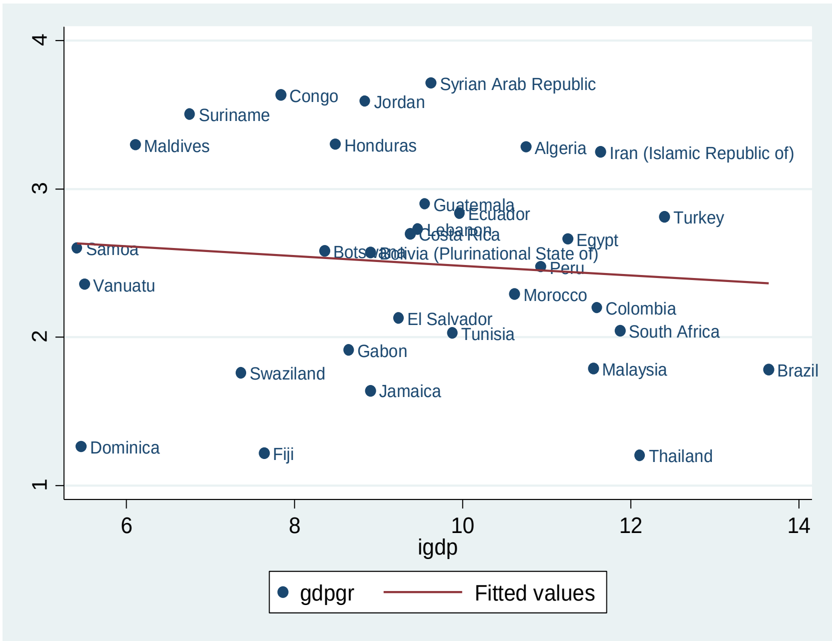


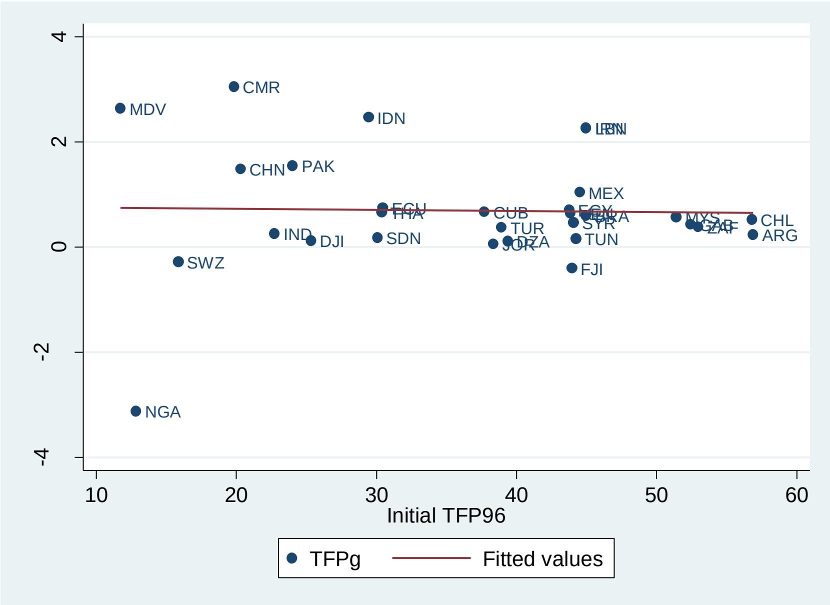


Note: Author's calculation from World Bank database (2011).

However, in figure 2-3 for middle-income countries, the slope of curves becomes negative but not that sharp to support absolute convergence. This means that countries tried to reduce the gap between their incomes.

Figure 2-3: Convergence Middle-income Countries in terms of GDP per capita and productivity, 1996–2010

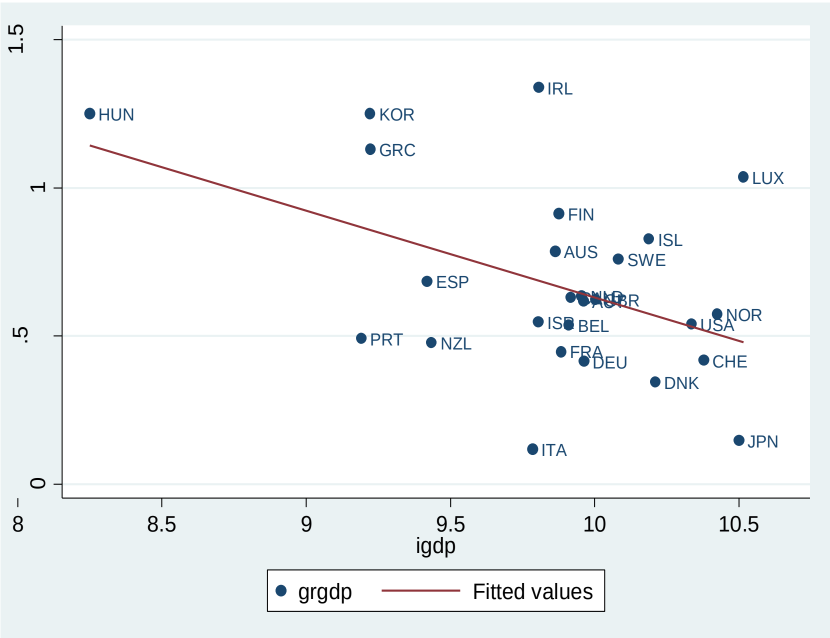


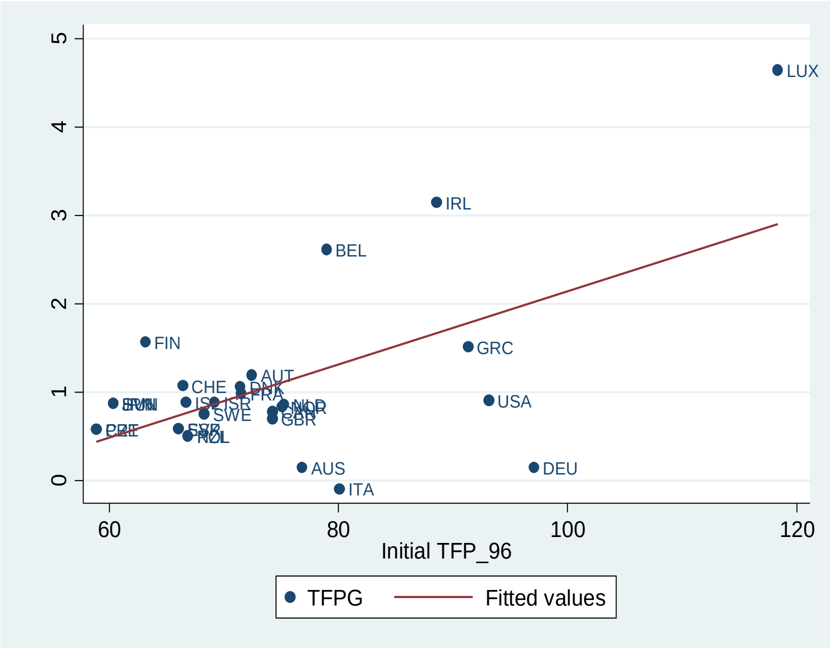


Note: Author's calculation from World Bank database (2011).

Finally, in figure 2-4, the absolute convergence is tested across high-income countries. As can be seen, there is a strong negative relationship between initial GDP per capita and the growth rate of GDP, while in terms of productivity it is exactly the opposite, the relationship is positive. This means that unconditional convergence is not happening across high-income countries in terms of productivity.

Figure 2-4: Convergence across high-income Countries in terms of GDP per capita and productivity, 1996–2010



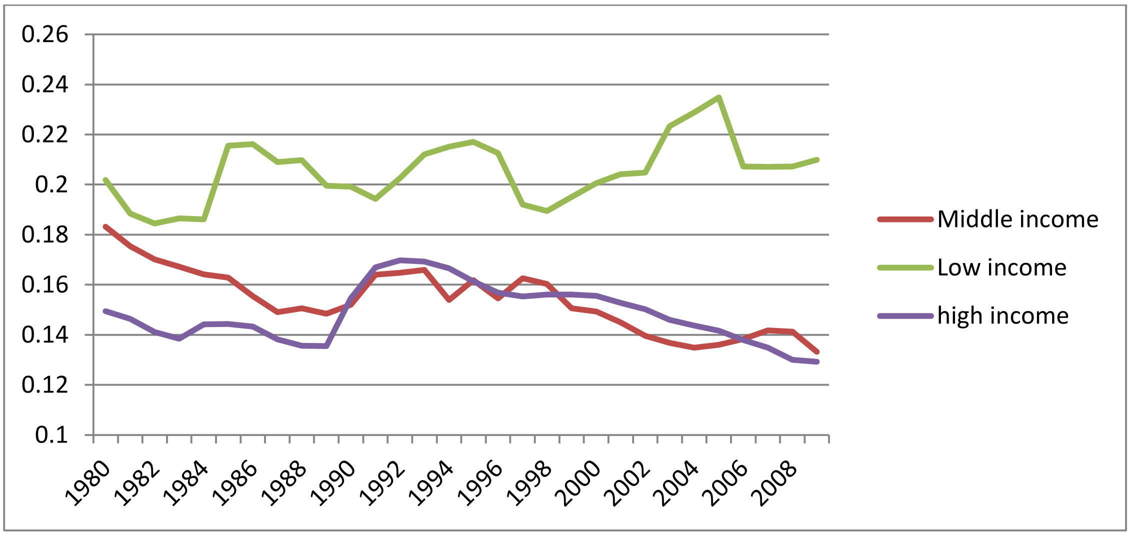


Note: Author's calculation from World Bank database (2011).

Although the convergence hypothesis will be tested in detail in the next chapter, these graphs help to give a perspective about the convergence hypothesis.

The second concept is δ convergence. Figure 2-5 shows the δ convergence in three groups of countries.

Figure 2-5: GDP per capita dispersion in the high-income, Middle-income and low-income countries, 1980-2010



Note: Standard deviation of the logarithm of GDP per capita. Author's calculation from World Bank database (2011).

As can be seen, across low-income countries, there is no trend to reduce the gaps between their incomes per capita; however, across high-income and middle-income countries δ convergence can be seen.

2.3 Growth Models and Convergence

Since one of the purposes of this study is to compare two models of growth together, in the next section exogenous and endogenous growth models are defined and the concepts of convergence based on each model are discussed in detail.

2.3.1 Exogenous Growth Models and the Concept of Convergence

Quantitative growth models have had over half a century of history. In the early studies, economists believed that physical capital was the main factor for explaining growth in countries. Harrod (1939) and Domar (1946), for the first time in their famous model, showed the effect of capital on growth. In their model, society is divided into two groups: firms and households. The increase in production capacity and aggregate demand are the two main sources for forming capital. In their model, fluctuation of the whole production is related to physical capital accumulation. As it is assumed the capital is rising in proportion to labour; production is carried out in a fixed proportion of labour and capital. However, an uneven rapid growth rate in some countries showed that physical capital could not explain the whole fluctuation in growth, which led to the eventual emergence of neoclassical growth models.

Most of the modern growth models came from the studies done by Solow (1956) and Swan (1956). In their model, they assumed that there is diminishing return to capital and labour. The prediction of convergence is derived primarily from this assumption.

Constant returns to scale [1] and Inada conditions [2] are other assumptions that they assumed in their model. While some economists believed that assuming these assumptions causes the results to be unrealistic, Solow (1956) argued that if the assumptions that are used in research do not lead to the right results, they are not wrong. The results showed that policies, which were assumed to be able to change the long-run growth patterns, could not be effective since they could only affect the short-run growth rate. The results of their study also asserted that exogenous factors like savings rate, technological progress and the growth rate of population could affect the growth rate of an economy (Solow, 1956). Their theory, now referred to as the neoclassical growth theory, states that, in the long-run, only technological change and population, which are exogenous, can affect growth (Solow, 1956). Furthermore, in the long-run, economies are leaning towards zero in their steady state. Therefore, it can be seen that in this model, the rate of long-run growth is determined totally by exogenous factors and that it does not depend on other factors like saving rate and policies (R. J. Barro & X. Sala-i-Martin, 1995).

The steady state for the country is determined by its rate of saving, depreciation and population growth; if countries have a different steady state, there is no tendency for convergence among them. Therefore, the only thing that can affect the growth rate in the long-run, as said before, is the rate of exogenous technological progress.

Hence, according to the neoclassic growth theory, two equations are important in analysing growth: production function equation (2-1) and accumulation equation (2-5). The factors in Cobb-Douglas production function can be summarized into two items: physical capital K (t) and effectiveness of labour$A_t L_t$. Then the production function takes the form as below:

---

[1] -“ A production function exhibits constant returns to scale if changing all inputs by a positive proportional factor has the effect of increasing outputs by that factor.”

[2] - “are assumptions about the shape of a production function that guarantee the stability of an economic growth path in a neoclassical growth model”

$$Y_t = K_t^{\propto}(A_t L_t)^{1-\propto} \qquad 0<\alpha<1 \qquad (2\text{-}1)$$

Where Y_t is output, K_t is physical capital, A_t is technology, L_t is labour, α is capital share so there is diminishing return to capital. L and A assumes growth at an exogenous rate according to the following functions:

$$L_t = L_0 e^{nt} \qquad \text{(Simply normalize } L_0 \text{ to unity)} \qquad (2\text{-}2)$$

$$A_t = A_0 e^{gt} \qquad (2\text{-}3)$$

Considering the constant return to scale assumption, the intensive form of production function is as follows:

$$\hat{y}_t = \hat{k}_t^{\alpha} \qquad (2\text{-}4)$$

Where, $\hat{k}$=K/AL and $\hat{y}$=Y/AL. One of the assumptions in the neoclassical model is to consider that the economy is closed. Therefore, when a country reaches to its steady state, equilibrium happens and so saving and investment would be equal. Therefore, a change in capital during time is determined by the following equation (accumulation equation):

$$\dot{k_t} = s\hat{k}_t^{\alpha} - (\delta + g + n)\hat{k}_t \qquad (2\text{-}5)$$

Where s is saving rate, δ is the depreciation rate of capital, n is the constant growth rate of the population and g is the growth rate of technology (R. Barro & Sala-i-Martin, 2004)

In the steady state the accumulation of capital is constant; therefore, we have:

$$k^* = [\frac{s}{(n+g+\delta)}]^{1/(1-\alpha)} \qquad (2\text{-}6)$$

Insert this equation into (2-4), the equilibrium effective per output equation is as follows:

$$y^* = (\frac{s}{(n+g+\delta)})^{\alpha/_{1-\alpha}} \qquad (2\text{-}7)$$

Taking logarithm from equation (2-7):

$$\ln(y^*) = \frac{\alpha}{1-\alpha}\ln s - \frac{\alpha}{1-\alpha}\ln(n+g+\delta) \qquad (2\text{-}8)$$

Since there are no data for the effective per income equation, the equation should be transferred back to a per capita income form. We had $\hat{y}$ = Y/AL, therefore, by taking logarithm, we have:

Ln($\hat{y}$) = Ln(Y) - Ln (L) – Ln (A) (2-9)

=Ln(y) - Ln (A) (2-10)

Then taking logarithm from equation (2-3) and substituting it in equation (2-10),

Ln($\hat{y}$)= Ln(y)- Ln(A_0) – g_t (2-11)

And, finally, we have:

$$\ln[y^*] = lnA_0 + g_t + \frac{\alpha}{1-\alpha}\ln(s) - \ln(n+g+\delta) \quad (2\text{-}12)$$

This equation is for the level of per capita income, Where A_0 reflects country specific factors, such as climate and culture (N. G. Mankiw et al., 1992). For deriving a model for growth of income per capita, we linearize the transition growth path, and we assume the country is sufficiently close to its steady state so linearization is appropriate.

$$\frac{dLn\widehat{y_t}}{dt} = \lambda(Ln\hat{y}^* - ln\hat{y}_t) \quad (2\text{-}13)$$

Where $\lambda = (n+g+\delta)(1-\alpha)$ is speed of convergence. Now we want an equation to treat it like a regression equation. We integrate equation (2-13) from y_t to y_0:

$$\text{Ln}(\hat{y}_t) = \left(1-e^{-\lambda t}\right)Ln(\hat{y}^*) + \left(e^{-\lambda t}\right)\ln\hat{y}_0 \quad (2\text{-}14)$$

Where $\hat{y}^*$is the steady state for output per effective worker and let y_o be the initial level of output, therefore, we have to transfer it to the format of per worker by using equation (2-11). Therefore, we have:

$$Ln\, y_t - lny_0 = \left(1-e^{-\lambda t}\right)g + \left(1-e^{-\lambda t}\right)\ln(A_0) + \left(1-e^{-\lambda t}\right)Ln(y^*) + \left(e^{-\lambda t}\right)\ln y_0$$

(2-15)

And by substituting $Ln(y^*)$ by its amount in equation (2-15):

$$\text{Ln}(y_t - y_0) = \left(1-e^{-\lambda t}\right)g + \left(1-e^{-\lambda t}\right)\ln(A_0) + \left(1-e^{-\lambda t}\right)\frac{\alpha}{1-\alpha}Ln(s) +$$

$$\left(1-e^{-\lambda t}\right)\frac{\alpha}{1-\alpha}Ln(n+g+\delta) - \left(1-e^{-\lambda t}\right)\ln y_0 \quad (2\text{-}16)$$

A more general form of equation, which is used in empirical panel studies, is:

$$\text{Ln}(y_{t,i} - y_{i,t-1}) = \beta_1 Ln(s_{i,t}) + \beta_2 Ln(n_{i,t} + g + \delta) - \gamma \ln y_{i,t-1} + \varepsilon_{i,t} + \mu_i + \varphi_t \quad (2\text{-}17)$$

Where μ_i and φ_t are time specific and country specific effects and β_1, β_2 and γ are parameters to be estimated. By equation (2-17), which is from the Solow-Swan model, the link between the growth model and convergence becomes clear. As we can see the speed of convergence (γ) is dependent on the initial level of income and the structural parameter of neoclassical growth model, which is what economists like R. J. Barro and X. Sala-i-Martin (1995), and N. G. Mankiw et al. (1992) called conditional convergence. When an economy starts with a level of capital per unit of effective labour lower than the steady state, the level of capital monotonically increases to its steady-state value. This means that the growth rate decreases monotonically. Since output varies with the capital, the growth rate of production also declines monotonically when the level is below its steady state level. In other words, poor countries grow faster than rich countries, on the assumption that both have the same technologies and preferences, until they converge to the same steady state.

2.3.2 Endogenous Growth Models and the Concept of Convergence

For the period after World War II, empirical studies showed that the neoclassical model is incapable of explaining the differences across growth rates of countries. Economists believed that by taking technological progress as an endogenous factor, each country's growth rate can be determined. Therefore, attempts to endogenize technology started. The only problem that this class of model faced was about the assumption of increasing return in a general equilibrium framework rather than decreasing return, which was the fundamental assumption of the neoclassical model. In other words, according to the Walrasian theory of general equilibrium, all factors must be paid their marginal products. However, according to the Euler theory on assuming increasing return, all factors cannot be paid their marginal products. Therefore, something beyond the Walrasian theory should be found.

Arrow (1962) made the initial study that tried to endogenize technology into the growth models. He assumed that the growth rate of technological progress is a result of commodities produced by labour based on their experience. In other words, the technology can be affected by “learning by doing”. This means that labour productivity is endogenous. The important point here, in this model, is to assume that the learning factor is free for all firms, with no cost, like public commodity. The problem with Arrow’s model was that the model only works when the ratio for capital-labour is fixed. That means in the long-run the growth rate is limited to labour growth rate, and, therefore, the saving rate does not play a role and the model is not dependent on saving behaviour, like the Solow model.

Another person who tried to endogenize technology was Nordhaus (1969), who made an assumption of an economy based on the neoclassical framework except for knowledge production. Capital and labour produce output through an aggregate production function. What makes his model different from the previous ones is that it integrates an invention factor into the economic analysis. In general, invention means the activities that can expand the level of technology. As opposed to the “Schumpeter tradition”, which believed that invention is an exogenous factor in an economy, Nordhaus (1969) believed that there is a relationship between invention and economic activities. He equated the rate of technology as an increasing function of the number of innovations produced, and, therefore, he endogenized technology in his model. He generated some new twists for the new model of invention. He took invention as a variable that is produced in the system as a new production process. Invention is regarded as a public commodity and available for any firm without costs. In practice, the inventor can keep his invention as a secret for a specific period of time but after this period, his monopoly is relinquished and it is free to be used by any other firm. However, in the Nordhaus model, just as Arrow's model, the growth rate cannot be sustained without accounting for population growth because of the assumption of increasing returns. Economists like Hicks (1963) also introduced "invention possibility set" models and Kennedy (1964), Samuelson (1965) and von Weizsäcker (1966) followed suit and fully collaborated their findings. Uzawa (1965) studied the "optimal education" model and emphasized the role of an educated labour force as an input in the production function, and analysed the optimal growth path. However, all these models faced the problem of increasing return. They could not answer the question of how the economy would compensate activities to make technology grow when there is an increase in returns and endogeneity of technology.

2.3.2.1 First Generation of Endogenous Growth Models

According to the neoclassical growth model, technological progress is an exogenous factor and is the only factor that can permanently affect growth rate in the long-run, while other permanent shocks like change in human capital; saving rate and population have a temporary effect on growth. However, P.M. Romer (1986) argued that this assumption is not reliable since it does not explain how or why technological progress occurs. Therefore, to answer these questions of new growth theories, endogenous growth models were introduced. P.M. Romer (1986) lumped physical capital from saving and intellectual capital from technology together, therefore it can offset the effect of diminishing returns. In these models technological progress is an endogenous factor of economic growth and the heart of growth that is determined by the growth process through the accumulation of workers employed in knowledge-producing activities. In other words, growth is explained by technological progress and technological progress is the outcome of optimizing firms and individuals undertaking investigation in R&D and schooling. The production function of ideas is the source of growth. The parameters in the idea production function show whether innovation through R&D can affect growth permanently or temporary. As can be seen, in the endogenous theory, the role of human capital is important since it is a source of knowledge and knowledge is directly related to technological progress. Furthermore, human capital is a source for creating different new products and is also the only source that can inherit knowledge from past generations. In the endogenous growth models the long-run growth is accrued because of the accumulation of knowledge. Knowledge, as P. Romer (1991) said, is a basic form of capital, which changes the nature of the aggregate growth model. He believed that "an economy with a large total stock of human capital will experience faster growth". Therefore, he explained that growth is not happening in underdeveloped countries, because of the low level of human capital and that less developed countries have less growth because of their large population. In these models, there is a positive relationship between the level of R&D and productivity growth(P. Aghion & Howitt, 1997; P. Romer, 1991). An increase in the size of population will increase researchers in the R&D sector, which increases activities, and, ultimately, increases productivity.

The important point in these new models is the role of increasing returns as opposed to diminishing returns in neoclassic models. Knowledge and other inputs, as a function of production of goods, have increasing marginal product. The presence of externalities and increasing returns in producing new knowledge introduce a very competitive equilibrium growth model. The existence of equilibrium is dependent on the externalities. Even without the condition of increasing returns, equilibrium will coexist with externalities. The increasing return to knowledge is necessary to ensure that the consumption and utility do not grow too fast. The important item here, which makes this model different from the older one is the assumption of increasing marginal productivity of the intangible capital good knowledge (P.M. Romer, 1986)

P.M. Romer (1986), in his study, following the Maddison database 1979 (Maddison, 1979) for emphasizing the role of knowledge, showed that there is no relationship between the initial income per capita and the growth rate of a country. He indicated that output per person has increasing returns relative to the growth rate of the technology leader. He believed that technology came from innovation and innovation is directly related to the rate of scientific progress. In addition, economic activities and decisions can also affect technological progress. For example, one of the factors that can affect technological progress is research and the development sector, which occurs through economic policies that can affect competition, trade and education. He selected eleven industrialized countries and showed that the growth rates of these countries are higher than the previous decade by 0.85 for Sweden and 0.81 for Norway. Furthermore, in 22 developed economies he found a positive relationship between the growth rate of output and the number of scientists and engineers who are employed in research. Today, his approach is known as the AK model. The simplest form of AK model mentioned is the Cobb-Douglass production function:

$$Y = AK^{\alpha}L^{1-\alpha} \tag{2-18}$$

In the AK model, α is equal to one, therefore, the equation is remodelled to this form:

$$Y=AK \tag{2-19}$$

Where A represents the level of technology, which is a positive amount, and, here, K includes human and physical capital. Therefore, this makes the absence of diminishing returns more realistic. As said before, in the neoclassical model the fundamental equation is as follows, which depends solely on K:

$$\dot{K} = s.f(k) - (n + \delta).K \tag{2-20}$$

The growth rate of k is driven by division of both sides by k:

$$\dot{k}/_{k} = s.\frac{f(k)}{k} - (n + \delta) \tag{2-21}$$

By substituting f (k)/k= A in equation (2-21), then the following equation results in:

$$F(k)/k = s.A-(n+\delta) \tag{2-22}$$

This shows the growth rate of K. This equation shows that growth can happen even without technological change. Moreover, growth is not only dependent on technological change, but can also be affected by parameters in the model like the savings rate and population growth. Except for diminishing returns, this is one of the main differences between the neoclassical models and endogenous ones.

The other difference concerns the prediction of convergence; in the endogenous growth models of P.M. Romer (1986), there is no convergence at all at any level of y, which is contrary to what neo-classical models predicted about convergence. As said by Solow (1956), “the speed of convergence is determined by:

$$\lambda = (1 - \alpha).(g + n + \delta) \tag{2-23}$$

In the AK models $\alpha=1$, the share of capital in the Cobb-Douglas function, therefore, when λ is equal to zero, it means that there is no convergence, and it does not matter whether the country is poor or rich.

After P.M. Romer (1986), Lucas (1988) was another economist who had a significant effect on endogenous growth models. The model that Lucas developed was a two-sector model that emphasized the role of education on growth, assuming that population growth and all the other factors were endogenous. He divided capital into two categories: one is physical capital that is accumulated in production and produced by the technology of consumption good and the other kind of capital is human capital that increases productivity on its own and is produced by a different technology. Human capital here has increasing marginal returns and creates endogenous growth. He believed that a labour force with high education is able to learn faster than one without high education. The importance of human capital came from the idea that the formation of the next generation of human capital is affected by earlier generations. He believed that every unit of human capital produces new units of human capital. Lucas believed that human capital has a positive effect on growth. In his model, the first sector is for the production of output and the second sector is for the production of new human capital. Therefore, if one ignores the positive external effects of human capital, endogenous growth can only be possible if there are constant or increasing marginal returns to human capital accumulation. This model, just as Romer's model (1986), predicts no convergence and there is no decline in the growth rate of developed countries. Economists like Scott (1991) supported this idea and showed that there has been no tendency of a decline in the productivity growth rate in the US, United Kingdom and Japan in the last thirty years.

During the second half of the twentieth century, some empirical studies indicated that some countries have been converging to the same steady state; however, these results were not consistent with the first generation of endogenous theory in which there is no convergence for countries in terms of GDP per capita. In 1992, Mankiw, Romer and Weil (henceforth MRW) reconsidered the Solovian production function and argued that it is not necessary to rely on the endogenous models to explain the divergence across countries. As explained before, λ is the speed of convergence in the Solow model: λ= (1 -α). (g+ n +δ). As we can see here, the share of capital α, which is highlighted in the assumption of diminishing returns, is very important in determining the speed of convergence. The Solow model explains that a smaller α, leads to faster convergence. As it becomes equal to zero the diminishing return disappears and there will be no convergence. The contribution of MRW to the literature here, is that they augmented human capital to the model in addition to physical capital and argued that if we consider the process towards steady state transitional dynamics, as protracted, the Solow model could explain the different growth rates across countries. By augmenting human capital to the model the income elasticity becomes 1 rather than ½ in the Solow model and the performance of the model improves. Furthermore, they obtained an expression for the steady state of income per capita:

$$\ln(\dot{y}_t) = lnA(0) + g_t + \frac{\alpha}{1-\alpha-\beta} lns_k + \frac{\beta}{1-\alpha-\beta} lns_h - \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n + g + \delta) \qquad (2\text{-}24)$$

Equation (2-24) shows that the steady state level of income per capita is positively related to A(0), which, according to MRW, is not just the level of technology but also other variables like culture, institutions and climate. Furthermore, more importantly, it is related to the rate of accumulation of human capital in addition to other Solow factors. In their analysis, they let the population growth rate, saving rate and secondary school enrolment change across countries and determine the steady state. By doing so, they found evidence of convergence even in a big sample of countries with different structures. The MRW model is influential in the growth-convergence debate for two reasons. First, they augmented human capital as an additional controlling variable for steady state. Second, the empirical evidence of their model considered convergence, which was rejected by the first generation of endogenous growth models.

Evans and Karras (1996) also showed that the Solow-Swan (1956) models could explain the growth rate of countries with common technology around the world. In addition, R. J. Barro and X. Sala-i-Martin (1995), in their studies, indicated that convergence happened based on the neoclassical models but not endogenous ones. These findings had a double impact, on the one hand, some economists think that the Solow model could explain the convergence progress across countries and are working to extend the model and test it with new controlling variables and updated time series and methods. On the other hand, these findings pushed economists to study more about technological advances and pay more attention to the role of innovation, which was used by Schumpeter years before and led them to a new aspect of growth theory.

2.3.2.2 Second generation of endogenous growth models

In 1995, C. Jones (1998), in his book, argued that the "scale effect" predictions of many recent ideas for production functions (P. Aghion & Howitt, 1997; P. Romer, 1991) are not consistent with empirical evidence. For example, in the case of the US, between 1950 and 1990, the number of researchers was five times bigger than before but still the growth rate was 2 per cent. Therefore, the prediction "constant return to knowledge" of these models was not consistent with the empirical evidence. However, this inconsistency does not refute the important role of R&D based growth models. Therefore, in the other generation of growth models the researchers eliminate this fact and retain the other features of R&D based models. In addition, semi endogenous growth models were introduced. In these models, they relaxed the assumption of constant or increasing return to knowledge and substituted diminishing return to knowledge. Therefore, for a sustained growth rate, growth in R&D is required. Kortum (1998) and P. Aghion and Howitt (1997) supported these ideas. On the one hand, this class of model was similar to Romer's, in which growth drives endogenously through R&D, while, on the other hand, it is similar to the Solow model in which long-run growth only depends on those factors that are usually exogenous, especially population growth rate, which could be a proxy for innovators and scientists, and, therefore, is independent of policy changes in economies.

Considering the following Cobb-Douglas production function (J Ha & P Howitt, 2007):

$$Y = AK^{\alpha}L^{1-\alpha} \tag{2-25}$$

Where Y is output, A is level of technology, K is capital stock, L is labour force and α is capital share, which is assumed to be constant. The growth in ideas production function for the first generation of endogenous growth models is given by:

$$\frac{\dot{A}}{A} = \gamma(X)^{\sigma} \tag{2-26}$$

Where $\dot{A}$ is the number of new ideas generated, A is the stock of knowledge, γ is the research productivity parameter, X is R&D input and σ is the duplication parameter (1 if there are no duplication innovations and 0 if there are a number of innovations). In the first generation of endogenous models, they assumed a constant return to knowledge, and, therefore, that policies that determine R&D input will affect the long-run growth rate. The failure of this model is the back to scale effect item, which states that the higher the level of R&D input, the higher the productivity growth.

As mentioned above, C. Jones (1998) refuted this theory and introduced the semi endogenous growth model, as follows:

$$\frac{\dot{A}}{A} = \gamma(X)^{\sigma} A^{\theta-1} \quad , \quad \boldsymbol{\theta<1} \tag{2-27}$$

Where**,** θ is return to scale in knowledge, which is diminishing here. Therefore, this model assumes that there is a positive relationship between R&D growth and productivity growth.

P. Aghion and Howitt (1997) wrote a paper in response to Jones' critique. In their paper, they argued that having sustainable productivity growth in an economy requires a sustained R&D intensity, and the size of the labour force (GDP) employed (spent) in the R&D sector rather than growth in R&D (Dinopoulos, 2006; J. Ha & P. Howitt, 2007; Madsen, 2008).

$$\frac{\dot{A}}{A} = \gamma(\frac{X}{Q})^{\sigma} A^{\theta-1} \quad , \quad Q \propto L^{\varphi} \quad , \theta<1 \text{ and } \quad 0 < \theta \leq 1 \qquad (2\text{-}28)$$

Where, Q is product variety, L is employment or population and φ is the parameter of proliferation and $\frac{X}{Q}$ is research intensity. This equation implies that the increasing rate of population will increase the number of people who can innovate new products. The difference between this model and previous ones concerns the assumptions of increasing complexity of innovation, which enter R&D as research intensity instead of just R&D input.

They assumed a constant return to scale like the first generation; however, they added a new assumption – increasing complexity of new innovation. These models are famous as the Schumpeterian fully endogenous growth models. They called them Schumpeterian fully endogenous growth models because they were inspired by the theory of "creative destruction" which was introduced by Schumpeter:

> "The process whereby each innovation creates some new technological knowledge that advances our material possibilities, while rendering obsolete some of the technological knowledge that was created by previous innovations"(Howitt, 2000).

In these models, physical capital and intellectual capital were separate and saving is the result of former growth and later growth is from innovation (P. Aghion & P. Howitt, 2006). Here, growth is the reason for the innovation process that improves the quality of outputs, which is inspired by “research activities with uncertain results”. New inventions render previous technologies obsolete; this is called “the factor of obsolescence”, which is the embodiment of Schumpeter’s idea of “creative destructive”. The “creative destructive” progress pointed out two conflicting aspects of research activity. On the one hand, researchers in this period will develop research and new inventions in the next period, and, on the other hand, new inventions and research render the previous ones obsolete. Furthermore, if the research that firms have done is successful, they can have the monopoly of that patent (P. Aghion & P. Howitt, 2006). It is clear that in this class of models, the role of R&D is very important, and, as J. Ha and P. Howitt (2007), and Madsen (2008) pointed out, if a country wants to have sustainable productivity growth, more labour force (GDP) should be employed in the R&D sector.

Howitt (2000), based on the fully Schumpeterian endogenous growth models, suggested that those countries that attempt to increase their R&D sector will reduce the gap with rich countries and will increase their growth while those that do not will not grow at all. The growth rate of productivity is determined by multiplying the research intensity with the technological gap between a country and a country in the technology frontier. Countries that are further from the frontier will grow faster in this model.

$$\frac{\dot{A}}{A} = \tau \left(\frac{X}{Q}\right) \left(\frac{A^{Max} - A_t}{A_t}\right) \quad (2\text{-}29)$$

Where τ is the R&D productivity parameter, $\frac{X}{Q}$ is the research intensity and A^{Max} is the country in the frontier. If A^{Max} remains at the same level and the research intensity increases, the countries lying behind can converge to the leader’s level of productivity. Nelson and Phelps (1966) argued that human capital plays an important role in absorbing foreign technology. They added the human capital time technology frontier to the model and named it “theoretical level of technology, T”, and showed that improvement in technology is not only dependent on human capital but also on the gap between the level of theoretical technology and technology in practice. In their model, similar to the Solow model, the long-run growth rate of technical progress is still exogenous.

$$\frac{\dot{A}}{A} = \omega(HC)(\frac{T_t - A_t}{A_t}) \quad (2\text{-}30)$$

In other words, according to this equation, the technological gap will be dependent on the level of human capital (Raiser et al., 2001).

R. Griffith, Redding, and Reenen (2004) employed a model, which tested the two faces of R&D: one is the effects of R&D on innovation and the other is the effect of R&D on absorptive capacity and promoting convergence. This model implies that R&D is not just promoting TFP growth but also helps technology transfer across countries:

$$\frac{\dot{A}}{A} = \gamma\left(\frac{X}{Q}\right) + \beta\left(\frac{A^{Max}}{A_t}\right) + \alpha\left(\frac{X}{Q}\right)\left(\frac{A^{Max}}{A_t}\right) \quad (2\text{-}31)$$

The third term on the right shows the effect of research intensity based on absorptive capacity.

From equation (2-31), the link between TFP growth and distance to technology frontier can be seen. The sign of β shows whether or not catching up happened across countries, if it is positive it means that countries are catching up to advanced economies. Since technology is very important for growth, especially in this class of model, knowing the channels for innovating new technologies and also the channels through which these technologies can be transferred to other countries is very important. Therefore, innovation and imitation play an important role in the catching up process. This research tries to focus on this part and contribute to literature by looking through different channels for transferring technology across countries. In the next section the history of growth theories will be discussed to see how different classes of growth model have been created and how they deal with the convergence issue and also technology and other important factors as sources of growth.

Later, R Griffith, Redding, and Van Reenen (2004) extended the model of P Aghion and Howitt (1998) by focusing more on the role of R&D as an accelerator of absorptive capacity and incorporated it in the Schumpeterian fully endogenous model. They were inspired by the idea of P Aghion and Howitt (1998), who introduced income convergence by “allowing the size of the quality-augmenting innovation to depend on a firm’s distance behind the technological frontier” (R Griffith et al., 2004) (R Griffith et al., 2004) (R Griffith et al., 2004) (R Griffith et al., 2004) (R Griffith et al., 2004) . In these models, the rate of technological progress depends on research and countries can benefit from the backwardness in their technology and grow faster. Therefore, according to this backwardness these recent models also cover the convergence debate through technology transfer (R Griffith et al., 2004). R Griffith et al. (2004), in their paper, extended the P Aghion and Howitt (1998) model and emphasized three parts – R&D based innovation, the potential for technology transfer and the role of R&D in promoting absorptive capacity. They argued that countries further from the technology frontier can grow because of both innovation and technology transfer. The important point in their paper is that if the research is not successful in the first period the technology can transfer independent from R&D activities. They called it “autonomous technology transfer”. In addition, they emphasized that the pace of this transfer is a function of government policies, institutions, international trade, and level of human capital. In other words they captured the role of R&D as a promoter of absorptive capacity and not just innovation. More investment in the R&D sector and more foreign technology could be absorbed and the important thing here is that developing countries should not only focus on importing technology from developed countries but also work on their own domestic technological activities (Fagerberg, 1994). Therefore, a country that is far from the technology frontier has more benefit and can grow faster considering the role of human capital, trade, institutions as well as investment in R&D. The following equation (2-32) was employed by R Griffith et al. (2004):

$$E_{t-1}Ln\left(\frac{A_{i1t}}{A_{i1t-1}}\right)=\lambda_i\hat{H}^R_{it-1}Ln\gamma+\mu_i Ln\left(\frac{A_{f1t-1}}{A_{i1t-1}}\right)+\lambda_i\hat{H}^R_{it-1}\varphi_i Ln\left(\frac{A_{f1t-1}}{A_{i1t-1}}\right) \qquad (2\text{-}32)$$

Where E is an "expectations operator". This equation is inspired from Schumpeterian endogenous growth. Innovation is the main factor in determining economic growth. This equation also includes empirical evidence of productivity convergence. The potential of transferring technology denotes that those countries far from the frontier ($A_{i1t-1}\langle A_{f1t-1}$), can experience a faster growth rate than the others. Although all of the countries that are away from the technology frontier have this potential to grow, the possibility of this event depends on the institutions and government policies (μ_i) and the absorptive capacity of countries. With more investment in the research and development sector, the ability of a country to assimilate from new technology will be increased, and, therefore; it can increase the rate of technology transfer.

According to this equation, the equilibrium level of relative TFP depends on the following factors:

- Institutions and government policies, which affect research productivity (λ_f, λ_i).
- Size of labour force that works in the research sector ($\hat{H}^R_f$,$\hat{H}^R_i$).
- The size of innovation, which is at the technology frontier (δ).
- Political-economic variables, which form the speed of abstractive capacity during technology transfer (φ_i , μ_i).

Now we can see the concept of convergence through these models. The further a country is from the technology leader, the greater the productivity growth it could have. This is the concept of convergence in the Schumpeterian fully endogenous growth models. In our study, we were inspired by the Schumpeterian fully endogenous growth theory to drive our productivity regression.

2.4 Summary

The question about income inequality across countries has been an important question since 1820, when the great divergence happened in the world. Since then, economists have tried to explain this disparity by employing different theories, models and methods. In previous studies economic indicators like saving, investment, capital, trade, foreign direct investment (FDI) and socioeconomic indicators like education and health have been used to explore the different growth across countries. However, the uneven growth disparities across countries make it difficult to conclude which factors are more effective. In addition, in the new growth theories the concept of technological catch up came into sharp focus. Technologies have always been an engine of growth in all growth theories. In the neoclassical theory, they treat it as an exogenous factor; however, in the new growth model it is endogenous, which is determined inside the model. While in previous studies most researchers focused on the concept of convergence in terms of GDP per capita (or β convergence), recent studies supported that a large fraction of income disparities can be explained by technological change (or total factor productivity, TFP). They argued that income convergence can be the outcome of both capital deepening and technological catch up. Therefore, economists directed their attention to this concept (Charles Jones, 1998; Madsen, 2008; Raiser et al., 2001). Since TFP is the closest measure for technology, researchers use it for investigating whether or not countries are closing their gap in terms of their TPF levels. In this debate, the distance to the technology leader is very important. The further from the technology leader the country, the more advantage it has from this backwardness and grows faster. Therefore, we can see that the concept of convergence here changes from the distance from steady state to distance from technology frontier.

In this section we described the different growth models and compared them, and described the theoretical framework of these models, making clear the link between the growth models and convergence hypothesis, which is how we can test the convergence hypothesis through these models. Also, we described the different concepts of convergence that exist in the literature, absolute β convergence and σ convergence in terms of GDP per capita and technology catch up in terms of TFP.

Chapter 3

Reopening the Debate of Technology: Innovation and Imitation Perspective, Empirical Framework

3.1 Introduction

Looking back through history we can see that the role of technology became very important during World War I and II, and even more important after the emergence of three tigers in Asia (Singapore, Thailand and Korea). Economists have conducted a lot of research to understand what is going on and tried to explain this massive growth rate through different channels. A large portion of literature in this field investigated the role of technology and how it can affect growth in different countries. However, most of the studies in this field are radical and stick to the school of thought that they believed. For example, the neoclassical people try to prove that capital accumulation is the main source of growth without considering the role of technology. They believed that technology is important but they did not try to look at the role of imitation and innovation of technology through the accumulation of capital in their model.

Furthermore, in the new growth theory they considered the role of imitation and innovation in their model but they ignored other items like the role of institutions and globalization as factors that could increase the pace of imitation, and, consequently, increase the growth rate of countries.

Therefore, this research tries to reopen the role of technology in these two classes of model by focusing on the role of imitation and innovation.

3.2 Reopening the Debate of Technology

Although technology is assumed to be a main source of growth in all kinds of growth model, it can affect growth through different channels in each class of model. Neoclassic economists argue that technology is a public good and the same across countries, and, therefore, the rate is constant and exogenous, while in the endogenous theory they argue that it is not the same across countries and that the rate is endogenous and determined inside the model. Therefore, the debate of how it should be endogenized in the model remains an interesting topic.

At the same time, the disagreement between neoclassic people and new growth, make this debate more interesting. Researchers have conducted empirical studies using these different theories with different methods, which have contributed considerably to this area.

Such studies include those done by N. G. Mankiw et al. (1992) who introduced the augmented Solow model, separating human capital from physical capital, or Charles Jones (1998), who introduced the semi endogenous models by emphasizing R&D activities or P. Aghion and Howitt (1997), who introduced the fully endogenous growth models, which is also famous as the technology-gap models that emphasize the role of R&D intensity and absorptive capacity. In recent attempts, economists focussed more on the role of innovation and imitation on these models and tried to endogenize them into growth regressions (Phelps, 1966; J. D. Sachs, 2003). The more investment, for example, in R&D departments, causes more innovation, which has a direct effect on increasing productivity and growth. Furthermore, increasing the ability of the country to imitate these new innovations from the other countries can also increase the productivity and growth. These two aspects are seen to be very important in explaining the growth rate across countries.

However, in considering the role of two factors – institutions and globalization – that appear to have been ignored, we shall contribute to the analytical literature by discussing their role as accelerators of absorptive capacity as well as the role of human capital, which has been extensively discussed. We shall derive the technology-gap regression taking into account these new variables. Furthermore, to show how these different dimensions of technology evolved in past years, this study follows the standard analysis of testing β and σ convergence. Finally, to link the technological change to convergence in terms of income we estimate the classic growth regression, which decomposes GDP per capita growth into the sum of dynamic of technology change and physical capital accumulation rate. Section two extends the Solow model by including these new aspects of growth, which are highlighted in the new growth theories. In line with the augmented Solow model, this study applies globalization and institutions as well as innovation as factors that increase the accumulation of human capital, and drives a regression, which can be tested empirically.

3.3 Reopening the Debate of the Knowledge Transfer on NGM

New growth models are different from NCGM in that knowledge is a key source of growth. The stock of knowledge plays an important role in explaining the different growth rates across countries. Therefore, the components of knowledge stock are very important. Creation (CK_i) and imitation (IK_i) are two components of knowledge stock growth that have attracted considerable attention in recent growth literature (Castellacci, 2011).

$$\frac{\Delta A_i}{A_i} = CK_i + IK_i \tag{3-1}$$

Technology (knowledge) spillovers or imitation is considered as an important item in explaining growth. Hitherto, in most of the existing models, technology transfer was considered as an automatic phenomenon, and none of the models could explain through which mechanism technology transfer happens across countries and affects growth. Therefore, factors that can be considered for imitating and implementing new technologies from advanced countries are becoming very interesting in empirical studies. Imitation depends on the distance to technology frontier (DTF_i), in which countries that lie behind the technology frontier have the opportunity to catch up by imitating technology from leaders, and absorptive capacity (AC_i), which shows to what extent countries have the ability to absorb technology from frontiers (Beck & Laeven, 2006; Jess Benhabib & Rustichini, 1996; R. Griffith et al., 2004; R. R. Nelson, 2008; Phelps, 1966; Pomeranz, 2001; Raiser et al., 2001; J.D. Sachs, 2003).

$$KI_i = {DTF_i}^{\mu} * AC_i \qquad (3\text{-}2)$$

In previous studies, the absorptive capacity depends on R&D (R. Griffith et al., 2004) and human capital (HC_i) (D. Dollar & Kraay, 2004; Madsen, 2008), and, by the study done by Castellacci (2011), it is a function of human capital and infrastructure. In this study, we argue that institutions (INS_i) and globalization ($GLOB_i$) are the other factors that can improve the ability of a country to observe foreign advanced technologies. Without having proper institutions (e.g. property rights) in a country, inventors do not innovate, and, therefore, there is no knowledge to transfer across borders. The other factor is globalization ($GLOB_i$), which can improve the absorptive capacity. Flow of ideas, as well as flow of goods, are very important in accelerating growth. Therefore, human capital would be useless without the support of proper institutions and the existence of globalization in terms of ideas.

$$AC_i = {HC_i}^{\beta 1} * {INS_i}^{\beta 2} * {GLOB_i}^{\beta 3} {R\&D_i}^{\beta 4} \qquad (3\text{-}3)$$

The other component is creation of knowledge (CK_i), which can be a function of the innovation intensity of a country (INO_i) and the level of human capital. Innovation intensity refers to the research intensity and the number of scientific journals (P. M. Romer, 1990).

$$CK_i = R\&D_i^{\gamma} HC_i^{\propto 1} \qquad (3\text{-}4)$$

Taking the lags of equations (3-2) and (3-4) and substituting those in (3-1), gives us the following equation for knowledge stock growth (or productivity growth):

$$\Delta A_i / A_i = (\gamma + \beta_4) logR\&D_i + (\beta_1 + \propto_1) logHC_i + \beta_2 logINS_i + \beta_3 logGLOB_i + \mu logDTF_i \qquad (3\text{-}5)$$

This equation highlights five sources of productivity growth: innovation intensity undertaken by R&D sector; human capital, which affects both imitation (technology transfer) and innovation; institutions and globalization, which affect the absorptive capacity in a country; and, finally, distance to technology frontier, which shows the tendency for catching up in terms of technology across countries. The interesting point here is how we take care of distance to technology frontier in this equation. It is obvious that it will take some time to transfer technology from the advanced countries to the developing and less developed ones. Therefore, since the technology in the leader country affects a country far from the frontier by lagged, we enter this variable by lagged here also. Therefore, we rewrite the equation (3-5) like this:

$$\Delta A_i / A_i = (\gamma + \beta_4) logINO_i + (\beta_1 + \propto_1) logHC_i + \beta_2 logINS_i + \beta_3 logGLOB_i + \mu \log(TFP_{i,t-1} - TFP_{F,t-1}) \qquad (3\text{-}6)$$

Now we can drive the equation that shows the relation between technology changes and growth of GDP per capita in terms of endogenous theories. We do this by considering the classic Cobb-Douglas production function (in per worker):

$$y_i = A_i {K_i}^{\alpha} \tag{3-7}$$

Where Y_i is the GDP per capita of country i, A_i is knowledge stock and K_i is level of physical capital. The growth rate of GDP per capita over time is:

$$\Delta y_i / y_i = \Delta A_i / A_i + \Delta {k_i}^{\alpha} / {k_i}^{\alpha} \tag{3-8}$$

This equation decomposes the growth of GDP per capita into technological changes and physical capital accumulation, which here, is capital formation. By plugging equation (3-5) into equation (3-8), we have the following equation:

$$\Delta y_i / y_i = (\gamma + \beta_4) logINO_i + (\beta_1 + \propto_1) logHC_i + \beta_2 logINS_i + \beta_3 logGLOB_i + \mu \text{log} y_{i,t-1} - \mu log y_{F,t-1} + \theta FC_i \tag{3-9}$$

Where Y_f is GDP per capita of country in the frontier and Y_i is a GDP per capita of sample country, these two terms substitute to terms $TFP_i - TFP_F$ (Castellacci, 2011). FC_i indicates the formation of physical capital.

3.3.1 The Dynamics of Technology

To show how these different dimensions of technology have evolved in recent years, this study follows the standard analysis of testing convergence, β convergence, for innovation intensity, human capital, institutions, globalization and studies how their statistical distributions have evolved over the past thirteen years. We call it φ convergence here.

φ convergence:

φ convergence for each dimension means that less developed countries have experienced more rapid technological growth than developed ones. The following equation is a basic cross-country regression form, which is used in applied growth theories for testing the convergence hypothesis:

$$\Delta A_i / A_i = \alpha + \beta_1 A_{i,0} + \varepsilon_i \qquad (3\text{-}10)$$

Where $\Delta A_i / A_i$ is the growth rate of each technology dimension of country i over the period 1996-2010, and $A_{i,0}$ is the the log of its initial level at the beginning of period. β_1 shows the speed of convergence for each dimension of technology.

3.4 Extending the Solow Model in Terms of Knowledge Transfer

In line with the new aspects of the endogenous growth theories, innovation and imitation, we want to reconcile the neoclassic growth model by incorporating the essence of these theories mentioned in the previous sections. Starting from the augmented neoclassic production function, N. G. Mankiw et al. (1992) , equation 11-3 is given:

$$Y_t = K_t^{\propto} H_t^{\beta} (A_t L_t)^{1-\propto-\beta} \qquad \alpha+\beta<1 \qquad (3\text{-}11)$$

Where Y is output, K is physical capital, A is technology, L is labour, H is human capital, α and β is capital share, and according to NCG assumptions, there is a diminishing return to capital. Labour force and technology are assumed to grow at an exogenous rate according to the following functions:

$L_t = L_0 e^{nt}$ (We simply normalize L_0 to unity) (n=exogenous growth of labour force)

$A_t = A_0 e^{gt}$ (g= exogenous growth of technology) (3-12)

According to the assumption of constant to scale, the intensive form of production function is as follows:

$$\hat{y}_t = \hat{k}_t^{\alpha} \hat{h}_t^{\beta} \quad (3\text{-}13)$$

Where $\hat{k} = K/AL$, $\hat{h} = H/AL$ and $\hat{y} = Y/AL$. In the Solow-Swan model the saving rate is determined exogenously according to the decision of savers or government policy. Therefore, the capital accumulation equation is written in terms of per effective worker like this:

$$\frac{d\hat{k}_t}{d_t} = s_k \hat{y}_t - (n + g + \delta)\hat{k}_t \quad (3\text{-}14)$$

And N. G. Mankiw et al. (1992) accumulated human capital through investing in education in the model.

$$\frac{d\hat{h}_t}{d_t} = s_h \hat{y}_t - (n + g + \delta)\hat{h}_t \quad (3\text{-}15)$$

Here, we want to contribute to the literature by accumulating human capital through other channels – imitation and creation – which is important in recent growth literature. In the recent new literature, the role of R&D activities is highlighted as an important source of growth. Countries that spend more money on the R&D sector can innovate more, and, therefore, can accelerate their growth rate. Although, empirical evidence shows that other countries that are not involved in R&D activities can take advantage of these new ideas by the diffusion of technology, the effect of innovation has its own place. Another way of accumulating human capital is through technology spillovers and absorbing new technology (imitation) that need a certain level of human capital. However, there are several difficulties in absorbing technology (imitation) from advanced countries. This research considers globalization as a way for technology spillovers. Globalization leads to a sense of openness, international trade and infrastructure, all of which are included in the KOF index. Furthermore, institutions, which have become important determinants of economic growth in recent literature, are the other channel for accumulation capital. These two concepts are employed in the model by considering this fact from the new growth theory that the absorptive capacity of a country can present a possibility for accelerated human capital accumulation (Pääkkönen, 2010).

Now, in this study, we want to enter creation and imitation (absorptive capacity) as accelerators of human capital accumulation. Therefore we rewrite equation (3-18) like this:

$$\frac{d\hat{h}_t}{d_t} = s_h(1+GLOB)^{\pi}(1+INO)^{\vartheta}(1+INS)^{\rho}\hat{y}_t - (n+g+\delta)\hat{h}_t$$

$$0 < GLOB < 1,\ 0 < INO < 1,\ 0 < INS < 1 \qquad (3\text{-}16)$$

3.4.1 The Steady State

In the steady state, the levels of physical and human capital per effective worker are constant (M. Knight, N. Loayza, & D. Villanueva, 1993). The steady state values are given in the following equations:

$$\hat{k}^* = \left(\frac{s_h^{\beta} * (1+GLOB)^{\pi\beta} * ((1+INO)^{\vartheta\beta} * ((1+INS)^{\rho\beta} * s_k^{\alpha}}{n+g+\delta}\right)^{\frac{1}{\alpha+\beta}} \qquad (3\text{-}17)$$

$$\hat{h}^* = \left(\frac{s_h^{1-\alpha} * (1+GLOB)^{\pi(1-\alpha)} * ((1+INO)^{\vartheta(1-\alpha)} * ((1+INS)^{\rho(1-\alpha)} * s_k^{\alpha}}{n+g+\delta}\right)^{\frac{1}{\alpha+\beta}} \qquad (3\text{-}18)$$

Substituting these equations into (3-13), we have:

$$\hat{y}^* = \left(\frac{s_h^{\beta} * (1+GLOB)^{\pi\beta} * ((1+INO)^{\vartheta\beta} * ((1+INS)^{\rho\beta} * s_k^{\alpha}}{(n+g+\delta)^{\alpha+\beta}}\right)^{\frac{1}{\alpha+\beta}} \qquad (3\text{-}19)$$

And the econometric equation to estimate it should be written in logarithm form:

$$Ln(\widehat{y_t}) = \frac{\beta}{1-\alpha-\beta} lns_h + \frac{\alpha}{1-\alpha-\beta} lns_k + \frac{\pi\beta}{1-\alpha-\beta} \ln(1+GLOB) + \frac{\vartheta\beta}{1-\alpha-\beta} \ln(1+INO) + \frac{\rho\beta}{1-\alpha-\beta} \ln(1+INS) - \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n+g+\delta) \quad (3\text{-}20)$$

Following M. Knight et al. (1993) linearization of the transition path around the steady state is given as:

$$\frac{dLn(\widehat{y_t})}{dt} = \lambda(\ln(\hat{y}^*) - Ln(\widehat{y_t})) \quad (3\text{-}21)$$

Or integrating equation (3-19) from T=t-1 to T= t:

$$Ln(\widehat{y_t}) - \ln(\hat{y}^*) = e^{-\lambda t} \ln(\hat{y}^*) - e^{-\lambda t} Ln(\hat{y}_{t-1}) \quad (3\text{-}22)$$

We can rewrite it like this:

$$Ln(\widehat{y_t}) = 1 - e^{-\lambda t} \ln(\hat{y}^*) + e^{-\lambda t} Ln(\hat{y}_{t-1}) \quad (3\text{-}23)$$

Where λ= (n+g+δ)(1-α-β) is the speed of convergence.

Substituting for $Ln(\widehat{y_t})$ in equation (3-23) we have:

$$Ln(\widehat{y_t}) = (1 - e^{-\lambda t}) \frac{\beta}{1-\alpha-\beta} lns_h + (1 - e^{-\lambda t}) \frac{\alpha}{1-\alpha-\beta} lns_k + (1 - e^{-\lambda t}) \frac{\pi\beta}{1-\alpha-\beta} \ln(1+GLOB) + (1 - e^{-\lambda t}) \frac{\vartheta\beta}{1-\alpha-\beta} \ln(1+INO) + (1 - e^{-\lambda t}) \frac{\rho\beta}{1-\alpha-\beta} \ln(1+INS) - (1 - e^{-\lambda t}) \frac{\alpha+\beta}{1-\alpha-\beta} \ln(n+g+\delta) + e^{-\lambda t} Ln(\hat{y}_{t-1}) \quad (3\text{-}24)$$

Since the format of equation (3-24) is per effective worker we have to transform it to per worker for the purpose of estimation. Therefore, as we had $A_t = A_0 e^{gt}$, by taking logarithm we have:

$$LnA_t = LnA_0 + gt \tag{3-25}$$

And we have, $\hat{y}$=Y/AL, we can write it in per worker like this: $\hat{y} = y/A$, $ln\hat{y} = lny - lnA$

Therefore we have:

$$ln\hat{y} = lny - LnA_0 - gt \tag{3-26}$$

$$Ln(y_t) = LnA_0 + gt + (1 - e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}lns_h + (1 - e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}lns_k + (1 - e^{-\lambda t})\frac{\pi\beta}{1-\alpha-\beta}\ln(1 + GLOB) + (1 - e^{-\lambda t})\frac{\vartheta\beta}{1-\alpha-\beta}\ln(1 + INO) + (1 - e^{-\lambda t})\frac{\rho\beta}{1-\alpha-\beta}\ln(1 + Ins) - (1 - e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n + g + \delta) + e^{-\lambda t}Ln(y_{t-1}) \tag{3-27}$$

For estimating the growth regression we subtract $Ln(y_{t-1})$ from both sides.

$$\Delta Ln(y_t) = LnA_0 + gt + (1 - e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}lns_h + (1 - e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}lns_k - (1 - e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n + g + \delta) + (1 - e^{-\lambda t})\frac{\pi\beta}{1-\alpha-\beta}\ln(1 + GLOB) + (1 - e^{-\lambda t})\frac{\vartheta\beta}{1-\alpha-\beta}\ln(1 + INO) + (1 - e^{-\lambda t})\frac{\rho\beta}{1-\alpha-\beta}\ln(1 + INS) + (e^{-\lambda t} - 1)Ln(y_{t-1}) \tag{3-28}$$

Equation (3-28) is the one that provides us with a good specification for empirical research; however, we will not use it literally. This equation shows the effect of different factors on the GDP per capita growth rate. The first two terms $LnA_0 and\ gt$ represent the cross specific effect and time specific effect, respectively. A_0 represents all the unobserved factors that affect efficiency. These two items might be correlated to the other explanatory variables on the model. The third and fourth coefficients show that the more saving and investing in human and physical capital, the more rapid growth it has.

The fifth term is about the role of population growth on economic growth. With a given β, α, δ and g, population growth rate has a negative effect on GDP per capita growth. The coefficient of GLOB shows that if π is positive, it means that opening up the borders and being globalized can help speed up the rate of GDP per capita growth. This is also the same for the coefficients of INS and INO. In addition, for the last term, if λ is positive it means that there is a negative relationship between the initial level of GDP per capita and growth rate. "Countries below their steady states growth path, can grow faster: conditional convergence" (R. J. Barro & X. Sala-i-Martin, 1992).

3.5 Summary

This chapter reopened the debate of technology as a source of growth in both neoclassical and new growth theories. In neoclassical theory, Solow (1956) contributed to the literature by talking about technological improvement as a source of growth in the long-run. However, he could not explain how and through which channels technology can affect growth. In addition, he believed that factors like saving, population growth and capital depreciation are the only factors that can affect growth in the short-run and that it is unaffected by policies.

During the 1960s and 70s, massive changes in the growth rate of some Asian countries – Singapore, Korea and Taiwan – attracted the attention of economists to investigate the causes of these changes, and, finally, Romer (1986) introduced his new idea of endogenizing technology to the model, which talked about the important role of R&D and innovation in explaining the growth rate of countries. In line with his studies, other economies extended his model and highlighted the other factors that can contribute to growth like the role of imitation and technology transfer on growth.

In this research we want to contribute to the literature by reopening the debate of technology in these two growth theories by focusing on the role of imitation and innovation. In the new growth theory, economists consider these two factors as sources of growth. However, they did not explain the factors that can increase the pace of imitation and innovation like the role of institutions and globalization. Therefore, this study considers the other factors like R&D expenditure, human capital, institutions and globalization as factors that can increase the capacity of countries to absorb technology from frontiers.

In the neoclassical theory, capital-deepening theories, we contribute to the literature by considering these new aspects of growth, imitation and innovation as accelerators of accumulation of capital that is important in this class of model. Further, we consider institutions and globalization as factors that can accelerate the accumulation of human capital.

Chapter 4

Empirical Studies on Testing Convergence

4.1 Introduction

Looking back through the literature, economists tried to test convergence hypothesis in different samples of countries, data sets and using different econometric methods. In terms of data, cross-sectional data, time series, as well as panel data that pooled both were used. The attempt of this chapter is to highlight the most important studies done in each different field and also highlight the shortcomings of these studies, which are going to be addressed by the current research.

4.2 Cross-Sectional Analysis to Test Convergence

There are two types of study in cross sectional analysis. One discusses convergence within a country and the other type argues convergence among countries. We try to separate these studies from each other, since, for example, regions within a country can converge because of government regional development policies, while it is different across countries, which have different structures. Therefore, the convergence arguments for both types are different.

4.2.1 Convergences across Countries

As mentioned earlier, the pioneer study for testing convergence dates back to the end of the nineteenth-century, when Baumol (1986) tried to investigate the relationship between productivity and the annual growth rate in 16 industrialized countries between 1870 and 1979. His study began with a cross sectional analysis on standard Solow growth regression, where the speed of convergence depends only on the initial level of GDP per capita. The results indicated that there was a negative relationship between the initial level of productivity and the growth rate. In his research, he did not control any factors except the initial level of productivity in each country, and, therefore, the results showed absolute convergence. In another attempt to support the previous results, he chose a sample of 72 countries over the period 1950-1980. Although, this time he analysed GDP per capita for testing convergence, he asserted that these data, like the previous sample, could be used to proxy Maddison's productivity data. This time the results were not compatible with the preceding one. The poorest countries grew most slowly, meaning, that there was no tight negative relationship between GDP per capita and annual growth rate.

> "This suggests that there was more than one convergence club. Rather, there are perhaps three, with the centrally planned and the intermediate groups somewhat inferior in performance to that of the free-market industrialized countries. It is also clear that the poorer less developed countries are still largely barred from the homogenization processes" (Baumol, 1986).

However, De Long (1988) wrote a comment on Baumol's paper (1986) and argued that,

> "Baumol's regression uses an ex post sample of countries that were now rich and have successfully developed. By Maddison's choice, those nations that have not converged were excluded from his sample because of their resulting present relative poverty. Baumol's sample suffers from selection bias, and the independent variable was unavoidably measured with error. Both of these create the appearance of convergence whether or not it exists in reality" (De Long, 1988).

Therefore, De Long (1988) used an unbiased sample in his study named Once-Rich Twenty-Two. The result of the study showed that,

> "In the long-run, data do not show convergence on any but the most optimistic reading. They do not support the claim that those nations that should have been able to rapidly assimilate industrial technology have all converged. Nations rich amongst the once-rich twenty-two in 1870 have not grown more slowly than the average of the sample" (De Long, 1988).

Finally, De Long (1988) argued that finding divergence in the sample led us to think in the way that "in the long-run there may not be technology transfer that can be a key factor for economic growth" (De Long, 1988).

It also pushes us away from the belief that the West, even in industrialized countries, in 2090 or 2190 living standards would be roughly equal. The absence of convergence, even among wealthy nations in 1870, forces us to argue like P. M. Romer (1990) that the relative income gap between the rich and poor may tend to be wide. This argument leads studies to investigate income convergence among different samples and periods. While researchers try to figure out this problem, different concepts of convergence have emerged.

The most important studies done in this field can be traced back to the early 1990s when Robert Barro and Sala-i-Martin did a series of studies on economic growth with a focus on economic convergence using the cross sectional approach. These studies were the most influential, which made convergence an on-going debate until now. In their research, important questions were raised, like is there a tendency in poor countries to grow faster than rich ones? Are the factors that lead to convergence automatic forces? And, which factors can accelerate the growth across countries and so speed up the convergence process (R. J. Barro & X. Sala-i-Martin, 1995)? Their studies rely on the neoclassical growth model, which emphasizes the negative relationship of the initial level of income or GDP per capita and annual growth rate, which is known as β convergence. Lichtenberg (1994) tested the convergence hypothesis that R. J. Barro and X. Sala-i-Martin (1992) discussed in a sample of 22 OECD countries between 1960 and 1986. The results of his study do not support the convergence hypothesis. He claimed that the rate of convergence was overestimated in previous studies.

However, the results of other studies, like Carree and Klomp (1997), support the convergence hypothesis across countries. In their study they applied the same sample like Lichtenberg (1994), OECD countries, and between 1950 and 1994.

4.2.2 Convergence within Countries and Regions

R. J. Barro and X. Sala-i-Martin (1995) focused on the concept of convergence among the 48 states of the US from 1840 to 1988 and 73 regions in Europe from 1950 to 1985. The results showed convergence. The basis of their analysis is their paper in 1992. Their findings support the idea of β-convergence between and within regions, meaning that poor eastern states can grow faster than rich eastern states. Furthermore, in another attempt, R. J. Barro (1991) tried to test convergence among 48 US states by using gross state product (GSP) between 1963 and 1986 by using the cross section approach. This research also supports the existence of convergence among states.

In the US, between 1880 and 1990, the B-convergence was examined (1996) and supported in 48 states by X. X. Sala-i-Martin (1996). Per capita income was used in the area as the dependent variable; however, he chose real per capita GDP as the dependent variable in the second empirical study and no convergence was found between 1960 and 1990 for 110 selected countries. Even though in OECD countries B-convergence was found for the same period at the rate of 1.4 per cent. Siriopoulos and Asteriou (1997) also tested regional convergence across different regions of Greece by applying cross sectional analysis. They focussed on neoclassical theory and divided Greece into two sides: south and north. They did not find any evidence for supporting the convergence hypothesis, and, therefore, they supported the idea of Baumol (1986) on club convergence.

4.3 The Time Series Analysis to Test Convergence

While the main concern of most research was on the traditional unit root test on developed countries, economists tried to extend the sample of countries. For the first time, K. Lee, M. H. Pesaran, and R. Smith (1997) used the Dickey-Fuller unit root test for testing convergence across 102 countries. The results indicated that the null hypothesis of unit root could only be rejected for a few.

Bernard and Durlauf (1996), and Quah (1996) were the other economists who tested the convergence hypothesis. Bernard and Durlauf (1996), first tested the convergence across fifteen OECD countries between 1900 and 1989. The multivariate unit root and cointegration tests both rejected the convergence hypothesis. Furthermore, in another study, Bernard and Durlauf (1996) examined the factors that affected labour productivity and convergence during the period 1963-1989 in the United States' industries. They compared two methods in their research: cross sectional and time series. The results from both methods only support the convergence hypothesis in labour productivity for two departments – mining and manufacturing. Pesaran (2007) used the "Pair-wise" test for testing convergence hypothesis and their results were similar to Bernard and Durlauf (1996).

However, Evans and Karras (1996) used time series analysis for a sample of 56 countries between 1950 and 1990 and used "unit root test of pooled deviation". The results supported the convergence hypothesis.

4.4 The Panel Data Analysis to Test Convergence

Economists, like N. Islam (1995), F. Caselli et al. (1996), Bianchi (1998), Kevin Lee et al. (1997), Shioji (2005), Evans and Karras (1996), and Beyaert and Camacho (2008) pooled cross section and time series data together to improve the information set and increase the power of testing. Each of them used different methods in panel to test the convergence hypothesis across countries. However, each of them has their own shortcoming. For example, Shioji (2005) applied both panel data and the cross sectional method for testing convergence hypothesis across 48 states of US between 1929 and 2001. Using cross sectional data, the results show that convergence happened at a slow rate reaching to the same steady state, while applying the fixed effect method (like N. Islam (1995)) the speed of convergence was higher and reached to a different steady state. It is true that by using the fixed effect methods he takes care of country specific affects but he did not consider time specific effects. The other problem with his study is that he assumed that all the explanatory variables are exogenous, so he ignored the problem of endogeneity of some variables that could lead to unbiased results.

Furthermore, F. Caselli et al. (1996) used the generalized method of moments for estimating (Arellano-Bond GMM) convergence rate across 98 countries between 1960 and 1985. In their study, the convergence rate was around 10% instead of 2%, which was common in cross sectional analyses.

In their study they addressed two sources of inconsistency compared to cross country analysis. One concerns the incorrect treatment for country specific effect, which leads to biased results. Second, in empirical cross country growth regression, all the variables account as exogenous, which raises the problem of endogeneity, because some of the variables are expected to be endogenous in the model. Therefore, the generalized method of moments takes care of these problems and gives robust results.

Now, here in this study, as we will describe in detail in chapter six, dynamic system GMM is used to test the convergence hypothesis in terms of GDP per capita and productivity in the neoclassical and fully endogenous growth models, to show which of the variables can explain the different growth rates across countries and what is the convergence rate for each group. In the next chapter we are going to talk about the role of human capital, globalization and institutions in the growth and convergence process.

4.5 Summary

There are a few ways through which we can classify and compare between studies. One is within and between countries, while another, which we are using, is cross section vs. time series vs. panel methods. We reviewed some important studies done in this field and highlighted the shortcomings of each method. Finally, we came to the conclusion that the dynamic system GMM is the best method because it gives the most robust results among the methods based on our sample. In addition, we showed in this chapter that most of the studies focused on high-income countries and some selected developing countries. Therefore, this research tries to cover other groups of countries as well as high-income countries and put them in four groups: whole sample, low-income, middle-income and high-income countries, to see how convergence happened in these different groups of countries and also compare them together. The other important contribution concerns the determinants of growth. The next chapter focuses on human capital area, globalization phenomenon, institutions and technology transfer and presents the studies done in these areas and introduces new comprehensive proxies for each area, which makes this research richer that the others.

Chapter 5

The Role of Human Capital, Institutions and Globalization on Growth and Convergence

5.1 Introduction

In the recent empirical studies it is accepted that technological change and physical accumulation alone cannot adequately explain the differences in economic growth across countries. The question as to which factors can explain these differences together with the question as to which factors can accelerate the growth rate of developing countries remains an important issue up to now. Therefore, there is a sharp focus on the factors that can contribute to growth. In recent literature, human capital, institutions and globalization are separately becoming the important factors that can explain the economic growth fluctuations. What we want to do here is review the past studies in each field and highlight the gaps that exist in them.

This study looks at these three areas according to the two different classes of model: neoclassical model and new growth theory. In the neoclassical model, according to the assumptions, human capital accumulation is important for growth as well as physical capital accumulation. Now we want to look at the factors that can increase the accumulation of human capital. In previous studies investing in education was highlighted. By introducing new growth theories, innovation and imitation are also important. Here, we reconcile the theory of neoclassical growth with these new factors that should contribute to growth. Institutions and globalization can increase the human capital accumulation. The more a country is open, the more it can observe advanced technology through FDI and international trade. Therefore, this item can be considered as an accelerator for observing technology. The other area that is important in accelerating technology diffusion is the role of institutions. When the rules are not respected or they are changed frequently or there is no protection for property rights there is uncertainty, which leads to a fall in investment – domestic or foreign – which can be a channel through which technology imports affect the economic performance J. Benhabib and Spiegel (1997); Fernandez and Rodrik (1991); D. Rodrik (1998); Tornell and Velasco (1992). By having proper institutions, countries that are far from the technology frontier can take advantage of this backwardness and can grow faster by adopting new technologies.

In new growth models, as creation and imitation become very important, we highlighted the role of human capital in each of them and especially the role of institutions and globalization as facilitators and accelerators of the imitation (absorptive capacity) rate.

5.2 History of Human Capital as a Factor Explaining Growth

The reference to human capital in studies of convergence has its roots in the related areas of labour economics and the theory of the firm. Mincer (1958), Schultz (1961), Becker (1994) and Denison and Poullier (1967) pioneered the concept of "human capital" into labour economics. Schultz (1961) emphasized the role of education in enhancing the ability of individuals and thereby boosting the economic productivity. Denison and Poullier (1967) were the other researchers who argued about the importance of human capital. They indicated that improving the level of knowledge of workers directly influences his/her performance through which they can learn newer production processes better than the uneducated ones.

At the macroeconomic level, R. J. Barro (1991) selected a sample of 98 countries for the period of 1960-1985 and noted the important influence of human capital in economic growth and convergence based on the neoclassical growth model. First, he tested convergence in GDP per capita for the selected 98 countries, but he did not find convergence and there was no relationship between initial GDP per capita and the growth rate over the period. Subsequently, he included primary and secondary school enrolment in the model as proxies for human capital. By adding these variables to the model, convergence appears. This result means that a sufficient level of human capital boosts the growth rate in poor countries. N. G. Mankiw et al. (1992), in testing the convergence hypothesis, also added human capital to the model as well as physical capital. Adding this explanatory variable to the model provides an explanation to the question of why some countries are poor while others are rich. The model that they used, which included human accumulation, predicted that convergence can take place in 35 years; meaning that countries reach their steady state in 35 years, while the Solow model predicted that countries reached their steady state in 17 years.

Evans and Karras (1996) examined the speed of convergence in 48 states in the US, which are near each other. In their paper they considered that only having physical capital as a production factor is not useful. Therefore, they added human capital to their model and estimated it with respect to the neoclassical growth model and found convergence. However, in contrast, Nazrul Islam (1995), using the same model as N. G. Mankiw et al. (1992), found a negative and insignificant effect of human capital on growth. F. Caselli et al. (1996) also found a negative significant effect for human capital on growth. Adding this additional variable started a new argument among economists. Economists like F. Caselli et al. (1996), and Bond, Hoeffler, and Temple (2001) stand contrary to this view and argue that "the relevant notion of capital is restricted to physical capital only" F. Caselli et al. (1996).

F. Caselli et al. (1996) argued that what R. J. Barro and Lee (2000) had mentioned about conditional convergence rate was inconsistent. They believed that countries cover more than 2 per cent of their distance from the steady state each year. In other words, countries converge at the rate of 2 or 3 per cent per year (F. Caselli et al., 1996). F. Caselli et al. (1996) believed that the estimation procedures were inconsistent, and, therefore, the coefficients and result were unreliable. The rate of convergence that he got from his investigation was 10%. The inconsistency that he spoke about has two explanations: endogeneity and omitted variable bias. Eliminating this biasness made the results different from before. For example, N. G. Mankiw et al. (1992) estimated the capital share in output of 0.75. Since this was too high, relative to the national-account figure of about 1/3, they rejected the model in favour of an augmented version that includes human capital in the production function. Instead, with his procedure he find a value of 0.10 for the capital share in the basic model, which is too low (F. Caselli et al., 1996). Therefore, they rejected the augmented Solow model. However, Kumar and Russell (2002), in their study, divided growth productivity into three components – technical, efficiency change and capital accumulation. They found that the growth rate of these countries was initially dependent on the human and physical capital accumulation, and they also found that capital accumulation (physical and human) was an important factor in economic convergence but not technological progress. In other words, as long as the economic convergence is considered, EU countries tend to converge of course with respect to physical and human capital accumulation and it seemed that focusing on technological progress leads us to divergence. Furthermore, Marelli and Signorelli (2008) examined the role of human capital in the European countries. In their paper they tried to explain the differences in productivity across EU countries by adding human capital to the growth model. They found that the education sector of an economy can be a “key factor of productivity differences”.

Djistera (2006) also tested "the role of human capital in the Asian countries". The results indicated that the level of human capital has a positive effect on economic growth and convergence process. They emphasized the role of a highly educated workforce in their study and mentioned "the quality of labour played particularly an important role in the outward orientation growth strategy through its impact on the quality of merchandise exports".

Highlighting the role of technology and knowledge on growth and trying to explain the different growth rate across countries through the channel of technology, makes the concept of human capital more important. Human capital becomes a source of imitation and innovation, which are stock of knowledge and important for growth. Economists like R. R. Nelson and Phelps (1966), Grossman and Helpman (1993), R. J. Barro and Lee (1994), and P.M. Romer (1986) emphasized the effect of human capital on growth through innovation as well as the level of human capital. In contrast to Lucas (1988), who argued that human capital accumulation is a main source of growth, they argued that the stock of human capital is important for the country not only to enhance its own technological innovation but also to increase its capacity to adopt these technologies from frontiers, and, therefore, accelerate their growth (Raiser et al., 2001). Human capital can generate new ideas and these new ideas induce technological progress. Therefore, the level of education and skill of the labour force becomes important in studies.

In recent studies it can be seen that the composition of human capital has become very important (P. Aghion & P. Howitt, 2006; Krueger & Berg, 2003; N. G. Mankiw et al., 1992; Raiser et al., 2001; J.D. Sachs, 2003; Solow, 1956). R. Islam (2010), in his paper, applied different levels of education – initial, secondary and higher – and his results showed that poor countries with no skilled workers cannot take advantage of technology or absorb technology from frontiers. He concluded that, "advanced countries are more likely to engage in innovating new technologies which require highly skilled human capital". In the new growth theory a country that has the highest TFP is known as a country leader and countries far from the technology leader can take advantage of this backwardness and grow faster. This is known as the technology catch up theory. However, as mentioned originally by Abramovitz and David (1996), being far away from the technology leader does not guarantee the catch up progress unless they have sufficient social capital including education. Investing in human capital could increase the rate of innovation in technology in developed countries (P. Aghion & P. Howitt, 2006). Therefore, the role of education has become very important and policies enhancing education are very important to close the gap between the rich and poor (J. Benhabib & Rustichini, 1991). As R. Griffith et al. (2004) argued in their paper, innovation and R&D intensity play an important role in explaining the growth rate. However, this does not mean that countries that do not have highly educated labour to innovate cannot take advantage of this knowledge; the technology can transfer through other channels like the ability to imitate (absorptive capacity), international trade and FDI. In the debate on technology transfer, again human capital becomes important. The ability of a country to absorb technology is dependent on its human capital level. Furthermore, R&D and other factors like institutions and trade can improve the absorptive capacity of a country.

This study tries to look at the debate of human capital through the two different classes of model: neoclassical model and new growth theory.

In the neoclassical model, according to the assumption, human capital accumulation as well as physical capital accumulation is important for growth. Now we want to look at the factors that can increase the accumulation of human capital. In previous studies, investing in education was highlighted. By introducing new growth theories, innovation and imitation are important as well in explaining the growth. Here we reconcile the theory of neoclassical growth with these new factors that should contribute to growth. Institutions and globalization can increase the human capital accumulation. The more the country is open, the more it can observe advanced technology through FDI and international trade. Therefore, this item can be considered as an accelerator for observing technology. The other area that is important in accelerating technology diffusion is the role of institutions. By having proper institutions, countries that are far from the technology frontier can take advantage of this backwardness and can grow faster by adopting new technologies.

In the new growth models, as creation and imitation become very important, we highlight the role of human capital in each of them, and, especially, the role of human capital in increasing the absorptive capacity.

5.3 Institutional Factors in Economic Growth and Convergence

As argued by D. Rodrik, Subramanian, and Trebbi (2002) the quality of institutions can be affected directly through three different ways: (1) "it reduces the informational asymmetries' problems; (ii) it contributes to lower the various types of risks, as institutions define and enforce property rights; and (iii) it raises greater restrictions on politicians and interest groups' actions, as institutions make them (more) accountable to citizens" (Dani Rodrik, Subramanian , & Trebbi, 2002). Also, De (2010) explained that "governance can also affect growth and income indirectly, through its impact on other determining factors such as trade, investments, infrastructure, and geography" (De, 2010). Therefore, this study uses six indicator proxies for good governance introduced by Kaufmann, Kraay, and Mastruzzi (2009): control of corruption, rule of law, regulatory quality, government effectiveness, political stability and absence of violence and finally voice and accountability. The definition for each variable is available in chapter six. It is expected that the relationship between each of the governance indicators and productivity will be positive, which means that improvement in governance increases the growth rate of countries. However, how does each class of model deal with the institutions phenomenon?

One important difference between the neoclassical and evolutionary growth theory is in the way that they look at institutions. "Neoclassical economists tend to see institutions as created through and operating as they do because of the maximizing behavior of economic agents, and prevailing institutions as an equilibrium configuration. In contrast, evolutionary economists tend to see the institutional structure as always evolving" (R. Nelson, 2007).

There is a class of model introduced by R. Nelson (2007), which was inspired by Schumpeter's model but in some dimensions different from the Schumpeterian model. What makes this model different from the Schumpeter' model is in identifying the role of institutional complexities of modern market economies.

Similar to the neoclassical models, in the first generation of the endogenous growth model, there is no place for these complexities. One reason for oversimplifying the role of institutions is to focus more on reforming the limitation of the equilibrium concept in the growth models. Therefore, economists did not pay enough attention to investigate the assumption that the institutions can effect growth. The theory that they worked with consisted of firms, households and markets. Firms employ inputs for producing outputs, households supply labour and consume final outputs and markets adjust prices to equal the supply and demand. To enter institutions into the model the relationships that exist among markets, their institutional and social structures and the way that they cooperate and trust each other should be recognized. The other important thing here is to identify the role of "non-market institutions" in the process of innovation. Developing institutional economics is a big step away from the Walrasian theory.

By bringing institutions into the growth model, Nelson made the theory capable of making sense out of the aggregate time series of output in terms of GDP per capita. He believed that "satisfactory theory" can explain growth through "co evolution of technologies, firm and industry structures and supporting and governing institutions" (Nelson, 2007, p: 8). Nelson mentioned that a successful development has all these features in addition to the role of government policies, which can have a positive or negative effect on the growth of countries.

Now, what is the perspective of the new growth theories about catching up and the convergence phenomenon? As said before, in the neoclassical theory, the accumulation of physical and human capital is very important. Neoclassical economists believe that as long as investment happens, they could have new technologies and new ways of doing things, even automatically. This point of view makes the new growth theory different. Although in the new growth models, investing in physical and human capital is very important to access new ways of doing things, it is not sufficient. Therefore, in this new growth theory, economists, like Nelson, Pack and Winter, believed that the main force of convergence is "Innovation and Assimilation": assimilation is the means of learning about what other successful countries have been doing in their process of development over time. As said above there is no doubt that capital accumulation is necessary for innovation; however, if the country does not have an effective institutional structure, innovation will stop.

The important question here is: how do the institutional factors affect economic growth and through which channels? One possibility is through political instability, this factor is a motivation for investment in economies, for instance if there is no protection for property rights in an economy, the investment will reduce and so will the FDI (J. Benhabib & Rustichini, 1991; Fernandez & Rodrik, 1991; Tornell & Velasco, 1992). Therefore, political instability has a negative effect on investment and as investment in an economy has a positive effect on growth; we can conclude that political instability has a negative effect on growth.

R. J. Barro (1991) used the number of revolutions and coups, and political assassinations as a proxy for political instability and showed that there is a negative relationship between political instability and growth. Levine and Renelt (1992) also tested the relationship between growth and revolutions, and coups, and the index of civil liberties as a proxy for political and institutional indicators. The results indicated that there is no relationship between growth and the political indicators. Mauro (1995), in his paper, examined the effect of bureaucratic inefficiency and political instability on the growth rate of countries. Their findings showed that political instability has a negative effect on growth; however, the effect of the index of bureaucratic inefficiency is insignificant.

Alesina and Perotti (1996) also examined the effect of political instability on growth. They used "the number of politically motivated assassinations, the number of people killed in domestic mass violence, the number of successful and attempted coups, and a categorical variable for whether the nation is a democracy or a dictatorship". The results indicated that the relationship is negative. In line with previous studies, X. X. Sala-i-Martin (1997) used different proxies for political and institutional indicators: law and order, political rights, civil liberties, number of revolutions, military coups and war dummies. The first three variables have a positive effect on growth while the rest have a negative effect on growth. Furthermore, Asteriou and Price (2001), Butkiewicz and Yanikkaya (2005); Carmignani (2003), in their papers, investigated the effect of political instability on growth, their results support the positive relationship.

Annett (2001); Bloom et al. (1998); Ellingsen (2000); Wayne Nafziger and Auvinen (2002), and Goldstone and Force (2005) used ethnic fractionalization as a proxy and showed that there is negative relationship between political instability and growth. Gastil (2002), in his study, indicated that civil liberties and political rights as proxies for institutional and political indicators have a positive effect on growth. Dreher (2003) used the same indicators as (Gastil), but the results were different. There was no significant effect on growth by these indicators.

D. Rodrik et al. (2002) investigated the quality of institutions on economies. The results were consistent with the theory in which better institutions have a positive effect on growth. Talukdar (2009) also examined the effect of institutional factors like law and order, democratic accountability and government stability, on growth. The results showed that there is positive relationship between institutional factors and growth.

The other possibility is through the channel of technology transfer (knowledge spillovers). As said before, R&D activities play an important role in accelerating the speed of innovation, and, finally, growth. However, empirical evidence shows that those countries that do not have sufficient human capital can also grow at a good rate. This matter highlights the role of imitation (absorptive capacity) and technology transfer. One of the important items that can help speed the pace of technology transfer and the ability to absorb technology from the frontiers is the role of institutions. Having proper institutions increases the chance for the countries behind the technology leaders to take advantage of this backwardness and grow faster. This means that countries that are far away from the technology leader, besides focusing on human capital and educating them, they should have an "appropriate institutional structure". The empirical studies of R. Nelson (2007) showed that those countries that could build appropriate institutions as fast as possible could be successful.

In previous studies most of the empirical studies use the structural and institutional change indicators of the European Bank for Reconstruction and Development (EBRD) as a proxy for institutions (Beck & Laeven, 2006; Eicher & Schreiber, 2005; Raiser et al., 2001; J.D. Sachs, 2003; Zeghni & Fabry, 2008). Some of the others, like Redek and Sušjan (2005), and Pääkkönen (2010) use the Heritage Foundation Index of economic freedom as a proxy for institutions, and, in some research, the results were insignificant and showed there is no relationship between institutions and growth. In this study, we employ different indicators for institutions, which were introduced by Kaufmann et al. (2009) and test two hypotheses: "in the new growth theory institutions have a positive effect on productivity through the channel of imitation (absorptive capacity) in high-income, middle-income and low-income countries" and "in the neoclassical growth theory, institutions have a positive effect on GDP growth through the accumulation of more human capital in high-income, middle-income and low-income countries".

Institutions affect growth through governance. According to Kaufmann et al. (2009), the governance indicators that they introduced are the best proxies, which they define as "Governance consists of the traditions and institutions by which authority in a country is exercised. This includes the process by which governments are selected, monitored and replaced; the capacity of the government to effectively formulate and implement sound policies; and the respect of citizens and the state for the institutions that govern economic and social interactions among them" (Kaufmann et al., 2009).

Nowadays, the role of policies and institutions are very significant in the debate on growth since having an efficient market needs good governance structures. Therefore, the major goal of governance is to enhance the condition of the markets (Kaufmann, Kraay, & Zoido-Lobatón, 1999; North, 1990).

5.4 Globalization, Economic Growth and Convergence Progress

As long as the consideration is about the economic growth and convergence across countries in the world, the debate of globalization arises. In this area there are two different ideas: one is supporting the positive force of globalization on decreasing the income gap across all countries, while the other idea is that globalization is a malignant and useless force for poor countries and that it only works for rich countries. In previous studies some of the authors like X. Sala-i-Martin (2002), D. Dollar and Kraay (2004), Bhagwati and Srinivasan (2002), Agénor (2004), Ganuza, Morley, Pineiro, Robinson, and Vos (2005), and Neutel and Heshmati (2006) consider this phenomenon as an accelerator of growth, which leads to income convergence. They believed that the only thing that a country needs to do is simply open up its borders, reduce tariff rates, and attract foreign capital. Therefore, the poor will become rich and inequality will disappear as the poor countries catch up with the rich.

However, some studies, like the one done by Slaughter (1997), show that trade liberalization leads to income divergence. D. Rodrik (1998), like Slaughter (1997), also did not find any effect of capital account openness on growth rate. In addition, economists like Tsebelis and Garrett (2001), when grouping countries into two groups, rich and poor countries, found that the effect of FDI is positive on growth but only in rich countries. Milanovic and Squire (2005) in their studies, also indicate that globalization only affects the rich and industrialized countries and cannot help poor and developing countries in the process of converging to the rich. Carkovic and Levine (2002) also found no relationship between foreign direct investment and growth. Nandakumar et al. (2004) found that trade and capital account liberalization has actually hurt the low-income countries, only benefiting higher income countries possessing stronger initial conditions in regard to infrastructure and human capital.

In these studies for measuring globalization, most researchers only focussed on the economic aspects of globalization and used variables like trade, capital flow and openness as proxies for globalization, and, usually, also relied on the neoclassical growth theory and its assumption. Furthermore, most of them used cross sectional analysis, which does not consider time in their method, and also does not solve the problem of endogeneity, like the studies done by Alesina and Perotti (1996); Blomström, Fors, and Lipsey (1997); Chanda (2005); D. Dollar and Wolff (1993); Frankel and Romer (1996); G. Garrett (2000); Grilli and Milesi-Ferretti (1995); D. Rodrik (1998). However, after becoming aware of the shortcomings of this method, economists started using new methods like time series and sophisticated panel data, which consider both time and unit, such as fixed effect, random effect and first difference GMM. However, they still only focused on the economic aspects of globalization and some of the results were still inconsistent with the theories. According to Dreher (2003), what is important to highlight in this area is examining the results of globalization on growth in “greater detail”. These inconsistent results might be because of the omission of other important aspects of globalization from regression (Dreher, 2003). Since the different dimensions of globalization are strongly related to each other, putting them separately into the model might cause a collinearity problem while omitting them could bias the results. Therefore, as what is more important here is the overall effect of globalization on growth, this study is going to contribute to the literature by using the new proxy for globalization introduced by Dreher (2003). As

Dreher (2003) said, globalization is not only about the economic aspects. Dreher (2003) introduced an index in which two other dimensions of globalization are considered: social integration, and political integration. This index was named the KOF index and is calculated for 158 countries in the world, which Dreher (2003) used for ranking countries. This index was updated every year and available on the website of the “KOF index of globalization” until 2008. Details of the index are available in the table (1) in the appendix. Before Dreher, A.T. Kearney/Foreign Policy (2002) calculated the overall index for globalization; however, their index has some problems. For example, some important dimensions of globalization are omitted and it was only calculated for three years, and, hence, it cannot be used for empirical investigations.

5.5 Summary

For decades the economic growth and its determinants have been the centre of attention. Why are some countries poor while others are rich? What causes growth in economies and which factors can accelerate this growth? Why can some countries catch up with the rich ones while others are trapped in the low-income level? These questions have led economists to conduct empirical studies to find a proper answer. This chapter tries to highlight the important areas that can contribute to economic convergence and growth: human capital, globalization and institutions. Governance indicators and the KOF index are the most comprehensive ones that can be found in databases that are ignored in recent studies for testing convergence. Therefore, in this research we apply them in our models by focusing on capital deepening accumulation and technological catching up theories.

Chapter 6

Research methodology, model specification and data

6.1 Introduction

As discussed in the previous sections, the importance of this study is its reopening of the debate on innovation and imitation. In respect of the innovation issue, the ability of a country to create and innovate new products is important, and, in imitation, the ability of a country to observe technology from advanced economies (absorptive capacity) becomes important. In this study, we contribute to the literature by introducing institutions and globalization indicators as accelerators of absorptive capacity. Furthermore, we applied these new aspects of innovation and imitation in the neoclassical growth regression through the human capital channel and reconcile the neoclassical regression with these factors. Now this chapter is going to describe the estimation method and the sample and data that are going to be used in this study. This chapter will be divided into 6 sections. The next section is a description of the estimation method in this study. The third section concerns the model and the variables used in the study, which are in two parts. The first part belongs to the new endogenous growth models while the second part concerns the neoclassical growth models. Then the variables applied in the research are defined and the expected sign described. Furthermore, the sources of data and list of countries that have been estimated are listed. Finally, the fourth section presents the research hypotheses.

6.2 Estimation Method

In the previous studies, researchers like R. J. Barro and X. Sala-i-Martin (1992), and N. G. Mankiw et al. (1992) used cross sectional analysis, which failed to address some problems. In cross sectional analysis, it is clear there is no place for showing the effect of time variation, therefore, since the economic growth is a process happening over time it is necessary to use an alternative method for showing the effect of variables over time. In addition, they did not account for the problem of endogeneity and omitted variables and country specific effects. The nature and structure of countries are different; therefore, it is far from reality to assume that countries are homogenous. Hence, in order to solve these problems and have more accuracy in estimations, panel methods are used. Panel data have some advantages compared to cross sectional data and time series data. Both the time series and cross section only consider one dimension: time and individual, respectively. However, panel data considers at least both dimensions – time and individual – which provides "more informative data, more variability, less co linearity among variables, more degrees of freedom, and more efficiency" (Gujarati, 1995).

Another advantage of using panel data is behind the power of analysing and evaluating policies and programmes. "One can better assess the impact of economic, political, institutional, and social policies and programs because the same cross-sectional units are observed in each time-period" (Papke & Wooldridge, 2008). R. J. Barro and Lee (1994) and R. J. Barro and X. Sala-i-Martin (1995) tried to solve the problem of endogeneity. Although they could solve the problem of serial correlation, the problems of "inaccurate standard error" and "correlated individual effects" still remain. M. Knight et al. (1993) and N. Islam (1995) tried to solve the problem of correlated individual effects. However, they ignored the problem of endogeneity. The problem with their method is that it is only applicable if all the explanatory variables are strictly exogenous and if some of the variables are predetermined or endogenous; there is a correlation between the explanatory variable and the error term, which make the results biased.

For solving these problems, scholars like Holtz-Eakin, Newey, and Rosen (1988), and Arellano and Bond (1991) developed an estimator for dynamic panel data models named first differenced generalized method of moments. In addition, F. Caselli et al. (1996) applied their method for the first time in growth literature, after which, many scholars used similar methods like J. Benhabib and Spiegel (1997); Jess Benhabib and Spiegel (2000), Easterly and Levine (1997), and Forbes (2000) in their research. However, this method has its own shortcomings, inasmuch as it behaves poorly when the time series are persistent, because the lagged levels of the variables, which are used as weak instruments for subsequent first difference, still correlate with the error term. Therefore, to solve this problem, Arellano and Bover (1995), and R. Blundell and Bond (1998) developed an estimator named system GMM. This estimates a system of equations in both first differences and levels, where in the levels equations the lagged first differences of the series are used as instruments and for the difference equation the lagged two period or more of the dependent variable and first differences of the series are used as instruments. Therefore, by using sysGMM the estimates are no longer biased by any omitted variables and there is no problem of endogeneity. Furthermore, by taking first differences the problem of the country specific effect is also solved.

Pedroni (2008), in his workshop in the IMF, discussed how to choose the best estimator for the panel dataset. He argued that the proportion of the number of individuals to the length of time (N/T) could be a good way for choosing the best method. He suggested that if the time series is short relative to individuals, fixed effect, generalized method of moments (GMM), system generalized method of moments (sysGMM) are the best estimators to apply for estimation amongst the others. For these panel datasets with the short time series, it is assumed that the data are stationary and so there is no need to do a unit root test. Using instruments variables are valid including owns lagged. However, in the cases where lagged dependent variables are included in the model, there is no place for fixed and random effects estimators and GMM is the best one.

Statistical diagnostics play an important role in identifying the validity of the results of estimations. In the OLS method, the estimator should be BLUE and there are some assumptions like normality, homoscedasticity, and non-autocorrelation, which, together, make the method reliable. However, System GMM allows for heteroscedasticity in data and the distribution of error terms should not necessarily be normal. As Baltagi (2009) argued in his book, dynamic panel models have a problem with heteroscedasticity of data; however, it can be controlled (Baltagi, 2009), p. 144). In dynamic system GMM, as the instruments are applied, the Sargan test is used for testing the correlation between the error tem and the instruments and the null hypothesis is whether the instruments are valid in the sense that they are not correlated with the error term in the first difference equation. If the Sargan test is rejected it means that the overidentifying restrictions are not valid so the instruments are not valid. For testing the residual serial correlation, there are the AR(1) and AR(2) tests, where the null hypothesis of each test is that the test should reject the null of no first order serial correlation, however, it should not reject the null that there is no second-order serial correlation (Baum, Schaffer, & Stillman, 2007; Roodman, 2006)

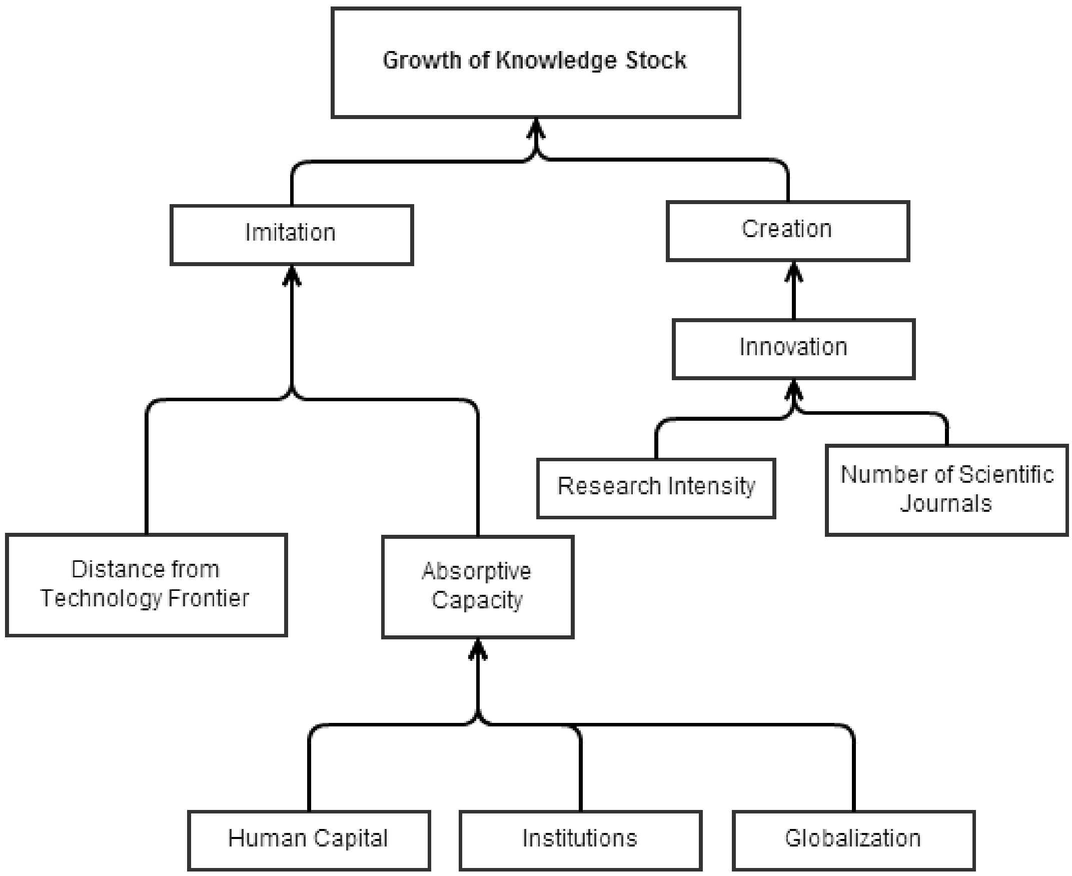
6.2.1 A Consistent Estimator for Growth Regressions

In this section we describe the growth regression that we derive from the Solow-Swan model and also from the new growth theory to be estimated by system GMM. The first section describes the first model, which is the new endogenous growth model. The second model describes the extended neoclassical growth model.

6.2.1.1 Estimating the New Growth Model by System GMM

The following chart shows the framework that we follow to insert variables into the model:

Figure 6-1: New growth model framework



In this class of models for explaining convergence, according to Paul M Romer (1986), P Aghion and Howitt (1998), and Charles Jones (1998), the stock of knowledge is very important in explaining the growth rate of countries in addition to accumulation of human capital. Therefore, we added two components of knowledge stock to the model: imitation and innovation. In addition, in the imitation part we focused on the role of institutions and globalization factors plus human capital and try to show their effect through the channel of absorptive capacity.

By combining the new growth theory with the empirical evidence of the role of creation and imitation the following equation is derived as the growth equation in our study (Castellacci, 2011).

$$\Delta y_{i,t}/y_{i,t} = (\gamma + \beta_4)logINO_{i,t} + (\beta_1 + \propto_1)logHC_{i,t} + \beta_2 logINS_{i,t} + \beta_3 logGLOB_{i,t} + \mu \text{log} y_{i,t-1} + \theta FC_{i,t} - \zeta_t + \rho_i + v_{i,t} \quad (6\text{-}1)$$

Since Y_F is constant across countries we can put it as a constant term, which can differ over time ζ_t (time dummy).

Where:

$\Delta logy_{i,t}$is annual GDP per capita growth rate between 1996 and 2010.

$\Delta y_{i,t-1}/y_{i,t-1}$is lagged annual GDP per capita growth rate between 1996 and 2010.

$logHC_{i,t}$ is annual Secondary school enrolment ratio

$FC_{i,t}$ is annual gross formation of capital

$logGLOB_{i,t}$ is annual index and FDI

$logINO_{i,t}$ is research intensity and number of scientific journals

$logINS_{i,t}$ is governance indicators

$logy_{i,t-1}$ is annual lagged level of GDP per capita (PPP, constant 2005 international $) between 1996 and 2010.

μ is convergence rate

ζt is time dummy

ρ_i Country specific effect

This equation is our guide to have a useful specification for empirical research. Using the cross sectional approach in previous studies just assumed away the cross-country specific and time affects across countries and assumes that countries are homogenous. Since this assumption is far from reality, in the case of this study, by using panel estimators there is a place for reflecting country specific effects (ρ_i) and period specific intercepts ζ_t, which captures things that are common in all countries like technology changes in the US. As can be seen, we indexed all of the variables by time to explore the changes of the variables during time in each country (i) rather than just across countries, this is the notion of panel data. Clearly the above equation (6-1) can be written as:

$$logy_{i,t} = (\gamma + \beta_4)logINO_{i,t} + (\beta_1 + \propto_1)logHC_{i,t} + \beta_2 logINS_{i,t} + \beta_3 logGLOB_{i,t} + (1+\mu)\text{logy}_{i,t-1} + \theta FC_{i,t} - \zeta_t + \rho_i + v_{i,t} \quad (6\text{-}2)$$

In addition, according to R Blundell and Bond.S (1998) , by taking first difference from equation (6-2) the country specific effects will be removed from the equation and so the assumption $\text{E}(\rho_i \Delta y_{i,t}) = 0$ is satisfied.

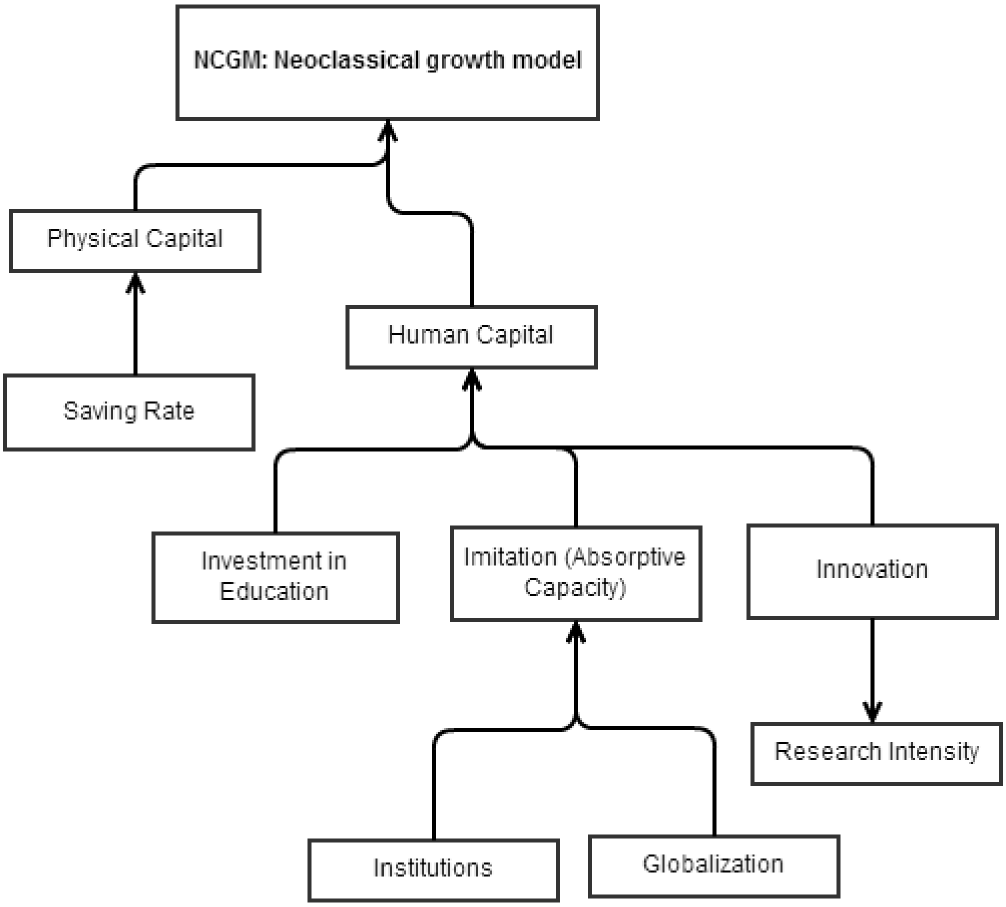
$$\Delta y_{i,t} = (\gamma + \beta_4)\Delta logINO_{i,t} + (\beta_1 + \propto_1)\Delta logHC_{i,t} + \beta_2 \Delta logINS_{i,t} + \beta_3 \Delta logGLOB_{i,t} + (1+\mu)\Delta\text{logy}_{i,t-1} + \theta \Delta FC_{i,t} - \zeta_t - \zeta_{t-1} + v_{i,t} \quad (6\text{-}3)$$

It should be highlighted here that this assumption does not imply that the country specific effect does not have any effect on growth, however, these effects will be presented in the model by other steady state determinates, like investment rate and physical capital. This assumption means that there is no correlation between economic growth and the country specific effect in the absence of other variables.

6.2.1.2 Estimating the Neoclassic Growth Model by System GMM

The following chart shows how we apply the variables to the model.

Figure 6-2: Neoclassical growth model framework



As can be seen, human capital can be accumulated through four channels in this study:

1- investment in education, the most common proxy for human capital accumulation,

2- globalization (through technology transfer), for late-comer countries,

3- institutions (through imitation or increasing absorptive capacity), and

4- innovation (through investing in R&D activities)

Part of GDP is going to be invested in education, which leads to the formation of human capital. Therefore, secondary school enrolment as a proxy for investment in primary education is added to the model and the number of scientific journals can be a proxy for higher level of education. Another way of accumulating human capital is through technology spillovers and absorbing new technologies as these need a certain level of human capital. Globalization, particularly in the form of FDI, is a way for technology spillovers to take place. Globalization is multi-dimensional, even if limited to economics. It covers trade, capital flows, migration, but, very importantly, technology transfer. The KOF index covers the dimensions of political, social and economy. Furthermore, institutions, which become the important determinants of economic growth in recent literature, are the other channel for accumulation of human capital. These two concepts, institutions and globalization, are included in the model by considering the fact from the new growth theory that the absorptive capacity of a country can present a possibility for accelerated human capital accumulation(Bidlingmaier, 2007).

From chapter 3, we have equation (3-28), which is our guide for a useful specification for empirical research. As mentioned before, using the cross sectional approach just assumed away the cross-country specific and time affects across countries and assumes that countries are homogenous; since this assumption is far from reality, by using panel estimators there is a place for reflecting country specific effects (ρ_i) and period specific intercepts ζ_t, which captures things that are common in all countries. As can be seen, we indexed all of the variables by time to explore the changes of the variables over time in each country (i) rather than just across countries; this is the notion of panel data.

$$\Delta Ln(y_{i,t}) = (1-e^{-\lambda t})\frac{\beta}{1-\alpha-\beta}lns_{h,i,t} + (1-e^{-\lambda t})\frac{\alpha}{1-\alpha-\beta}lns_{ki,t} + (1-e^{-\lambda t})\frac{\pi\beta}{1-\alpha-\beta}\ln(1+GLOB_{i,t}) + (1-e^{-\lambda t})\frac{\vartheta\beta}{1-\alpha-\beta}\ln(1+INO_{i,t}) + (1-e^{-\lambda t})\frac{\rho\beta}{1-\alpha-\beta}\ln(1+INS_{i,t}) - (1-e^{-\lambda t})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n_{i,t}+g+\delta) + (e^{-\lambda t}-1)Ln(y_{i,t-1}) + \zeta_t + \rho_i + \varepsilon_{i,t} \quad (6\text{-}4)$$

And the general form of equation 6-4 is like the following equation:

$$\Delta Ln(y_{i,t}) = \theta_2 lns_{h,i,t} + \theta_3 lns_{ki,t} + \theta_4\ln(1+GLOB_{i,t}) + \theta_5\ln(1+INO_{i,t}) + \theta_6\ln(1+INS_{i,t}) - \theta_7\ln(n_{i,t}+g+\delta) + \theta_8 Ln(y_{i,t-1}) + \zeta_t + \rho_i + \varepsilon_{i,t} \quad (6\text{-}5)$$

Where:

$\Delta Ln(y_{i,t})$ is annual GDP per capita growth rate between 1996 and 2010.

$Ln\left(s_h\right)$ is annual secondary school enrolment rate

$Ln(s_k)$ is annual gross capital formation(%GDP)

$\ln(1+GLOB)$ is annual KOF index and annual foreign direct investment (%GDP)

$\ln(1+INO)$ is research intensity and number of scientific journals

$\ln(1+INS)$ is governance indicators

$Ln(n + g + \delta)$ is population growth rate plus 0.05, based on the assumption of the Solow model. (n is population growth rate, g is technology progress and δ is depreciation rate)

$Ln(y_{t-1})$ is annual lagged level of GDP per capita (PPP, constant 2005 international $) between 1996 and 2010.

ζ_t is time dummy

ρ_i is country dummy

Clearly the above equation (6-1) can be written as:

$$Ln(y_{i,t}) = \theta_2 lns_{h,i,t} + \theta_3 lns_{ki,t} + \theta_4 \ln(1 + GLOB_{i,t}) + \theta_5 \ln(1 + INO_{i,t}) + \theta_6 \ln(1 + INS_{i,t}) - \theta_7 \ln(n_{i,t} + g + \delta) + (1 + \theta_8) Ln(y_{i,t-1}) + \zeta_t + \rho_i + \varepsilon_{i,t} \quad (6\text{-}6)$$

And, according to R Blundell and Bond.S (1998) , by taking first difference from equation (6-6) the country specific effects will be removed from the equation and so the assumption $E(\rho_i \Delta y_{i,t}) = 0$ is satisfied.

$$\Delta y_{i,t} = \theta_2 \Delta lns_{h,i,t} + \theta_3 \Delta lns_{ki,t} + \theta_4 \Delta\ln(1 + GLOB_{i,t}) + \theta_5 \Delta\ln(1 + INO_{i,t}) + \theta_6 \Delta\ln(1 + INS_{i,t}) - \theta_7 \Delta\ln(n_{i,t} + g + \delta) + (1 + \theta_8) \Delta Ln\left(y_{i,t-1}\right) + \zeta_t - \zeta_{t-1} + \varepsilon_{i,t} \quad (6\text{-}7)$$

It should be highlighted here that this assumption does not imply that the country specific effect does not have any effect on growth; however, these effects will be presented in the model by other steady state determinants, like investment rate and physical capital. This assumption means that there is no correlation between economic growth and the country specific effect in the absence of other variables.

To make a comparison between this model and the augmented Solow model, G. Mankiw, D. Romer, and D. N. Weil (1992) argued that we consider two different models in our analysis. The first model is the augmented Solow model that includes human capital, and the second one is the model that we explained above. The first model can be derived from the second model by applying some restrictions to the second model: $\theta_4 = \theta_5 = \theta_6 = 0$

$$\Delta Ln\left(y_{i,t}\right) = \theta_2 lns_{h,i,t} + \theta_3 lns_{ki,t} + \theta_4 \ln(n_{i,t} + g + \delta) + \theta_5 Ln\left(y_{i,t-1}\right) + \zeta_t + \rho_i + \varepsilon_{i,t}$$

(6-8

This equation is the augmented Solow model. We test both these two equations (6-5) and (6-8) investigate the significant effect of each explanatory variable added to the Solow model on economic growth.

6.2.2 Data and measurement issues

For estimating equation (6-3) the data for GDP per capita growth rate, level of GDP per capita, gross formation of capital, secondary school enrolment ratio, FDI, KOF index, governance indicators, R&D inputs, TFP and product varieties are used. For estimating equation (6-4) population growth is added to the equation according to the assumption of the Solow-Swan model. The data included here are from low-income, high-income and middle-income countries, which are listed in the next section. The data covers the period of 1996 to 2010. The data are constructed as follows.

- **GDP per capita growth rate:** GDP per capita growth rate is used for testing the convergence process, as a dependent variable. The growth rate is calculated by subtracting the values of real GDP per capita from the values of previous year. According to the World Bank (2010) the definition of real GDP per capita is “the total value of the final uses of goods and services, plus exports and minus imports of goods and services produced annually by a country divided by the country's total population". The values are in constant 2005 international Dollar. The data is available from the World Bank database (2010).

- **Lagged level of GDP per capita** (PPP, constant 2005 international $)**:** according to the theory for testing the convergence hypotheses the initial level of GDP per capita (PPP, constant 2005 international $) should be added to the model as one of the independent variables to see whether or not developing and undeveloped countries can converge and catch up with the developed ones. The sign and statistical significant of this variable is very important since if it is negative it means that convergence is happening otherwise there is divergence. The values are in constant 2005 international Dollar adjusting for inflation by PPP. The data are available from the World Bank database (2010).

- **Formation of Capital:** according to the Solow model, and following G. Mankiw et al. (1992), gross capital formation is included in the model as another independent variable for physical capital accumulation. The data are available from the World Bank database (2010).

- **Population growth rate:** According to the Solow model population growth rate is added to the model as a proxy for labour supply and population age structure and following G. Mankiw et al. (1992) we add (0.05) to this rate as a reasonable assessment of the value of $(g+\delta)$. The data are available from the World Bank database (2010).

- **Human capital:** G. Mankiw et al. (1992) in their paper made a criticism about the standard Solow model and argued that the growth rate of countries cannot be explained by only considering physical capital, and, to solve the problem, they added human capital to the model. The variable that they considered as a proxy for human capital was school enrolment in primary and secondary. In this study, we want to contribute to the literature by incorporating three other aspects that can be considered as accelerators of human capital accumulation: globalization, institutions and innovation. These new aspects were introduced by the new growth theory through technology channel in the literature, but since we want to retain the assumptions of the neoclassical models, exogenous technology assumption, we applied them through the channel of human capital and count them as accelerators of human capital accumulation in the model. Therefore, we applied the following variables:

- **Secondary school enrolment ratio:** is included as an independent variable as a proxy for human capital. According to UNESCO the definition is "gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers". The data are available from the World Bank database (2010).

- **Total factor productivity growth rate:** According to the World productivity database (WPD), the definition of TFP is part of the changes in production that are not related to labour and capital inputs. For calculating the TFP growth rate, we are following "growth accounting",[3] which was inspired by Hall Jones' (1999) production function.

$$Y = A\,K^{\alpha}L^{1-\alpha} \quad (6\text{-}5)$$

[3] "Growth accounting" is a procedure used in economics to measure the contribution of different factors to economic growth and to indirectly compute the rate of technological progress, measured as a residual, in an economy. This methodology was introduced by Robert Solow in 1957

Where, Y is real GDP, k is capital stock, L is labour force and α is share of income in capital stock, which is assumed to be constant.

By dividing equation (6-5) by L, we can examine how much of the variation of Y can be explained by the observed factor as K and how much by unobserved "residual" factor as TFP. Therefore, we have the following equation:

$$y = Ak^{\alpha} \qquad (6\text{-}6)$$

And from this equation we can estimate TFP:

$$A = TFP = \frac{y}{k^{\alpha}} \qquad (6\text{-}7)$$

The share of capital is assumed to equal to 0.30. For estimating TFP the amount of capital stock is needed, which is not available from the World Bank dataset or Penn World table (PWT). Therefore, following Francesco Caselli, Gerardo Esquivel, and Fernando Lefort (1996)'s method, the equation for capital accumulation is as follows:

$$K_{it} = I_{it} + (1 - \delta)K_{i,t-1} \qquad (6\text{-}8)$$

Where, K is the amount of capital, δ is depreciation rate assumed to be 5% according to Bosworth and Collins (2003), I is investment, i denotes country and t is for time period.

According to Griliches (1996) and Lee and Guo (2004) , for having initial capital stock we can estimate the following equation:

$$K_{t-1} = \frac{I_{t-1}}{g+\delta} \qquad (6\text{-}9)$$

Where, g is economic growth measured by annual average of real GDP over 1960 to 2010.

- **R&D:** This study drives R&D from R&D expenditure, because the data for R&D expenditure are available for most of the countries. Timing R&D

expenditure by GDP per capita (PPP, constant 2005 international $) divided by 100 gives the R&D input. According to the World Bank, R&D expenditure is "the gross domestic expenditure on R&D (GERD) is composed of the combined expenditures of business enterprise, higher education, government, and private non-profit sectors and is expressed as a percentage of GDP in constant 2005 dollar".

- **Product varieties:** According to the Schumpeterian growth models, employment (P Aghion & Howitt, 1998; J Ha & P Howitt, 2007) and GDP (Krugman, 1994) are usually measures of product variety. In this study we run the models by applying both, and because the results are more promising using employment we use that one accordingly.

- **Research intensity:** For measuring research intensity, R&D input should be normalized. This study follows J Ha and P Howitt (2007) and Madsen (2008), so R&D input is divided by employment (population) and TFP for measuring research intensity.

- **Number of scientific journals:** are included as an independent variable, which affect human capital accumulation. According to the World Development Indicators (WDI 2010) database this variable refers to scientific articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, engineering and technology and earth and space sciences. The data are available from the World Bank database (2010).

- **Globalization (GLOB):** KOF index and FDI are included as independent variables, which affect human capital accumulation. What we contribute to the literature here is using an alternative factor, KOF index, instead of applying trade and openness as proxies for globalization. Since in the recent growth literature it is very important to consider trade as a flow of ideas and goods instead of just considering it as the flow of goods, in this study we are going to use the index introduced by Dreher (2003) that covers all of these aspects. The advantage of this index is that it covers three different dimensions: economic integration, political integration and social integration.

- **KOF index:** is included as an independent variable as a proxy for globalization. According to Dreher (2003), the KOF index "is covering three most important aspects: economic integration, social integration and political integration. To measure these dimensions, 23 variables have been combined to three sub-indexes using an objective statistical method" (Dreher, 2003). The values are between zero to ten scales. The higher the value the more open the economy.

- **Foreign direct investment (FDI):** is included as an independent variable as a proxy for globalization. According to the World Bank website: "Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors. Data are in current U.S. dollars."

- **Institutions:** Governance indicators are included as independent variables, which affect human capital accumulation. As the role of governance – as a proxy for institutional factors – is often cited as the missing link in the recent growth literature, the current study aims to clarify these effects. Kaufmann et al. (2009), on a research project, introduced indicators that covered 212 countries and measured six dimensions of governance. The data are available on worldwide governance indicators in Worldwide Governance indicators (WGI), World Bank database 2010. We cannot add all of these six dimensions into one equation because the results of the pairwise correlation test, which are shown in the appendix, indicate that these six indicators are highly correlated with each other, so they should be added separately to the model[4]:

- **Voice and accountability(G6) :** "Captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media" (WGI, 2010).

- **Political stability and absence of violence (G3):** "Measures the perceptions of the likelihood that the government will be destabilized or overthrown by unconstitutional or violent means, including domestic violence and terrorism" (WGI, 2010).

- **Government effectiveness(G2):** "Captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies" (WGI, 2010).

- **Regulatory quality (G4):** "Captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development" (WGI, 2010).

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[4] - The methodology of calculation of these indicators can be found on the appendix

- **Rule of law (G5):** “Captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and, in particular, the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence” (WGI, 2010).

- **Control of corruption (G1):** “Captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests” (WGI, 2010).

Table 6-1 shows all the variables used in the model with their expected signs.

Table 6-1: Expected signs of variables

Independent variables	**Signs**
Ln. GDP per capita	Negative
Gross capital formation (% of GDP)	Positive
Population Growth	Negative
Secondary school enrolment	Positive
Number of Scientific journals	Positive
FDI	Positive
KOF index	Positive
R&D intensity	Positive
Government Effectiveness	Positive
Regulatory Quality	Positive
Rule of law	Positive
Voice and accountability	Positive
Control of corruption	Positive
Political stability and absence of violence	Positive

According to the initial works of R. Barro and Sala-i-Martin (1995), the relation between GDP per capita growth rate and initial level of GDP per capita is negative. Many economists after them confirm this negative sign; therefore, I also expect to find a negative relationship between GDP per capita and TFP and respective growth rates.

The relationship between the formation of capital, economic growth and convergence is expected to be positive. Solow believed that the saving rate is constant, however, others like Cass (1965) and Koopmans (1965) considered it as an endogenous factor, which affects economic growth. In addition R. J. Barro (1991) discussed that more savings shift the level of steady state upward, which increases the growth. Moreover, several studies like those done by G. Mankiw et al. (1992), Bassanini and Ernst (2002) and Ederveen, Groot, and Nahuis (2006) approved the positive effect of saving rate on economic growth.

Population growth rate is a key factor to show the structure of age in an economy and also indicates the amount of labour supply in an economy. According to Solow (1956), the more population growth, the less capital-labour ratio an economy has, which reduces investments in that economy. G. Mankiw et al. (1992), and S. Ederveen, H.L.F. Groot, and R. Nahuis (2006) show that population growth has a negative effect on growth. This research is also expecting a negative sign for population growth on growth.

Paul M Romer (1986), in his research, discussed the role of human capital on growth and considered it as another engine of growth. After him, several people worked on this area and proxied different variables for measuring human capital. In general, it is difficult to find an adequate proxy for this factor. School enrolment rate is used by G. Mankiw et al. (1992), R. J. Barro (1991) and R. Barro and Sala-i-Martin (1995). This study uses the secondary school enrolment variable as a proxy for human capital to examine the effect of each on growth and to determine the effect of it on convergence process. This is expected to have a positive sign.

The KOF index and foreign direct investment are used as proxies for globalization. The expected sign is positive for this group of indicators. Dreher (2003) introduced the KOF index, which includes three sub-indexes: economic integration, political integration and social integration. In his paper he concludes that, in general, globalization can promote growth. Here, in this study, we use these two indices to show their effect on the growth and convergence process. Kottaridi (2005), Krueger and Berg (2003), and D. Dollar and Kraay (2004) found a positive relationship between trade and growth. We also expect to find a positive relationship. For FDI, some researchers argued that there is a positive relationship between this and growth in countries that are rich Blomström et al. (1997), while others believe that there is negative relationship between them in low-income countries (Geoffrey Garrett, 2000). In this research we investigate this relationship according to three groups of countries with different levels of income.

According to several economists, such as Cappelen, Fagerberg, and Verspagen (1999), and Bassanini and Ernst (2002), research intensity is an item that can increase productivity, and, therefore, growth through improving technology. However, an important matter here is a good combination of labour force and technology progress. Human capital should have sufficient skills to use these technologies (Miles & Scott, 2002). Therefore, here we expect to find a positive relationship between research intensity and growth.

Political and institutional factors are also very important in growth. As explained in the literature review, economists use several indicators for the proxy. However, here, for the first time, we want to examine the effect of six different variables, named as governance indicators, which were introduced by Kaufmann et al. (2009).

6.2.3 Sources of Data and List of countries

6.2.3.1 Sources for Data

The sources of data used for analysis consist of:

- World Development Indicators, 2010: “World Development Indicators” (WDI) is the primary World Bank database for development data from officially-recognized international sources. The WDI includes data from 209 countries spanning from 1960 to 2010. It presents the most current and accurate global development data available, and includes national, regional and global estimates.” (World Bank, 2010). This database covers 16 topics including:

  1. Agriculture and rural development
  2. Infrastructure
  3. Aid effectiveness
  4. Labour and social protection
  5. Economic policy and external debt
  6. Poverty
  7. Education
  8. Private sector
  9. Energy and mining
  10. Public sector
  11. Environment
  12. Science and technology
  13. Financial sector
  14. Social development
  15. Health
  16. Urban development

- The Worldwide Governance Indicators (WGI) project (1996-2010): the dataset includes six dimensions of governance for 213 economies over the period 1996–2010:
  - Voice and Accountability
  - Political Stability and Absence of Violence
  - Government Effectiveness
  - Regulatory Quality
  - Rule of Law
  - Control of Corruption

The dataset is available for 1986, 1998 and 2000 and annually from 2002 to 2010. The data collected through the responses of citizens and experts on the government quality. The range of tolerance for these indicators is from -2.5 to +2.5, the lower value belongs to the country with lower government quality.

6.2.3.2 List of Countries

This study has grouped countries as listed in table 6-1, which are divided based on their income-level based on World Bank classification in 2011.[5]

For high-income countries, OECD countries have been chosen, and, since the data was not available for most of the variables in Estonia and Korea Rep., these two were dropped from the sample. For low-income countries, Afghanistan, Somalia, Zimbabwe and Mauritania were dropped because there were no data for governance indicators and KOF index for these countries. Across middle-income countries (108 countries), 90 countries have been chosen and 18 countries dropped because the lack of data for most of the variables. These groups of countries, for which most of the data are available, are evaluated from 1996-2010.

Table 6-2: list of Countries in each group

High-income	**High-income**	**High-income**
Australia	Hungary	Poland
Austria	Iceland	Portugal
Belgium	Ireland	Slovak Republic
Canada	Italy	Slovenia
Czech Republic	Israel	Spain
Denmark	Japan	Sweden
Finland	Luxembourg	Switzerland
France	Netherlands	United Kingdom
Germany	New Zealand	United States
Greece	Norway	

[5] - For operational and analytical purposes, the World Bank's main criterion for classifying economies is gross national income (GNI) per capita. Economies are divided according to 2010 GNI per capita, calculated using the World Bank Atlas method. The groups are: low income, $1,005 or less; lower middle income, $1,006 - $3,975; upper middle income, $3,976 - $12,275; and high income, $12,276 or more.

Table 6-2: continued

Low-income	Low-income	Low-income
Bangladesh	Gambia, The	Niger
Benin	Guinea	Rwanda
Burkina Faso	Haiti	Sierra Leone
Burundi	Kenya	Tajikistan
Cambodia	Kyrgyz Republic	Tanzania
Central African Republic	Liberia	Togo
Chad	Madagascar	Uganda
Comoros	Malawi	Myanmar
Congo, Dem. Rep	Mali	Nepal
Eritrea	Mozambique	Ethiopia

Table 6-2: continued

Middle-income	Middle-income	Middle-income	Middle-income
Angola	Ecuador	Seychelles	Cameroon
Algeria	Jordan	South Africa	Cape Verde
Philippines	Kazakhstan	St. Lucia	Congo, Rep.
Antigua and Barbuda	Latvia	St. Vincent and the Grenadines	Côte d'Ivoire
Honduras	Lebanon	Suriname	Djibouti
Azerbaijan	Libya	Thailand	Egypt, Arab Rep.
Belarus	Lithuania	Tunisia	El Salvador
Bosnia and Herzegovina	Macedonia, FYR	Turkey	Albania
Botswana	Malaysia	Uruguay	Armenia
Brazil	Maldives	Venezuela, RB	Belize
Bulgaria	Mauritius	Samoa	Bhutan
Chile	Mexico	São Tomé and Principe	Bolivia
China	Namibia	Senegal	Cuba
Colombia	Indonesia	Solomon Islands	Dominica
Costa Rica	India	South Sudan	Dominican Republic
Papua New Guinea	Vietnam	Paraguay	Yemen, Rep.
Zambia	Fiji	Panama	Georgia
Peru	Ghana	Romania	Guatemala
Russian Federation	Guyana	Morocco	Tonga
Mongolia	Syrian Arab Republic	Nicaragua	Ukraine
Nigeria	Uzbekistan	Iraq	Sri Lanka
Pakistan	Vanuatu	Kiribati	Sudan
Moldova	Swaziland		

Note: This group is a combination of upper middle-income and lower middle-income countries

6.3 Research Hypotheses

Given the discussion of research objectives in chapter one the following hypotheses will be tested in this research for three groups of countries with different levels of income from the period 1996 to 2009.

Hypothesis 1: There is no difference in the explanatory power of the NCGM and NGM across the sample of countries. There is a big disagreement between these two schools of thought on the sources of growth: whether technological changes are the most important sources of growth or formation of capital.

Hypothesis 2: Convergence in middle- and low-income countries is faster than in high-income countries in both the neoclassical and new growth theories. According to the theories of convergence, in both theories, countries that are poorer and are far away from technology leaders tend to grow faster than rich ones or the leaders.

Hypothesis 3: Globalization, institutions and innovation factors have a positive impact on productivity growth (as components of knowledge growth) and have the fastest convergence speed in the sample of countries.

To show how different dimensions of technology evolved in past years, this study follows the standard analysis of testing convergence, β convergence, for innovation intensity, human capital, innovation, globalization and studies how their statistical distributions have evolved over the past thirteen years and which of them have the fastest speed among the others in each group of countries.

Hypothesis 4: Globalization can help poor countries to come out of the trap of low-income level in both models. There are two points of view about globalization phenomenon. One group believes that globalization is a malignant force that only helps advanced countries to take advantage of backwardness(Carkovic & Levine, 2002;

Milanovic & Squire, 2005; Slaughter, 1997). However, the other group believes that globalization can also help poor countries to come out of the low-income trap and catch up with the rich ones(Agénor, 2004; Bhagwati & Srinivasan, 2002; Ganuza et al., 2005; Neutel & Heshmati, 2006).

Hypothesis 5: Institutions have a positive relationship with growth in both classes of models. Appropriate institutions and government policies can help countries further from their leader to take advantage of this backwardness and grow faster.

Chapter 7

Estimation Results

7.1 Introduction

In presenting the empirical results, this chapter seeks to do the following. The overall objective is to provide an empirical basis for the many theories of convergence and to benchmark other research on these theories. The first specific objective is to test the convergence hypothesis across different countries using the neoclassical and new growth models. The second is to evaluate the applicability of these models to the data set we are using. The third is to study the explanatory power of additional variables like globalization, innovation and institutions on growth that have not been taken into account in existing studies. In doing so, we shall also explore whether the level of economic development matters in the explanatory power of these variables.

The rest of this chapter is as follows. The next section reports the results of β convergence in terms of GDP per capita based on augmented Solow-Swan regression (neoclassical growth regression) in low-income, middle-income and high-income countries. It also examines the role played by the variables cited above in explaining β convergence. The results of sigma convergence are also reported in this section. Section three is about the results of β convergence in terms of GDP per capita based on applying new growth regression in low-income, middle-income and high-income countries. This section also reports the results of φ convergence in terms of each technology dimension that is considered in this study – innovation, globalization and institutions – to show how the technology gap evolved in recent years. Finally, section four is the conclusion.

7.2 Neoclassical growth model

This section tests the β convergence hypothesis in terms of GDP per capita in three groups of countries – high-income, middle-income and low-income countries – using the DSGMM[6] method. As said before, convergence happens when there is a negative relationship between the average annual growth rate of GDP per capita and initial amount of GDP per capita, which means that countries that are far from their steady state (poor countries) can grow faster and reach to the steady state growth path rather than those that are closer (rich countries). Therefore, if the sign of initial GDP per capita is negative it means that convergence happened across countries.

β convergence is tested by applying equations (7-1) and (7-2) in samples of low-income, middle-income and high-income countries between 1996 and 2010 in terms of GDP per capita based on the neoclassical theory.

$$\Delta Ln\left(y_{i,t}\right) = \theta_2 lns_{h,i,t} + \theta_3 lns_{ki,t} - \theta_4 \ln(n_{i,t} + g + \delta) + \theta_5 Ln\left(y_{i,t-1}\right) + \zeta_t + \rho_i + \varepsilon_{i,t} \quad (7\text{-}1)$$

$$\Delta Ln\left(y_{i,t}\right) = \theta_2 lns_{h,i,t} + \theta_3 lns_{ki,t} + \theta_4 \ln\left(1 + GLOB_{i,t}\right) + \theta_5 \ln\left(1 + INO_{i,t}\right) + \theta_6 \ln\left(1 + INS_{i,t}\right) - \theta_7 \ln(n_{i,t} + g + \delta) + \theta_8 Ln\left(y_{i,t-1}\right) + \zeta_t + \rho_i + \varepsilon_{i,t} \quad (7\text{-}2)$$

All the variables are taken in natural log form. In addition, for institutions, innovation and globalization in equation (7-2) all the variables are normalized before entering for estimation to become between zero and one. Therefore in this form they can act like an accelerator coefficient for the human capital factor.

[6] - Dynamic system Generalized method of moments

7.2.1 Testing β Convergence in First Augmented Solow-Swan Model

We begin with the augmented Solow-Swan model (equation 7-1). Table (7-1) reports the results for the whole as well as the split samples.

Table 7-1 Testing convergence in the first Augmented Solow-Swan Model using dynamic system GMM

VARIABLES	Whole sample	High-income	Low-income	Middle-income
$\Delta Ln(y_{i,t-1})$	0.139***	0.196***	-0.118**	0.0164*
	(0.00483)	(0.0278)	(0.0479)	(0.00994)
$Ln(y_{i,t-1})$	-0.00106***	-0.0139***	-0.0212	-0.478***
	(3.26e-05)	(0.369)	(0.415)	(0.0370)
$lns_{h,i,t}$	0.158***	0.280	0.191**	1.198***
	(0.00448)	(0.388)	(0.841)	(0.0830)
$lns_{ki,t}$	2.157***	3.484***	0.231***	4. 609*
	(1.00496)	(1.067)	(0.0806)	(1.0313)
$\ln(n_{i,t} + 0.05)$	-1.208***	-0.115***	-0.218***	-0.022***
	(0.0817)	(0.0803)	(0.00989)	(0.00789)
Implied λ	0.0000707	0.00107	…	0.0500
Observations	1,616	392	298	1231
Number of code	149	29	30	90
Sargan test,P-value	0.3435	1.0000	0.9987	1.0000
AR(1),P-value	0.0000	0.0042	0.3226	0.0003
AR(2),P-value	0.0768	0.2548	0.3654	0.9269

Note: Standard errors in parentheses,*** p<0.01, ** p<0.05, * p<0.1, time dummies are also included in estimated regression, the results are not reported here.

According to the Augmented Solow-Swan regression we are expecting a positive sign for θ_2 and θ_3 and negative for θ_4. As can be seen from table (7-1), we can see that for all of the variables this prediction is true for all groups. However, the significance and magnitude coefficient of each variable are different in different groups, which will be discussed later.

The other implication of this model is about speed of convergence, which is calculated by the following formula (G. Mankiw et al., 1992):

Implies speed of convergence: $\theta = (e^{-\lambda t} - 1) \rightarrow \lambda = -1/t[Ln(1 + \theta)]$

The implied speed of convergence is reported in the same table (7-1). As can be seen, the speed of convergence is 0.0000707 for the whole sample, 0.05001 for middle-income countries, 0.001 for high-income countries and no convergence for low-income countries. This means that middle-income countries of the sample move halfway to the steady state in about 13 years,[7] for high-income countries the speed of countries is very slow and takes decades to move to the steady state. In addition, the results show no convergence according to this model for low-income countries. The results for middle-income countries is much larger from the results of G. Mankiw et al. (1992), which reported a speed of convergence for 0.0137 a year using the same regression, and lower than that found by Malcolm Knight, Norman Loayza, and Delano Villanueva (1993), which is 0.0631 for developing countries, also using the same regression. These huge differences can be discussed by the method and nature of the data that they used for estimating the growth regressions. In their study, G. Mankiw et al. (1992) did not care about the country specific effect and the relationship that it could have with other explanatory variables. It is true that Knight applied panel data analysis but even in his study he ignored the problem of endogeneity of some variables in the model and also the fact that the lagged level of the dependent variable, in this study, lagged GDP growth, can also affect the dependent variable. Therefore, they ignored the problem of endogeneity, which, in this study, by applying dynamic system GMM, we account for country specific effects by taking first difference from the regression and we account for omitted and endogeneity by adding instrument variables to the model. Therefore the coefficients are no longer biased towards zero.

[7] The formula for calculation half-life is T= Ln (2)/ λ, T is number of years.

7.2.1.1 Determinants of Growth in the First Augmented Solow-Swan Model

Table (7-1) also reports the effects of investing in human capital, physical capital and population growth on economic growth across these groups of countries. As can be seen the signs of investing in physical capital are positive and significant in all groups. However, it is less productive for low-income countries compared to high-income and middle-income countries. Moreover, between high-income and middle-income countries, it is stronger in middle-income countries.

For investing in education for the secondary level, as the results show, it is less productive for low-income countries than middle-income countries. This means that by investing more in their secondary education middle-income countries can speed their economic growth. The sign of this variable is positive but not significant for high-income countries, meaning that they already have enough level of human capital with secondary education and investing in this section will not affect growth. This is consistent with the argument of M. R. Islam (2010) who said that “advanced countries are more likely to engage in innovating new technologies which required highly skilled human capital”.

The growth rate of population has a negative and significant effect on GDP growth, especially when we eliminate middle-income and high-income countries from the sample.

7.2.2 Testing β Convergence in the Second Augmented Solow-Swan Model

Table (7-2), (7-3), (7-4) and (7-5) report the second augmented version of Solow-Swan model, equation (7-2), by including institutions, globalization and innovation variables to the model in the whole sample as well as the split ones. By including globalization indicators, institutions factors and innovation proxies we try to control the unobserved effects. The important fact here is the way that we apply these variables into the model. According to the neoclassical growth theory the accumulation of capital is important in explaining the growth rate across countries so we apply these variables through the accumulation of human capital rather than endogenizing them through technology to the model. This means that these factors are more closely related as factors that can speed up the process of capital accumulation for increasing production than to the efficiency variable.

First, we discuss the speed of convergence in each group of countries. As can be seen, each of the governance indicators is included separately; therefore, we have six equations.

Table 7-2 Second Augmented Solow-Swan model in the whole sample using dynamic system GMM panel data.

VARIABLES	(1) gdppcgr	(2) gdppcgr	(3) gdppcgr	(4) gdppcgr	(5) gdppcgr	(6) gdppcgr
$\Delta Ln(y_{i,t-1})$	0.221***	0.217***	0.198***	0.206***	0.207***	0.211***
	(0.00315)	(0.00220)	(0.00389)	(0.00361)	(0.00402)	(0.00302)
$Ln(y_{i,t-1})$	-0.00084***	-0.00077***	-0.000717***	-0.00076***	-0.0006***	-0.000732***
	(1.29e-05)	(9.44e-06)	(1.56e-05)	(1.54e-05)	(1.57e-05)	(1.24e-05)
$lns_{h,i,t}$	0.0646***	0.0542***	0.0639***	0.0564***	0.0742***	0.0581***
	(0.00478)	(0.00651)	(0.00523)	(0.00516)	(0.00535)	(0.00573)
$lns_{ki,t}$	5.118***	5.111***	5.110***	4.112***	5.120***	5.117***
	(2.00313)	(2.00273)	(2.00565)	(2.00238)	(2.00275)	(2.00277)
$\ln(1+FDI_{i,t})$	0.0549***	0.0531***	0.0534***	0.0533***	0.0544***	0.0565***
	(0.00192)	(0.00242)	(0.00312)	(0.00218)	(0.00284)	(0.00346)
$\ln(n_{i,t}+0.05)$	-2.208***	-2.164**	-1.218***	-1.0653***	-2.249**	-2.0274**
	(1.117)	(1.118)	(1.0602)	(1.126)	(1.113)	(1.102)
$ln(1+Jornal_{i,t})$	0.00982***	0.00956***	0.00839***	0.00971***	0.0084***	0.00827***
	(0.000520)	(0.000423)	(0.000438)	(0.000487)	(0.000435)	(0.000418)
$ln(1+R\&D_{i,t})$	3.88***	4.67***	6.10***	5.24***	4.59***	4.96***
	(3.7)	(4.15)	(4.18)	(5.41)	(4.25)	(4.18)
$\ln(1+KOF_{i,t})$	4.276***	4.268***	4.054***	4.159***	3.421***	4.996***
	(3.107)	(3.136)	(3.132)	(3.110)	(3.154)	(3.124)
$ln(1+G1)$	2.986***					
	(0.117)					
$ln(1+G2)$		2.172***				
		(0.122)				
$ln(1+G3)$			2.017***			
			(0.111)			
$ln(1+G4)$				2.113***		
				(0.132)		
$ln(1+G5)$					-0.210	
					(0.268)	
$ln(1+G6)$						1.561***
						(0.152)
Obs.	1,116	1,116	1,116	1,116	1,116	1,116
No.id	149	149	149	149	149	149
sargan	11.56	11.55	11.43	7.43	9.52	10.38
AR2-p Value	.1935	.081	.082	.187	.298	.293
AR1-p Value	.365	.578	.165	.0454	.376	.257

Note: $\Delta Ln(y_{i,t-1})$: lagged GDP per capita growth rate, $Ln(y_{i,t-1})$: lagged GDP per capita,

$lns_{h,i,t}$: secondary school enrolment ratio, $ln(n_{i,t}+0.05)$: Population growth rate plus 0.05,

$lns_{ki,t}$: gross capital formation, R&D: research intensity, Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals, which also give validity to the model. The Sargan statistics test the null hypothesis of the correct model specification and validity of the instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-3 Second Augmented Solow-Swan model in high-income countries using dynamic system GMM panel data

VARIABLES	Eq.(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Ln(y_{i,t-1})$	0.753***	0.688***	0.708***	0.714***	0.723***	0.702***
	(0.0322)	(0.0604)	(0.0617)	(0.0518)	(0.0648)	(0.0646)
$Ln(y_{i,t-1})$	-0.4108***	-0.41***	-0.4117***	-0.4104***	-0.4107***	-0.4106***
	(7.42e-05)	(7.24e-05)	(5.74e-05)	(7.06e-05)	(6.53e-05)	(6.34e-05)
$lns_{h,i,t}$	-0.0481***	-0.0392***	-0.0430***	-0.0176	-0.0356***	-0.0279**
	(0.00447)	(0.00737)	(0.00784)	(0.0168)	(0.00757)	(0.0128)
$lns_{ki,t}$	4.070***	4.184***	4.896***	4.969***	4.503***	3.958**
	(1.557)	(1.523)	(1.563)	(1.519)	(1.555)	(1.543)
$\ln(1+FDI_{i,t})$	0.970***	1.071***	1.055***	1.136***	1.045***	0.880***
	(0.150)	(0.196)	(0.169)	(0.162)	(0.177)	(0.162)
$\ln(n_{i,t}+0.05)$	-0.346***	-0.246**	1.366***	0.157**	-0.326***	1.750**
	(0.887)	(0.791)	(1.250)	(0.752)	(0.907)	(0.812)
$ln(1+Jornal_{i,t})$	0.538**	0.449***	0.544**	0.455**	0.540**	0.563***
	(0.153)	(0.154)	(0.159)	(0.154)	(0.154)	(0.152)
$ln(1+R\&D_{i,t})$	5.50**	4.34**	9.78***	6.17***	6.05***	6.62***
	(2.78)	(2.06)	(2.30)	(2.35)	(2.06)	(2.01)
$\ln(1+KOF_{i,t})$	3.085***	3.081***	3.299***	2.870**	2.912***	1.584**
	(2.331)	(2.600)	(2.714)	(1.149)	(2.434)	(2.781)
$ln(1+G1)$	2.563**					
	(1.291)					
$ln(1+G2)$		3.689***				
		(2.803)				
$ln(1+G3)$			3.390***			
			(1.141)			
$ln(1+G4)$				6.015***		
				(3.931)		
$ln(1+G5)$					3.857**	
					(1.507)	
$ln(1+G6)$						1.626
						(1.765)
Obs.	388	388	388	388	388	388
No.id	29	29	29	29	29	29
sargan	13.68	13.25	12.63	8.403	12.72	11.28
AR2-p Value	.0935	.181	.092	.287	.198	.193
AR1-p Value	.395	.538	.1621	.0484	.362	.245

Note: $\Delta Ln(y_{i,t-1})$: lagged GDP per capita growth rate, $Ln(y_{i,t-1})$: lagged GDP per capita,

$lns_{h,i,t}$: secondary school enrolment ratio, $ln(n_{i,t}+0.05)$: Population growth rate plus 0.05,

$lns_{ki,t}$: gross capital formation, R&D: research intensity, Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals which also give validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-4 Second Augmented Solow-Swan model in middle-income countries using dynamic system GMM panel data.

VARIABLES	(1) gdppcgr	(2) gdppcgr	(3) gdppcgr	(4) gdppcgr	(5) gdppcgr	(6) gdppcgr
$\Delta Ln(y_{i,t-1})$	0.329***	0.327***	0.243***	0.244***	0.330***	0.309***
	(0.0263)	(0.0165)	(0.0227)	(0.0252)	(0.0113)	(0.0288)
7.2.2.1 $Ln(y_{i,t-1})$	-0.72***	-0.72***	-0.71***	-0.72***	-0.71***	-0.71***
	(0.00018)	(0.0001)	(0.00015)	(0.000103)	(0.00018)	(0.00019)
$lns_{h,i,t}$	0.214***	0.11***	0.112***	0.122***	0.115***	0.106***
	(0.0264)	(0.0358)	(0.0329)	(0.0242)	(0.0272)	(0.0364)
$lns_{ki,t}$	5.335***	5.24***	5.218***	5.212***	5.225***	5.305***
	(0.0209)	(0.0118)	(0.0129)	(0.00912)	(0.0102)	(0.0151)
$\ln(1+FDI_{i,t})$	0.024**	0.048***	0.079***	0.087***	0.024**	0.015
	(0.00986)	(0.0091)	(0.0175)	(0.0177)	(0.0109)	(0.0138)
$\ln(n_{i,t}+0.05)$	0.753***	0.0389**	0.604***	0.196***	0.088***	0.393***
	(0.228)	(0.243)	(0.405)	(0.284)	(0.153)	(0.403)
$ln(1+Jornal_{i,t})$	0.944**	1.138**	9.9805*	0.9536**	0.907*	1.0797*
	(0.328)	(0.330)	(0.347)	(0.328)	(0.325)	(0.328)
$ln(1+R\&D_{i,t})$	4.963**	4.783*	5.081**	5.414**	4.929**	5.053**
	(2.450)	(2.476)	(2.444)	(2.504)	(2.439)	(2.435)
$\ln(1+KOF_{i,t})$	7.19***	8.15***	5.77***	3.07***	6.06***	9.43***
	(2.203)	(2.209)	(2.070)	(2.198)	(2.194)	(2.276)
$ln(1+G1)$	8.323***					
	(3.391)					
$ln(1+G2)$		5.567***				
		(2.628)				
$ln(1+G3)$			2.970***			
			(1.913)			
$ln(1+G4)$				7.961***		
				(3.845)		
$ln(1+G5)$					5.353***	
					(2.930)	
$ln(1+G6)$						5.458***
						(1.325)
Observations	1100	1100	1100	1100	1100	1100
Number of code	90	90	90	90	90	90
sargan	36.61	35.61	30.37	32.42	32.04	30.51
arm1	-2.406	-2.094	-2.038	-2.063	-2.146	-2.143
arm2	0.367	0.108	0.712	0.383	0.484	0.279

Note: $\Delta Ln(y_{i,t-1})$: lagged GDP per capita growth rate, $Ln(y_{i,t-1})$: lagged GDP per capita,

$lns_{h,i,t}$: secondary school enrolment ratio, $ln(n_{i,t}+0.05)$: Population growth rate plus 0.05,

$lns_{ki,t}$: gross capital formation, R&D: research intensity , Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals which also give validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-5 Second Augmented Solow-Swan model in low-income countries using dynamic system GMM panel data

VARIABLES	Eq.(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Ln(y_{i,t-1})$	0.0810**	0.0837***	0.0916**	0.0784***	0.0795***	0.0696***
	(0.0318)	(0.0140)	(0.0370)	(0.0303)	(0.0246)	(0.0229)
$Ln(y_{i,t-1})$	-0.121*	-0.132**	-0.11**	-0.172**	-0.181**	-0.151**
	(0.00617)	(0.00497)	(0.00452)	(0.00505)	(0.00547)	(0.00275)
$lns_{h,i,t}$	0.315***	0.276**	0.279***	0.247***	0.338***	0.289***
	(0.100)	(0.122)	(0.0827)	(0.0936)	(0.0751)	(0.0724)
$lns_{ki,t}$	6.0766***	6.0826***	6.0763***	6.0636**	6.0692***	6.0699***
	(1.0296)	(1.0146)	(1.0170)	(1.0248)	(1.0262)	(1.0178)
$\ln(1+FDI_{i,t})$	0.0749**	0.103*	0.156*	0.0728	0.0831	0.113*
	(0.0723)	(0.0574)	(0.0873)	(0.0697)	(0.0593)	(0.0683)
$\ln(n_{i,t}+0.05)$	-4.277**	-5.235**	-5.601***	-5.360***	-3.877*	-4.641***
	(2.057)	(2.052)	(1.178)	(1.306)	(2.325)	(1.279)
$ln(1+Jornal_{i,t})$	-0.000211	-0.00198	0.000865	-0.00132	-0.000308	-0.000211
	(0.00260)	(0.00381)	(0.00337)	(0.00403)	(0.00291)	(0.00445)
$ln(1+R\&D_{i,t})$	0.00502*	0.00413**	0.00346*	0.00288	0.00464**	0.00314*
	(0.00189)	(0.00156)	(0.00184)	(0.00176)	(0.00186)	(0.00184)
$\ln(1+KOF_{i,t})$	9.034***	10.68***	10.61***	11.57***	8.274**	9.199***
	(2.860)	(2.521)	(1.327)	(2.199)	(3.799)	(1.674)
$ln(1+G1)$	-0.352*					
	(0.178)					
$ln(1+G2)$		3.601				
		(3.097)				
$ln(1+G3)$			3.056			
			(1.663)			
$ln(1+G4)$				2.722		
				(4.448)		
$ln(1+G5)$					-0.370	
					(3.438)	
$ln(1+G6)$						1.075
						(2.869)
Obs.	298	298	298	298	298	298
No.id	30	30	30	30	30	30
sargan	13.68	13.25	12.63	8.404	12.72	11.28
AR2-p Value	.0935	.181	.092	.287	.198	.193
AR1-p Value	.395	.538	.1621	.0484	.362	.245

Note: $\Delta Ln(y_{i,t-1})$: lagged GDP per capita growth rate, $Ln(y_{i,t-1})$: lagged GDP per capita,

$lns_{h,i,t}$: secondary school enrolment ratio, $ln(n_{i,t}+0.05)$: Population growth rate plus 0.05,

$lns_{ki,t}$: gross capital formation, R&D: research intensity , Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals which also give validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-6 shows the implied speed of convergence, which is derived from the previous tables for the whole sample as well as the splits sample. The results indicate that the coefficients of the initial level of per capita GPP are significant having a negative sign, which shows an inverse relationship between the initial level of per capita GPP and the subsequent growth rate for all groups of countries. However, these rates are different across them.

Table 7-6 Speed of Convergence in second Augmented Solow-Swan model, 1996-2010

Countries		Eq. 1	2	3	4	5	6
Whole sample	Initial GDP per capita coefficient	-0.000846***	-0.000773***	-0.000717***	-0.000768***	-0.000649***	-0.000732***
	λ =Speed of convergence	0.00005642	0.00005155	0.00004782	0.00005122	0.00004328	0.00004882
High-income	Initial GDP per capita coefficient	-0.41***	-0.41***	-0.41***	-0.41***	-0.41***	-0.41***
	λ =Speed of convergence	0.03526	0.03517	0.03536	0.03522	0.03525	0.03524
Middle - income	Initial GDP per capita coefficient	-0.72***	-0.72***	-0.72***	-0.72***	-0.72***	-0.72***
	λ =Speed of convergence	0.08543	0.08443	0.08436	0.08522	0.08450	0.08455
Low-income	Initial GDP per capita coefficient	-0.121*	-0.132**	-0.11**	-0.172**	-0.181**	-0.151**
	λ =Speed of convergence	0.009920	0.01089	0.008964	0.014519	0.015359	0.012592

Notes: the first row of each group reports the coefficient of initial GDP per capita in each equation separately. The second row shows the speed of convergence related to each equation.

For high-income countries, as can be seen, almost 3% of the gap between the initial level of GDP per capita and the repetitive steady state vanishes in one year. We explained in section 7-2-1 about this higher rate of convergence compared to initial studies. However, in comparing the results of the second augmented Solow-Swan model to the first one, it can be seen that the speed is faster here, which shows that considering the other explanatory variables other than investing in human capital is effective in speeding the growth rate across countries. This is also the same for middle-income countries.

For middle-income countries, on average, almost 8% of the gap between the initial level of GDP per capita and the repetitive steady state vanishes in one year. This result supports the idea of convergence, which means that countries far away from the steady state growth path can grow faster.

Finally, for low-income countries 1% of the gap between the initial level of GDP per capita and the repetitive steady state vanishes in one year. As can be seen, in the first augmented Solow-Swan model there was no convergence across low-income countries, however, convergence appears after adding these explanatory variables to the model. This means that by considering these variables for controlling the steady state, convergence could emerge even in low-income countries albeit at a slower rate, which raises the idea of income threshold. Countries should reach to a certain level of income to be capable of taking advantage of the advanced technologies that is transferring from the frontier. The results of the explanatory variables in low-income countries also support this idea.

To sum up, in comparing the results in these three groups, it shows that the convergence rate is much higher for middle-income countries than for high-income countries. This is consistent with the convergence hypothesis, which said that countries far away from their steady state could grow faster than rich ones. However, the results of the low-income group contradict the hypothesis. Indeed, these results suggest that convergence is not monotonic with respect to income. An income threshold may need to be reached before convergence occurs. Countries below that threshold are caught in a poverty trap from which it takes a long time to escape.[8]

[8] Sachs, (2000) made a similar argument about low income / low institutional capacity countries never being able to take advantage of technologies like the Internet.

7.2.2.2 Determinants of Growth in second Augmented Solow-Swan Model

Tables (7-7),(7-8), (7-9) ,(7-10) and (7-11) report the effects of investing in human capital, physical capital, population growth, globalization indicators, FDI and KOF index, institutions factor, R&D inensity and number of scientific journals on economic growth across these groups of countries.

The estimated coefficient for investing in education is positive and significant for the whole sample, while by eliminating middle-income and low-income countries from the sample the coefficient becomes negative and significant. This result contradicts what R. J. Barro (1991), G. Mankiw et al. (1992) and others, who use cross sectional data analyses, found in their studies. One explanation for this result is that when the time dimension is added to the education variable it means that in addition to cross country difference we also consider changes in human capital over time in each country. Why are the coefficients negative in high-income countries but remaining positive for middle-income and low-income countries? This indicates that while investing in the secondary level of education increased in high-income countries between 1996 and 2010, output growth fell. However, this story is not true for middle-income and especially for low-income countries, where a one point increase in investing in education will increase their GDP growth by 0.3 percentage points. The explanation for this might be because for middle-income and low-income countries the cross sectional effects are strong enough to overcome the time series relations.

Table 7-7 The results for secondary school enrolment ratio in both models

Model	Variable	Whole sample	High-income	Low-income	Middle-income
First Model	$lns_{h,i,t}$	0.158***	0.280	0.191**	1.198***
Second Model	$lns_{h,i,t}$	0.0646***	-0.048***	0.315***	0.214***

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation.

Furthermore, as the results show, the coefficients are stronger for low-income than for middle-income countries. This means that low-income countries, by investing more in their secondary education level, can speed their economic growth. This result is not consistent with the first model, where investing in education at the secondary level was less productive for low-income countries than middle-income countries. Our explanation for this result is that it seems that the quality of education investment increases when the technology can transfer across low-income countries through globalization.

The sign for investing in physical capital is positive and significant in the whole sample and it is the strongest amongst the other variables. A one point increase in the formation of physical capital increases the GDP growth rate by 6 percentage points. When the middle-income and low-income countries are eliminated from the sample, the sign is still positive and a one point increases in the formation of physical capital increases the GDP growth rate by 4 percentage points. For middle-income countries and low-income countries it is the same and the sign is positive and significant and a 5 percentage and 6 percentage point variation in GDP growth can be explained by the physical capital accumulation in these two groups of countries, respectively.

Table 7-8 The results for investment in physical capital in both models

Model	Variable	Whole sample	High-income	Low-income	Middle-income
First Model	$lns_{ki,t}$	2.157***	3.484***	0.231***	4. 609*
Second Model	$lns_{ki,t}$	6.118***	4.070***	6.076***	5.335***

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation in this table.

As can be seen, the coefficients for investment in physical capital are larger in all groups when proxies like FDI, KOF index, institutions, R&D intensity are added to the model. Furthermore, the coefficient of investment in physical capital is largest in low-income countries compared to the middle-income and high-income countries, and, compared to the first model the coefficient becomes six times as large as it was in the first model. These results can indicate that the quality of investing in physical capital is improving in all groups, especially in low-income countries when the country lets technology transfer internationally. This scenario is proven by the positive and significant effect of the globalization variable in low-income countries.

P. M. Romer (1990), Philippe Aghion and Howitt (1992), and Talukdar (2009) were the pioneers who tried to explain the important role of innovation in the process of long-run growth in the new growth theory. In line with their study, we add R&D intensity and the number of scientific journals as a proxy for innovation. The sign of R&D intensity is positive and significant for the whole sample as well as for the split ones. However, the sign for number of scientific journals is negative and significant for the whole sample.

Table 7-9 the results for R&D intensity and Number of Scientific Journals in the second model

Variables	Whole sample	High-income	Low-income	Middle-income
R&D	3.88***	5.50**	0.01*	4.96***
No.Journals	-0.01**	0.538***	-0.0002	0.95**

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation in this table.

When eliminating the middle-income and low-income countries from the whole sample the coefficients of R&D intensity became strongly significant. Meaning that investing more in R&D activities has a positive effect on the productivity growth, which is in line with most of the research done in this field. Furthermore, this is a proof of what M. R. Islam (2010) argued, in that since high-income countries already have the educated people and the required level of highly skilled workers they can take advantage of the R&D outcomes in the most efficient way. The sign for the number of scientific journals is also positive and significant, although it is less significant than investing in the R&D sector.

The results are also positive and significant for middle-income countries but less significant than for the high-income group. This means that even when considering technology transfer they still have to work on their fundamentals to be capable of taking full advantage of the output of R&D activities. For example, they have to invest more in their higher level of education.

For low-income countries, the sign for R&D intensity is positive and significant in most equations albeit the effect is very small compared with the other two groups. In addition, for the number of scientific journals the sign is not significant in any of the equations. Our explanation is that investing more in R&D activities is not working since they do not have an adequate level of human capital or sufficient highly skilled workers to take advantage of the R&D activities outcomes.

The next step is to investigate the globalization phenomenon in the process of growth. As discussed earlier, economists do not reach the same conclusion concerning the effect of globalization indicators on growth. In earlier studies, trade, openness and FDI were used as proxies for globalization but their results were not consistent. Here, in this research, we apply an alternative proxy named as the KOF index, which was introduced by Dreher (2003) to explore the different dimensions of globalization on growth and the convergence process. We also apply the FDI index.

Table 7-10 The results for FDI and KOF index in second model

Variables	Whole sample	High-income	Low-income	Middle-income
KOF	4.27***	3.1***	9.03***	7.19***
FDI	0.05***	0.97***	0.07**	0.02**

Note: This table is derived from previous tables. Since the results of all 6 equations were familiar, we just put the results of the first equation in this table.

For high-income countries, the effect of the KOF index is positive and significant. This means that globalization can increase economic growth across countries with a high level of income. The sign of FDI is also positive and significant in this group but less powerful than the KOF index.

For middle-income countries the results for both variables are positive and significant, and these countries can also take advantage of international technology spillovers through globalization since they have an adequate level of human capital in their countries. Furthermore, here we can see that the KOF index is more powerful than FDI.

It is the same for low-income countries with the difference that the effect of globalization is very big in this group. This can be another reason for the significant sign of physical capital accumulation for this group of countries, as we discussed earlier. This positive and strong sign means that opening up the borders and allowing for international technology transfer can make a lot of difference in these countries. This is consistent with the argument of economists like Charles Jones (1998) who argue that although some countries do not have highly skilled workers to take advantage of the R&D output, they can still grow. These economists argue that it is true that there is low level of skilled human capital in these countries to take advantage of the advanced technologies but by opening up the borders to foreign investments, those countries bring them a skilled labour force and so they can train the labour force in the host country. In low-income countries we can also see that the results for the KOF index are more powerful than for FDI.

In general, we can conclude that this new KOF index is a better proxy for measuring globalization because it not only measures the flow of goods, but also the flow of technology and knowledge by considering the infrastructure, such as Internet users, and telephone lines.

What is the role of institutions in determining the growth path? In the recent literature, and, specifically, in the new growth models, numerous studies investigated the effect of institutions on economic growth. None of the previous studies in the area of convergence and growth used the governance indicators to study the effect of institutions on growth or investigated their role on the convergence process. Therefore, in this study, we apply these Governance indicators, which have six dimensions, and, as mentioned in chapter 6, because of the high positive correlation between these indicators that cause the problem of multi-collinearity we should add them separately to the model (Appendix). Because of the importance of these indicators we discuss them in each group and after that compare them among groups.

Table 7-11 The results for Governance indicators in the second model

Variables	Whole sample	High-income	Low-income	Middle-income
G1	2.98***	2.56**	-0.35*	8.32***
G2	2.17***	3.68***	3.60	5.56***
G3	2.01***	3.390***	3.05*	2.97***
G4	2.11***	6.015***	2.72	7.96***
G5	-0.210	3.87**	-0.37	5.34***
G6	1.56***	1.62	1.07	5.45***

Note: This table is derived from previous tables. G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability.

As the results show, for the whole sample the sign for all of the indicators except rule of law is significant and positive. When the group of middle-income and low-income countries are eliminated from the sample, the significance appears for rule of law, which means that this factor affects growth in countries with a high level of income. However, the significance of voice and accountability disappears, and the other indicators remain positive and significant in the equation. Regulatory quality (G4) has the highest positive significant effect on economic growth in the high-income group (6%). As mentioned before, in general, countries with high regulatory quality are those countries that have less regulatory restrictions in any kind of market; for example, labour and financial. These countries provide a more stable environment for private investors in the country to invest and even for foreign investors, which leads to more development. Therefore, the results in the high-income countries show that 6% of the violation of their growth can be explained by this factor. Therefore, this factor plays an important role in their process of growth.

The sign for rule of law (G5) is also positive and significant (3.8%). Having a high score for rule of law in an economy means the countries can protect the property rights of their citizens and protect the interests of its investors or inventors, which can speed its economic growth rate. In countries with a high score for the rule of law, patents can be invented and their rights are protected. Therefore, the rate of innovation will increase in such a country, and, finally, they can have a high rate of economic growth. The results show that this factor can be very effective on the growth rate of high-income countries if they consider this factor seriously.

The sign for political stability and absence of violence (G3) is also positive and significant in high-income countries (3.4%). In countries in which the process of selecting and replacing the government is stable, the investors feel safe to invest in such economies. Therefore, the rate of flight back of capital is less, which leads to the rapid growth rate in the economy.

The sign is also positive and significant for Government effectiveness (G2) across high-income countries (3.7%). Countries that ranked highly according to this factor are those countries that have a high quality in public services and powerful policy planning. The positive and significant sign for this variable in high-income countries suggests that having a powerful government increases the economic growth rate.

The sign for control of corruption (G1) is also positive and significant across high-income countries (2.56%), which show that developed countries with a high control of corruption are successful in giving confidence to the investors to invest in the economy.

Finally, the results show that the only factor that is not significant across high-income countries for economic growth is voice and accountability (G6). This means that the productivity of a country is not affected by the system in which the government is selected. In the other words, the other reason could be that all these high-income countries have strong voice and accountability indicators, so there is not much variation in this indicator to explain growth.

For middle-income countries the results show that for all of the indicators the signs are positive and significantly different from zero, and also stronger than for high-income countries. Among all the indicators, control of corruption (G1) has the highest positive significant effect on economic growth in the middle-income group. This shows that by controlling their corruption developing countries can be successful in giving confidence to the investors to invest in their economy and thereby grow fast (8.3% of the variation is explained by this factor).

The regulatory quality (G4) is the second highest positive significant effective factor on economic growth (7.96%). These countries, by providing a safe environment for private investors and foreign investors can increase their productivity.

The sign is also positive and significant for government effectiveness (G2) across high-income countries (5.56%). The results suggest that having a powerful government increases the economic growth rate across developing countries.

The results for voice and accountability (G6) are positive and significantly different from zero, thereby indicating that the productivity of a country is affected by the system in which government is selected across developing countries. This result contradicts the result of high-income countries where the voice and accountability did not affect the growth rate of the high-income countries.

The sign for rule of law (G5) is also positive and significant (5.35%). This shows that building a strong system of justice and law for protecting the rights of the citizens will be effective for growth.

The sign for political stability and absence of violence (G3) is also positive and significant in middle-income countries (2.9%). In countries in which the process of selecting and replacing government is stable, the investors feel safer to invest in such economies. Therefore, the rate of flight back of capital is less and leads to a rapid growth rate in the economy.

However, for low-income countries the significance disappears for almost all of the factors controlling for corruption for which the sign is negative and significant at 10%. This is an interesting result for two reasons. First, because again it raises the issue of the income threshold. Our explanation for this result is that since these countries do not reach a certain level of income and development, they cannot take advantage of these factors. Second, as we said, the sign of control for corruption is negative in this group, meaning that controlling for corruption is not effective in low-income countries. The issue of corruption and level of development is a big issue in recent literature. Some economists believe we can track developed countries and see that they are not fighting corruption in the initial stages of their development (Khan, 2004). Khan (2004) argues that fighting corruption, though necessary, is not the only prerequisite for growth. This itself is further support for reaching the income threshold. In the other research Mironov

(2005) analyses the effects of corruption on economic growth across 141 countries during 1996 and 2004. The results of his study are another support for what the current research found. His results show that residual corruption has positive effects on economic growth. In other words, he found out that the residual corruption is correlated positively with capital accumulation and so economic growth in developing countries and poor countries. Furthermore, Heckelman and Powell (2008) in another research show that limiting economic freedom causes the corruption to have a positive effect on economic growth.

7.2.3 δ - Convergence

"δ convergence" means that the dispersion of GDP per capita reduces over time. There exist several ways of quantifying the inequality of income distributions but a commonly used measure is the standard deviation of the logarithms of per capita GDP. If the value of standard deviation in a sample becomes smaller it means that the country reduced the gap that existed. Otherwise, there is no δ convergence. Table 7-12 shows the results of the analysis of δ convergence for GDP per capita in the following groups of countries.

Table 7-12 Results of testing δ convergence in terms of GDP per capita, 1996-2010

GDP per capita	Coefficient of variation in t_{96}	Coefficient of variation in t_{2010}	Rate of change (%)
High-income	0.898552	0.805812	-10.321
Middle-income (upper)	0.668754	0.522679	-21.8429
Middle-income (lower)	0.620489	0.539005	-13.1323
Low-income	0.54205	0.491879	-9.25579

Note: Standard deviation of logarithms of GDP per capita,1996-2010, Rate of changes=(t_{2010}-t_{96}/t_{96})*100

The results show that in all three groups of countries there is a decreasing dispersion in terms of GDP per capita across countries over time. However, the speed of δ convergence is rapid in upper middle-income countries. The lowest rate belongs to the low-income countries, which is 9 per cent. This result is exactly in line with our β convergence in which the rate of convergence is particularly rapid for the middle-income group.

7.3 New Growth Model

In this section, we are going to test β Convergence and φ Convergence by applying the dynamic system GMM across groups of sample countries. As can be seen the concept of β Convergence is the same as the neoclassic model, meaning that if the sign of initial GDP per capita is negative countries behind the steady state can grow faster, otherwise there is divergence across countries. What makes this model different from the NCGM is the way that the variables apply in the model. As we described in chapter 3, we focused on the new growth models where, in these models, technology plays an important role in explaining the different growth rate across countries unlike the NCG model where the emphasis was on capital accumulation. We expect the sign for innovation, globalization and institutions to be more sensitive than capital accumulation in these classes of models in our sample.

7.3.1 Testing β Convergence: The Link Between Technological Change and Convergence in Income

In chapter three we showed how we link technology change and growth of GDP per capita in terms of endogenous theories. This section presents the results of estimating the following equation:

$$\Delta y_{i,t}/y_{i,t} = \theta_1 logINO_{i,t} + \theta_2 logHC_{i,t} + \theta_3 logINS_{i,t} + \theta_4 logGLOB_{i,t} + \theta_5 FC_{i,t} + \mu \log y_{i,t-1} - \zeta_t + \rho_i + \varepsilon_{i,t} \quad (7\text{-}3)$$

Where $\Delta log y_{i,t}$,growth rate of GDP per capita at time (t), is related to $\log y_{i,t-1}$,the logarithm of GDP per capita at the start of the period, and other controlling variables, such as physical capital accumulation, the intensity of innovation activities, human capital level, the institutions (governance indicators) and globalization. By estimating this equation we can understand how much of the growth can be explained by technological changes and how much by physical accumulation. The coefficient of $\log y_{i,t-1}$ shows whether convergence happened across countries or not. If it is negative, it means that countries behind the steady state can grow faster, otherwise there is divergence across countries.

β convergence is tested by applying equation (7-3) in samples of low-income, middle-income and high-income countries between 1996 and 2010 in terms of GDP per capita based on the new growth theory. All the variables are taken in natural log form. The country specific effects are controlled by following the generalized method of moment's estimation procedure. Tables 7-13, 7-14, 7-15 and 7-16 show the results of testing β convergence for the whole sample as well as for high-income, middle-income and low-income countries:

Table 7-13 Testing β convergence in terms of GDP per capita in the whole sample, using dynamic system GMM

Equations	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta y_{i,t-1}/y_{i,t-1}$	0.261***	0.255***	0.235***	0.238***	0.239***	0.247***
	(0.0029)	(0.0020)	(0.0011)	(0.0022)	(0.0020)	(0.0021)
$\log y_{i,t-1}$	-0.0082***	-0.007***	-0.007***	-0.0074***	-0.0062***	-0.0072***
	(4.46e-06)	(8.19e-06)	(4.23e-06)	(6.76e-06)	(7.05e-06)	(6.82e-06)
$logHC_{i,t}$	0.0569***	0.042***	0.0544***	0.0495***	0.0717***	0.0450***
	(0.00295)	(0.0029)	(0.00270)	(0.00236)	(0.00302)	(0.00295)
$FC_{i,t}$	0.133***	0.123***	0.129***	0.125***	0.137***	0.123***
	(0.00224)	(0.0026)	(0.00203)	(0.00194)	(0.00240)	(0.00276)
Log(FDI)	0.0558***	0.053***	0.0546***	0.0525***	0.0525***	0.0547***
	(0.00160)	(0.0010)	(0.00188)	(0.00120)	(0.000790)	(0.00197)
log(journal)	0.0095***	0.0094***	0.0082***	0.0091***	0.0078***	0.0089***
	(0.000234)	(0.000179)	(0.000187)	(0.000196)	(0.000158)	(0.000119)
Log(R&D)	4.32***	5.50***	6.33***	6.74***	5.34***	6.30***
	(1.92)	(1.78)	(1.57)	(2.45)	(1.81)	(1.06)
Log(KOF)	1.318***	1.480***	1.150***	1.327***	0.398***	1.385***
	(2.0394)	(2.0439)	(2.0492)	(2.0578)	(2.0547)	(2.0633)
Log(G1)	3.251***					
	(1.0853)					
Log(G2)		2.506***				
		(1.101)				
Log(G3)			1.872***			
			(1.0568)			
Log(G4)				2.042***		
				(1.109)		
Log(G5)					-0.445***	
					(1.0945)	
Log(G6)						2.097***
						(1.0641)
Obs.	1385	1385	1385	1385	1385	1385
No.id	149	149	149	149	149	149
sargan	86.83	83.71	86.76	84.49	84.23	88.24
AR2-p Value	-1.816	-1.807	-1.873	-1.793	-1.833	-1.842
AR1-p Value	-1.078	-1.194	-1.010	-1.019	-1.018	-1.064

Note: $\Delta y_{i,t-1}/y_{i,t-1}$: lagged GDP per capita growth rate, $\log y_{i,t-1}$: lagged GDP per capita, log(HC): secondary school enrolment ratio, CF: gross capital formation, R&D: research intensity, Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals, which also gives validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that, the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-14 Testing β convergence in terms of GDP per capita using dynamic System GMM across High income countries

Equations	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta y_{i,t-1}/y_{i,t-1}$	0.644***	0.617***	0.637***	0.619***	0.643***	0.659***
	(0.0931)	(0.0920)	(0.0946)	(0.0922)	(0.0940)	(0.0933)
$\log y_{i,t-1}$	-0.45*	-0.488*	-0.455**	-1	-0.474**	-0.46*
	(0.085)	(0.011)	(0.950)	(0.000)	(0.247)	(0.063)
$logHC_{i,t}$	-15.91	-12.10	-20.36	12.94	17.14**	14.75*
	(5.258)	(5.435)	(5.076)	(5.409)	(5.454)	(5.168)
$FC_{i,t}$	0.520***	0.529***	0.558***	0.527***	0.544***	0.564***
	(0.0549)	(0.0802)	(0.0574)	(0.0681)	(0.0717)	(0.0607)
Log(FDI)	1.729***	2.791***	2.508**	2.739***	2.520**	1.288
	(1.234)	1.226)	(1.249)	1.222)	1.216)	(0.209)
log(journal)	1.0776***	1.0798***	1.0839***	1.0907***	1.0809***	0.9669***
	(1.00993)	(1.0134)	(1.0145)	(1.0139)	(1.0132)	(1.0123)
Log(R&D)	6.0484***	6.0510***	6.0489***	6.0540***	5.0501***	6.0446***
	(1. 468)	(1. 0317)	(1. 305)	(1. 364)	(1. 504)	(1. 489)
Log(KOF)	4.038*	4.608**	4.303**	4.515**	4.311*	4.353**
	(3.123)	(1.112)	(1.138)	(2.781)	(1.117)	(1.222)
Log(G1)	2.386***					
	(1.532)					
Log(G2)		4.364***				
		(1.666)				
Log(G3)			4.271**			
			(1.485)			
Log(G4)				7.770***		
				(1.127)		
Log(G5)					3.264*	
					(0.866)	
Log(G6)						1.502***
						(1.125)
sargan	207.79408	207.7880	209.07359	208.94014	209.60235	199.03852
AR2-p Value	.31235034	.4591524	.26509498	.29570693	.28689714	.90706144
AR1-p Value	.10597	.14082665	.11226635	.1434355	.12020117	.09581717
Obs.	379	379	379	379	379	379
No.id	29	29	29	29	29	29

Note: $\Delta y_{i,t-1}/y_{i,t-1}$: lagged GDP per capita growth rate, $log y_{i,t-1}$: lagged GDP per capita, log(HC): secondary school enrolment ratio, CF: gross capital formation, R&D: research intensity, Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals which also give validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-15 Dynamic system GMM, testing β convergence in terms of GDP in middle-income countries.

Equations	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta y_{i,t-1}/y_{i,t-1}$	0.674***	0.669***	0.653***	0.649***	0.652***	0.651***
	(0.0976)	(0.0981)	(0.0964)	(0.0956)	(0.0973)	(0.0980)
log$y_{i,t-1}$	-0.648***	-0.723***	-0.762***	-0.68***	-0.848***	-0.732**
	(1.024)	(0.961)	(0.932)	(0.919)	(0.959)	(0.929)
$logHC_{i,t}$	0.930	0.519	-0.0806	0.978	0.772	0.728
	(2.362)	(2.374)	(2.507)	(2.391)	(2.367)	(2.357)
$FC_{i,t}$	0.318*	0.154**	0.255*	0.115**	0.0720***	0.134**
	(1.749)	(1.745)	(1.735)	(1.717)	(1.734)	(1.731)
Log(FDI)	3.59***	1.99***	3.86***	3.87***	2.33***	2.91***
	(8.02e-07)	(7.31e-07)	(9.21e-07)	(5.97e-07)	(4.87e-07)	(8.78e-07)
log(journal)	1. 014**	1. 029***	1. 0558**	1. 0798**	1. 044**	1. 015*
	(0. 168)	(0. 102)	(0. 286)	(0. 217)	(0. 153)	(0. 344)
Log(R&D)	5.238**	5.455**	5.337**	5.937**	5.584**	5.0543**
	(1.590)	(1.630)	(1.686)	(1.466)	(1.578)	(1.572)
Log(KOF)	9. 234***	8. 41***	8. 618***	8. 661***	8. 426**	8. 415***
	(10. 818)	(1. 638)	(1. 850)	(1. 170)	(1. 180)	(1. 797)
Log(G1)	4.181*					
	(0.956)					
Log(G2)		4.513**				
		(0.921)				
Log(G3)			7.621**			
			(0.839)			
Log(G4)				6.806**		
				(0.887)		
Log(G5)					-4.557	
					(0.886)	
Log(G6)						5.503*
						(0.953)
sargan	165.48596	166.5270	168.9306	170.72275	168.59732	169.10407
AR2-p Value	.2696833	.2667295	.25331787	.25700299	.26083871	.2596185
AR1-p Value	.23076397	.2047918	.21083427	.26090361	.23084908	.20482335
Obs.	456	456	456	456	456	456
No.id	90	90	90	90	90	90

Note: $\Delta y_{i,t-1}/y_{i,t-1}$: lagged GDP per capita growth rate, $log y_{i,t-1}$: lagged GDP per capita, log(HC): secondary school enrolment ratio, CF: gross capital formation, R&D: research intensity, Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals which also give validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

Table 7-16 Testing β convergence in terms of GDP in low-income countries, Using dynamic system GMM.

Equations	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta y_{i,t-1}/y_{i,t-1}$	0.224	0.191	0.211	0.213	0.203	0.198
	(0.264)	(0.268)	(0.263)	(0.267)	(0.268)	(0.262)
$\log y_{i,t-1}$	-0.0289***	-0.0283***	-0.0295***	-0.0323***	-0.0277***	-0.0302***
	(0.102)	(0.960)	(0.093)	(0.007)	0.909)	(0.072)
$logHC_{i,t}$	3.415***	2.338**	3.217***	2.520***	2.629***	2.620***
	(2.078)	(1.727)	(1.716)	(2.045)	(1.758)	(1.576)
$FC_{i,t}$	3.0530**	3.750***	3.0313***	3.529***	3.202**	3.357**
	(2.051)	(2.287)	(2.082)	(2.432)	(2.118)	(2.106)
Log(FDI)	1.592	2.021	0.899*	1.216	0.165	1.433
	(6.826)	(6.148)	(0.871)	(6.053)	(0.088)	(5.893)
log(journal)	0.635	-0.293	0.522	0.326*	0.416	0.441
	(0.912)	(0.984)	(0.974)	(1.139)	(0.986)	(0.915)
Log(R&D)	0.734	-1.284	-0.413	0.00503	-0.411	1.146
	(4.570)	(4.740)	(0.860)	(0.008)	(0.702)	(4.640)
Log(KOF)	0.0726	0.0314	0.0494	0.0721	0.0185	0.0477
	(0.0693)	(0.0621)	(0.0743)	(0.0677)	(0.0468)	(0.0674)
Log(G1)	-0.575					
	(0.555)					
Log(G2)		3.885				
		(5.268)				
Log(G3)			-0.229			
			(0.521)			
Log(G4)				-0.993		
				(0.670)		
Log(G5)					1.349	
					(3.206)	
Log(G6)						-1.204
						(2.014)
sargan	22.370168	20.42315	22.151908	21.017792	21.099152	21.690762
AR2-p Value	.15293232	.1887076	.13746631	.29462389	.18951612	.277408
AR1-p Value	.43416257	.4610631	.41256745	.24585619	.33327424	.11344095
Obs.	198	198	198	198	198	198
No.id	30	30	30	30	30	30

Note: $\Delta y_{i,t-1}/y_{i,t-1}$: lagged GDP per capita growth rate, $log y_{i,t-1}$: lagged GDP per capita, log(HC): secondary school enrolment ratio, CF: gross capital formation, R&D: research intensity, Journal: number of scientific journals, KOF: Globalization indicator, G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability. The results for AR1 and AR2 show that there is no first and second serial correlation in the residuals which also give validity to the model. The Sargan statistics tests the null hypothesis of correct model specification and validity of instruments. As the results show we cannot reject the null hypothesis, which shows that the instruments are valid. Time dummies are also included, which is not reported here.

As can be seen, we have six equations estimated in each table and in each equation a different governance indicator is entered to be tested. First, we analyse the speed of convergence in each group separately. Table 7-17 shows the implied speed of convergence, which is calculated like before:

Table 7-17 Speed of Convergence in New Growth model, 1996-2010

Countries		Eq 1	2	3	4	5	6
Whole sample	Initial GDP per capita coefficient	-0.00828***	-0.00772***	-0.00702***	-0.00741***	-0.00623***	-0.00725***
	λ =Speed of convergence	0.000554	0.000517	0.00047	0.000496	0.0004166	0.0004851
High-income	Initial GDP per capita coefficient	-0.45	-0.488	-0.55	-1	-0.474	-0.46
	λ =Speed of convergence	0.039856	0.0446287	0.053234	……	0.04283	0.0410791
Middle-income	Initial GDP per capita coefficient	-0.648***	-0.723***	-0.762***	-0.68***	-0.848***	-0.732**
	λ =Speed of convergence	0.0696083	0.0855825	0.095699	0.075962	0.1255917	0.0877846
Low-income	Initial GDP per capita coefficient	-0.0289***	-0.0283***	-0.0295***	-0.0323***	-0.0277***	-0.0302***
	λ =Speed of convergence	0.00195	0.00191	0.00199	0.00218	0.00187	0.00204

Note: the first row of each group reports the coefficient of initial GDP per capita in each equation separately. The second row shows the speed of convergence related to each equation.

For the whole sample, as well as the split samples we can see that the convergence is similar to the neoclassical growth model. The coefficient of initial GDP per capita is negative, meaning that countries far from the steady state growth path can grow faster. It is interesting when we compare the result with the NCGM. As can be seen, for high-income countries, on average, almost 4% of the gap between the initial level of GDP per capita and the repetitive steady state vanishes in one year, which is higher than the result of the NCGM, which was 3%.

For middle-income countries, on average, almost 9% of the gap between the initial level of GDP per capita and the repetitive steady state vanishes in one year. Again the results of NGM show the faster convergence compared to NCGM, which was 8%.

Finally, for low-income countries less than 1% of the gap between the initial level of GDP per capita and the repetitive steady state vanishes in one year. This result is slower than the NCG model, which was 1%.

To sum up, comparing the results of NGM with NCGM, the rate of convergence for both high-income and middle-income countries is higher in the new growth model than the neoclassical growth model. However, for the low-income countries it is slower. Our explanation for this result is that since the middle-income and high-income countries have the capacity to take advantage of the technology of the frontiers, the explanatory variables that were added to the model to determine the steady state of growth path across these countries are effective on GDP growth, and, hence, accelerate the convergence process. This is consistent with the notion of the new growth theory in which technological change is the main source of growth. As discussed before in this study, the explanatory variables, in new growth regression, are components of productivity growth and through the channel of technology they affect GDP growth, so we can see that through this channel they are more effective on GDP growth across those countries that are developed or in the later stages of development. The set of results for low-income countries is another proof of this, since these countries are undeveloped or in the early stages of development these factors through the channel of technology are not effective on them. Therefore, the NCG model is the model that should apply for these countries with this level of income. In other words we can say that selecting which growth model should be applied for countries is monotonic to their income level, whether capital deepening models or technological catching up models. In other words, an income threshold may need to be reached before countries can take advantage of technological change. Countries below that threshold are caught in a poverty trap from which it takes a long time to escape.

7.3.1.1 Determinants of Growth in the New Growth Model

Tables (7-8),(7-9), (7-10) and (7-11) also report the effects of investing in human capital, physical capital, globalization indicators, FDI and KOF index, institutions factor, R&D intensity and number of scientific journals on economic growth across these groups of countries. Once again, it is necessary to emphasize the differences between this model and the NCGM. In the NGM all these factors except physical capital, affect technology, and, through the channel of technology, they affect economic growth, while in the NCGM, innovation, globalization and institutions are the factors that facilitate human capital accumulation in the process of growth.

If we take a look at the signs and significance of the variables in the new growth regression in the middle-income and high-income countries it is clear that they are stronger and more effective than in the NCG regression.

As can be seen, the sign of secondary school enrolment ratio is negative and not significant in most of the equations across high-income countries. Secondary education, while an important building block, cannot capture this skill level, given that it would be universal in all high-income countries. The sign of secondary school enrolment ratio is positive but not significant across middle-income countries as well. However, the sign is positive and significant in low-income countries and very significant. This means that by investing more in their secondary education level, low-income countries can speed their economic growth.

Table 7-18 The results of secondary school enrolments ratio in the NG model

Model	Variable	Whole sample	High-income	Low-income	Middle-income
NGM	$lns_{h,i,t}$	0.06***	-15.91	3.41***	0.93

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation in this table. NGM: New growth model. $s_{h,i,t}$: Secondary school enrolments ratio

The sign of investing in physical capital is positive and significant in all groups and more effective on growth across low-income countries.

Table 7-19 The results of investment on physical capital in both models

Model	Variable	Whole sample	High-income	Low-income	Middle-income
NGM	$lns_{ki,t}$	0.133***	0.52***	3.05**	0.31*
NCGM	$lns_{ki,t}$	6.118***	4.070***	6.076***	5.335***

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation in this table. NGM: New growth model. $s_{ki,t}$: gross capital formation

As table 7-19 shows, comparing the results of the NG model with the NCG model shows that physical capital accumulation is more effective when applying the NCG model for all groups.

The signs of R&D intensity are positive and not significant for the whole sample. The results are the same for the number of scientific journals. However, when we eliminate low-income and middle-income countries from the sample it becomes positive and significant across high-income countries, which means that investing more in R&D activities has a positive effect on the productivity growth. This is in line with most of the research done in this field. The sign of number of scientific journals is also positive and significant, although it is less effective than investing in the R&D sector.

Table 7-20 The results of R&D intensity and Number of scientific Journals in both models

	Whole sample		High-income		Low-income		Middle-income	
	NCG	NG	NCG	NG	NCG	NG	NCG	NG
R&D	3.88***	4.32***	5.50**	6.04***	0.01*	0.73	4.96***	5.23**
No.Journals	-0.01**	0.001***	0.538***	1.07***	-0.0002	0.63	0.95**	1.01***

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation in this table. NG: New growth model. NCG: Neoclassical growth model.

The results of R&D intensity are also positive and significant for middle-income countries, which mean that by considering technology transfer they can take advantage from the output of R&D activities. Comparing the results of R&D intensity with the NCG model shows that R&D intensity is more effective on growth in the NG model than in the NCG model. The sign of number of scientific journals is positive and significant in this group.

For low-income countries, as can be seen, the signs of R&D intensity and number of scientific journals are positive but not significant in most equations. We have the same explanation as for the neoclassical growth theory: investing more in R&D activities is not working since they do not have an adequate level of human capital or sufficient highly skilled workers to take advantage of the outcomes of R&D activities.

For high-income countries, the effect of the KOF index is positive and significant and more effective than the NCG model. This means that globalization can increase economic growth across countries with a high level of income. The sign of FDI is also positive and significant in this group but less effective than the KOF index. Again this could be a good sign that this new KOF index is a better proxy for measuring globalization, as it not only measures the flow of goods, but also the flow of technology and knowledge by considering the infrastructures, such as Internet users and telephone lines.

Table 7-21 The results of the KOF index and FDI in both models

	Whole sample		High-income		Low-income		Middle-income	
	NCG	NG	NCG	NG	NCG	NG	NCG	NG
KOF	4.27***	1.31***	3.1***	4.60**	9.03***	0.072	7.19***	9.23***
FDI	0.05***	0.05***	0.97***	1.72***	0.07**	1.59	0.02**	3.59***

Note: This table is derived from previous tables. For the second model, since the results of all 6 equations were familiar, we just put the results of the first equation in this table. NG: New growth model. NCG: Neoclassical growth model.

For middle-income countries the results for both variables are the same, and these countries can also take advantage of international technology spillovers through globalization since they have a high enough level of human capital in their countries. Again the results are more effective than the NCG model.

The story is different for low-income countries. Neither the KOF index nor the FDI has a significant effect on economic growth in this model. However, as can be seen, the results were significant for the NCG model. One explanation for this might be that since we apply these variables in NGM through the channel of technology, and as components of technology regression, they are not effective in countries with a low level of income or those countries that are not yet developed. This leads to the interpretation that the application of each class of growth model is dependent on the level of development. For example, in high-income countries where there is a sufficient level of human capital, technology spillovers through globalization and innovation are effective, whereas, when considering low-income countries with underdeveloped economies, these factors are no longer effective.

Governance indicators have a positive and significant effect on economic growth across high-income countries, and, as can be seen, they are more effective than the NCG model. For middle-income countries, except for the rule of law, the other governance indicators have a positive and significant effect on economic growth and are more effective than the NCG model on GDP growth. For low-income countries, none of the governance indicators are significant.

Table 7-22 The results of Governance indicators in both models

	Whole sample		High-income		Low-income		Middle-income	
	NCG	NG	NCG	NG	NCG	NG	NCG	NG
G1	2.98***	3.21***	2.56**	2.38***	-0.35*	-0.57	8.32***	4.18*
G2	2.17***	2.50***	3.68***	4.364***	3.60	3.88	5.56***	4.513**
G3	2.01***	1.87***	3.390***	4.27***	3.05*	-0.29	2.97***	7.62**
G4	2.11***	2.04***	6.015***	7.77***	2.72	-0.99	7.96***	6.80**
G5	-0.210	-0.44***	3.87**	3.26*	-0.37	1.34	5.34***	-4.55
G6	1.56***	2.097***	1.62	1.502***	1.07	-1.20	5.45***	5.50*

Note: This table is derived from previous tables. G1: Control of corruption, G2: Government Effectiveness, G3: Political Stability and Absence of Violence, G4: Regulatory Quality, G5: Rule of Law, G6: Voice and Accountability.

To sum up, the results obtained are two-fold. First, the explanation of the powers of the explanatory variables is only stronger in the new growth theory for the middle-income and high-income countries but not in the low-income countries. Second, we cannot apply this new growth theory to different countries with different levels of income. Actually this result is very interesting, because it demonstrates that the argument concerning which class of model is valid is not the right argument. Each theory should be applied by policy makers according to the fundamentals and the level of development and income.

7.3.2 φ Convergence

To show how different dimensions of technology have evolved in past years, this study follows the standard analysis of testing convergence, unconditional β convergence, for innovation intensity, human capital, innovation, globalization and studies how their statistical distributions have evolved over the past thirteen years. In this research, we are following the traditional way of testing β convergence, meaning that countries that are far away from the frontiers should reduce their gap to the technological leader faster in terms of technological dynamics compared to industrial ones; we call it φ convergence. We test the φ convergence for each dimension of technology over the period 1996-2010 to see the new aspects that can affect the distribution of technological activities in the world (Castellacci, 2011):

1- Governance indicators (6 indicators for institutions)
2- KOF index and FDI index (proxy of Globalization)
3- R&D intensity and number of scientific journals (proxy for innovation)
4- Secondary school enrolment (proxy for human capital)

Using exactly the same method that is used by R. Barro and Sala-i-Martin (1995) for testing the β convergence, the initial level of each variable is used as the only regressor and the annual growth rate of each dimension is the dependent variable.

$$\Delta A_i / A_i = \alpha + \varphi_1 A_{i,0} + \varepsilon_i \qquad (7\text{-}2)$$

Where $\Delta A_i / A_i$ is the growth rate for each technology dimension of country i over the period 1996-2010, and $A_{i,0}$ is the the log of its initial level at the beginning of the period. $\varphi_1$shows the speed of convergence for each dimension of technology. Table 7-23 shows the results.

Table 7-23: φ convergence in terms of technology dimensions, 1996-2010

φ convergence	High-income		Middle-income		Low-income	
	Coefficient	Speed	Coefficient	Speed	Coefficient	Speed
KOF index	-0.7160601	0.096846	-0.8471365	0.144478	-0.3062579	0.028127
FDI	-0.6153078	0.073486	-0.8462477	0.144032	-0.5363397	0.059123
R&D	-0.6386378	0.078298	-0.8561291	0.149141	+0.4651196	------
Journals	-0.7381398	0.103073	-0.8561395	0.149147	+0.4475	------
School enrolment	-0.2816667	0.025448	-0.4506667	0.046081	-0.8281398	0.135467
Control of corruption	-0.9257564	0.200031	-0.7331524	0.101621	-0.3806667	0.036855
Political stability and absence of Violence	0.9901717	0.355576	-0.7844689	0.11805	-0.4311259	0.043392
Governance effectiveness	-0.7247285	0.099231	-0.7281398	0.10019	-0.4989098	0.053151
Rule of law	-0.9285564	0.202988	-0.7405206	0.103775	-0.4456236	0.045378
Regulatory quality	-0.7323578	0.101393	-0.6825628	0.088267	-0.694108	0.091117
Voice and accountability	-0.8086918	0.127221	-0.8833463	0.165273	-0.7741196	0.114442

Note: The first column of each group reports the coefficient estimated from OLS regression and the second columns reports the speed of convergence.

The first column of each group reports the φ-coefficients, in which, in all the regressions, it turns out to be negative. This means φ-convergence is happening in terms of technology in these groups of countries. Of course, the speed of convergence among them is different. The speed of convergence is particularly rapid for governance indicators in high-income countries (on average 18%) and it is 11% for middle-income countries. However, on average, it is 6% for low-income countries. For human capital the story is different, the speed of convergence is particularly rapid in low-income countries at 13% and it is quiet low for high-income and middle-income countries, 2%

and 4%, respectively. This is consistent with the idea of M. R. Islam (2010) who said that “advanced countries are more likely to engage in innovating new technologies which required highly skilled human capital”. Furthermore, for globalization indicators, which, in this study, are KOF index and foreign direct investment (FDI), the speed of convergence is highest for middle-income countries on average 14% and 8% for high-income countries while it is 4% for low-income countries. For innovation activities it also has the highest rate for middle-income, which, on average, is 14% and 8% for high-income. However, the interesting thing is that the sign of innovation activities coefficient is positive for low-income countries, which means that across low-income countries there is no convergence in terms of innovation. This suggests that those countries that are very far from technology leaders are increasing the disparity in terms of innovation. This is a very significant result.

We can conclude that since the middle-income countries that are further away from the technology leaders have an adequate level of human capital they can take advantage of being more globalized and also invest more in their R&D activities, which will increase their productivity more than the others. However, as P Aghion and P Howitt (2006) argued in their paper, just being further away from the technology leader is not the only criterion to grow faster. The results here are another proof of this statement. As we can see in the low-income countries, although they are further away from the technology leaders compared to the middle-income countries, since they do not have an adequate level of human capital or the skill to take advantage from the imported technology, being more globalized and investing more in R&D activities is less effective for them.

7.4 Middle-income Trap: More Testing on Convergence

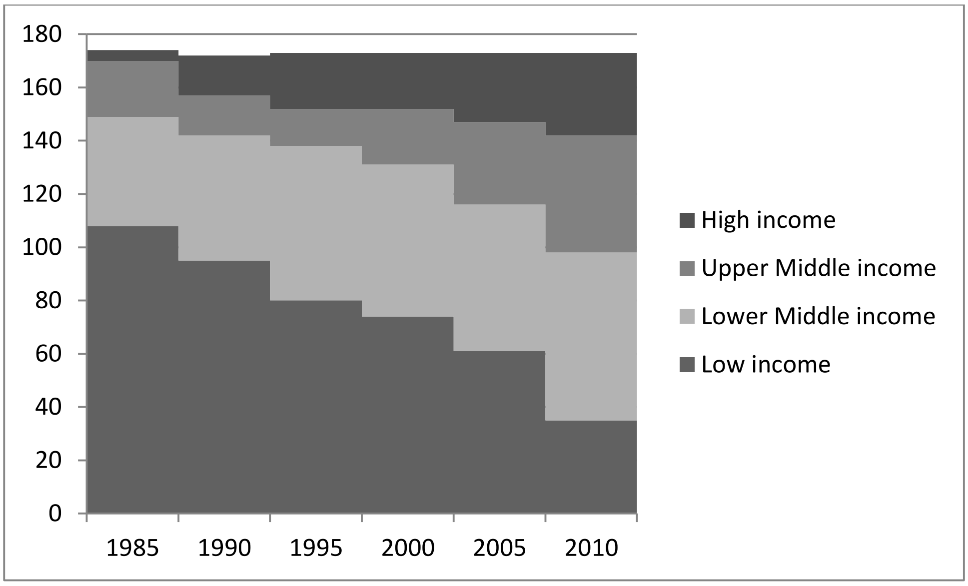
Understanding how countries go through the economic development sequence is the unending quest of development economists. Most often, the sequence is from low-income to middle-income and, ideally, to high-income. In some cases, however, countries get stuck in the low- or middle-income groups for a long period of time and do not move up. For the low-income countries we see empirically that these countries trapped in the poverty and cannot catch up to the upper stage. We discussed the reason behind this "poverty trap" in previous sections by testing convergence hypothesis and studying the effects of institutions and globalization and creation in these countries. However, the empirical evidence shows that some countries that moved from low-income to middle-income over two decades were still trapped and could not cross the border to the high-income level (Gill and Kharas, 2007). Economists like Spence (2011), in his book, claim that this is the "middle-income transition". He said that middle-income transition is the situation when "that part of the growth process that occurs when a country's per capita income gets into the range of \$5,000 to \$10,000" (Spence 2011, 100).

To study this middle-income trap, we are going to study the trend of growth in the sample of this study and see how many of the countries in middle-income group of this study have been trapped in this level of income for years and how many of them move to the high-income level.

As we described earlier, this study used the World Bank classification for grouping countries, which is based on the GNI Atlas method.

The most recent World Bank classification with data for 2012 is as follows: a country is low-income if its gross national income (GNI) per capita is \$1,025 or less; lower middle-income if its GNI per capita lies between \$1,026 and \$4,035; upper middle-income if its GNI per capita lies between $4,036 and $12,475; and high-income if its GNI per capita is $12,476 or above. Under this classification, 35 out of the 174 countries in the sample were considered low-income in 2012, 63 lower middle-income, 44 upper middle-income, and 31 high-income (see Appendix Table 1a and 1b).

Figure 7-1 Distribution of countries by level of income



Source: Author's calculations; World Bank

Figure 7-1 shows that the number of low-income countries decreased from 108 countries in 1985 to 35 countries in 2010. The largest decline in the number of low-income countries was during 2005 and 2010. Where 25 out of 26 of them moved to the lower middle-income group and 1 of them moved to the upper middle-income group (China). These countries could escape from the poverty trap and converge with the middle-income countries. However, the other 35 countries have remained in the poverty trap since 1985 and could not even move to the lower middle-income level.

Table 7-24 countries that have always been in the low-income group between 1985 and 2010

Afghanistan	Liberia	Gambia, The
Bangladesh	Madagascar	Guinea
Benin	Malawi	Guinea-Bissau
Burkina Faso	Mali	Haiti
Burundi	Mauritania	Kenya
Cambodia	Mozambique	Tanzania
Central African Republic	Nepal	Togo
Chad	Niger	Uganda
Comoros	Rwanda	Kyrgyz Republic
Congo, Dem. Rep.	Sierra Leone	Zimbabwe
Eritrea	Somalia	
Ethiopia	Tajikistan	

The more interesting thing concerns the countries that escaped from the middle-income trap since 1985.

In 1985, there were only 4 countries in the high-income group, but, after five years, 11 countries escaped from the middle-income trap, and, by 1995, there were 21 countries in this group. However, for nearly ten years, until 2005, no countries could escape from the middle-income trap when 5 countries – Greece, Ireland, Korea Rep., Portugal and Slovenia – caught up with the high-income countries. Between 2005 and 2010 another 5 countries escaped from the middle-income trap – the Czech Republic, Hungary, Estonia, Poland and the Slovak Republic. This is consistent with the results of testing β convergence, where convergence happened across the middle-income group. Of course, we cannot ignore the fact that some countries remained in the middle-income group, but, as the results of convergence show, they will move to the upper stage in approximately nine years.

7.5 Summary of Statistical Results

7.5.1 Convergence in each Class of Model

One of the hypotheses in this study is testing the convergence speed in GDP per capita for low-income, middle-income and high-income countries where poorer countries, according to the convergence hypothesis, should grow faster than the richer ones. In this study, we test the convergence hypothesis in the neoclassical growth model, capital deepening model, and also the new growth model and technology based models. The results show that the speed of GDP convergence is faster in the middle-income countries than the high-income countries in all models. This is widely known. However, it is the slowest across the low-income countries in the NCGM and there is no convergence in the NGM, which does not support the idea of convergence. Therefore, according to these results we can conclude that income convergence is not monotonic to income. An income threshold may need to be reached before low-income countries can benefit from policies like investing more in the R&D sector. The signs and significance of the explanatory variables is proof of this claim. Furthermore, the empirical evidence also shows the existence of a poverty trap. The results of section 7-4, for the study of the middle-income trap are another proof for this. The results show that the 30 countries in the low-income group have been in this group since 1985, according to our time panel, and could not escape from the poverty trap. Therefore, a minimum level of institutional capacity and human capital depth is required to accelerate the growth and convergence in this group to accelerate their growth rate and move to the upper stage (Hypothesis 2).

7.5.2 Impact of Globalization on Economic Growth and Convergence

The other hypothesis of this research is testing the impact of globalization on economic growth of the sample in both theories. In the growth literature, a large proportion of articles concern the effect of opening up the borders of countries and reducing the tariff rates to increase the international trade across countries. This still remains a debate up until now. As we discussed, some economists believe that globalization is a malignant force that only helps developed countries to take advantage of this openness (Rodriguez & Rodrik, 2001; Slaughter, 1997). However, other groups believe that globalization can also help developing and undeveloped countries to catch the rich ones and accelerate their growth rate (David Dollar & Kraay, 2001; Geoffrey Garrett, 2000; Greenaway & Torstensson, 1997).

In this research, the KOF index and FDI were chosen as proxies for globalization. In the new growth literature, globalization is not only about the trade of goods but also about the transferring of technology across countries through communication and infrastructure. Consequently, the KOF index was chosen, which covers two other aspects besides the economic aspect: political and social. The results of this study show that globalization affects the growth of the middle-income and high-income countries in both models irrespective of whether the focus is on capital accumulation (NCGM) or technological change (NGM). Furthermore, this impact is more effective on middle-income, which supports the faster rate for convergence across middle-income than high-income countries. However, in respect of low-income countries globalization is only effective on the growth through the channel of capital accumulation but not technology.

7.5.3 Impact of Institutions on Economic Growth and Convergence

The other hypothesis of this research is testing the impact of institutions on the economic growth of the sample in both theories. Economists, like R. Nelson (2007), believed that having proper institutions leads to promote growth. This is supported by many other economists who, recently, have argued that building strong institutions can positively affect growth in countries. However, measuring a good proxy for institutions has always been a debatable issue in literature, especially in recent years where the place of institutions has become important for growth. In this research we choose governance indicators as a proxy for institutions since these factors cover six different dimensions that are very important to analyse the effects of institutions in economies. Furthermore, the results of this research do not support the idea of having strong institutions that can promote growth in all countries. According to the results, institutions only affect growth across middle-income countries and high-income countries that are above the income threshold, but not for low-income countries in both models. Even the effect of controlling corruption is negative and significant in low-income countries, which means that if the government does not control the corruption in this group not only they cannot cease the growth but also they promote growth in these economies. This is further support for the existence of an income threshold (Hypothesis 5). This last point also shows that the level of development is an important context for any discussion of the relationship between institutions, technology catch-up and economic growth.

7.5.4 Testing the φ convergence

The other hypothesis of this research is to test how different dimensions of technology have evolved in recent years (φ convergence). This study follows the standard analysis of testing convergence, unconditional β convergence, for innovation intensity, human capital, innovation, globalization and studies how their statistical distributions have evolved over the past thirteen years. We call it φ convergence in this study. The results show that the gap that already exists between these groups of countries can be explained by the technological differences amongst them. The results again highlight the income threshold and the fact that countries can take advantage of those dimensions of technology that are appropriate to their income level and also the level of development. The results also emphasize the importance of creating and adopting technology across middle-income countries through investing more in the R&D sector and also through being more globalized to take advantage of the technology transfer through the Internet and foreign investment. Being more globalized, these two, together with innovation, are the fastest drivers of technology advance in middle-income countries. However, for low-income countries, capital accumulation and secondary schooling are the most important drivers. The results suggest that if low-income countries want to close the gap on the other groups they have to increase the level of investment and human skills. In referring to human skill the results show that at the later stages of development, secondary education becomes less important in explaining the differences in growth while in low-income countries the secondary enrolment factor has the largest effect on productivity growth (Hypothesis 3). This is also consistent with the previous results.

To sum up, the results for testing φ convergence show that low-income countries are not that successful in closing the gap separating them from middle-income and high-income countries in terms of innovation and institutions and globalization. However, these factors are important for those developed and developing countries since they contribute to the absorptive capacity as well as the innovative capability. This pattern of convergence is not only important because of its effect on income but also because these factors are important in terms of human welfare, and, hence, are important for policymakers.

The important policy implications according to the results of our analysis is that countries for closing the gap with other groups should implement policies that are appropriate with their level of development and not just follow the pattern of developed countries or developing ones.

7.5.5 Validity of Growth Models: Neoclassical or New Growth Models

One of the hypotheses of this research concerns which growth model can explain the differences in growth rate across the countries of the sample. However, the results of both growth theories, NCGM and NGM, show that even considering all the variables, what is important in both models is just the income level. This is the wrong argument. It should be that the factors that explain growth or convergence differ between lower and middle-income countries. For low-income countries, it is physical capital, whereas, for middle-income countries, it is R&D intensity, globalization and human capital. Therefore, the debate over which model is appropriate is not that meaningful without reference to a country's level of income.

We can conclude that for implementing policies in an economy, policymakers should first consider the stage of development in the country, and then decide which system to follow. The empirical results of this study are proof of this claim, since the results show that for low-income countries, despite much criticism, the NCGM still remains relevant. This means that for low-income countries, which are at the initial level of development, focusing on policies that can increase the investment rate could be effective on output. However, since they do not have a foundation for creation and innovation technology, implementing policies like investing in the R&D sector is not worthwhile (Hypothesis one). Furthermore, these countries can implement policies that improve the relations with other countries to benefit from foreign investment and the flow of ideas from those countries. The positive and significant sign of the KOF index and FDI supports this idea.

Chapter 8

Concluding Remarks and Policy Implications

8.1 Overview

This research is an empirical analysis that tests the convergence rate across three groups of countries classified based on their income according to the World Bank method by focusing on two growth models: neoclassical growth model and new growth model. The basic question in the convergence debate is whether poorer countries are converging with the richer ones, and, in the case of this research, if yes, which growth model can better explain the economic growth across the sample of countries over time and across countries. The other important aspect of this research is the argument concerning this issue in that some economists believe that testing convergence hypothesis besides estimating the speed of convergence across countries, gives validity to growth models. Therefore, another important question in this research is whether testing convergence is a good criterion to give validity to each class of model. Besides these two aspects, another concern of this study is about growth determinants. Studying the factors that explain economic growth across countries is always a debatable issue amongst economists. However, empirical studies in this area largely ignore the importance of institutions and globalization. Therefore, this study investigates the role of institutions and globalization on economic growth of the sample countries and also the process of convergence.

In the Solow model, NCGM, capital accumulations play an important role in explaining the different growth rates across countries. First, Solow (1956) focused on physical capital accumulation and after that G. Mankiw et al. (1992) talked about human capital accumulation. These models predict conditional convergence across countries, which are not at their steady state level of income. Growth relates negatively to the initial level of income, so poor countries can grow faster than rich ones.

Although in the new growth theory, in the latest models, convergence happens across countries, which is against P. M. Romer (1990) argument that countries can grow in the long-run, and, therefore, there is no convergence across countries. However, in these versions of the endogenous models they assumed that there is an increasing complexity of new innovation, and, therefore, they accept the existence of convergence across countries. Nevertheless, there is a big disagreement between these two schools of thought on the sources of growth: whether technological changes are the most important sources of growth or formation of capital.

Both theories try to explain the difference across countries and the convergence process by focusing on capital accumulation and technological change, respectively. However, as mentioned before, empirical studies in this area largely ignore the importance of institutions and globalization and technology transfer. Therefore, in this research we tried to reopen the debate of convergence according to these shortcomings in empirical studies and by applying the generalized method of moments, re-estimated the models across three different groups of countries that are classified by their level of income according to the world classification method.

8.2 Research Findings: Rate of Convergence in Neoclassical and New Growth Theory

Testing the convergence in the first augmented Solow-Swan model, where the accumulation of physical capital and human capital are considered as controlling variables for the steady state, show that this theory is supported by middle-income countries, meaning that they can grow faster than high-income countries. According to the theory it should be the same for low-income countries, however, the results of the convergence rate did not support this idea. There was no convergence in low-income countries according to this model. This result shows that just considering human and physical capital accumulation is not enough for countries with a low level of income to experience the fast growth rate and that other variables should be added to the model.

Therefore, other variables were added to the model to see how the convergence rate changes across these groups according to these determinants of growth. Institutions and globalization and innovation factors were added to the model through the human capital accumulation channel as controlling variables, which facilitate and accelerate the rate of human capital accumulation.

Table 8-1 Comparison of Convergence Rate Across Sample Groups Between NCG and NG Models

Groups	**First NCG Model**	**Second NCG Model**	**NG Model**
Whole sample	Less than 1%	Less than 1%	Less than 1%
High-income	Less than 1%	3%	4%
Middle-income	5%	8%	9%
Low-income	No convergence	1%	Less than 1%

Comparing the results of the second model with the first model shows that convergence also appears in low-income countries based on the second model, albeit it is very slow. In addition, for high-income countries it becomes 3 percentage points, which is faster compared to the first model, while for middle-income countries the rate also becomes faster than the first model. One explanation for these results is that adding these controlling variables as facilitators of human capital accumulation is effective on growth, and, also, controlling for these variables has a positive effect on the growth rate of these countries. The other explanation for what happens to low-income countries, which does not support the idea of convergence, is that an income threshold may need to be reached before convergence occurs in this group. Countries below that threshold are caught in a poverty trap from which it takes a long time to escape.

The results for the new growth model are more interesting. As table 8-1 shows, the results are promising for middle-income and high-income countries, although the rate for middle-income countries is still faster than for high-income countries, compared to the neoclassical growth the results for the rate become faster. However, the rate declines across low-income countries from 1 percentage point according to the NCG model to less than 1 by applying NG regression. One explanation for these results is that, in countries that are already above the income threshold or at the later stages of development, technological changes can have a stronger effect compared to countries that do not have the fundamentals and have not yet reached the income threshold. We can see that when we apply the new growth regression, where technological change is the main source of growth and where the globalization, innovation and institutions are components of knowledge growth, the rate of convergence becomes faster than when applying the NCG model. However, as the results show, this is not true for low-income countries. In low-income countries, where the income threshold is not reached, the main source of growth is still capital accumulation. The results of the growth determinants provide further evidence for this conclusion. The effects of physical capital in the NCG model are three times as large as in the NG model. In the other words, we can say that income convergence is not monotonic to the income level of countries, and that the income threshold may need to be reached before countries can take advantage of the technological change and so speed up the rate of convergence. In other words, we can say that applying which growth theory is appropriate is monotonic to income level or level of developments. The new growth regression can be applied in countries that are developed or in the process of development, but not for those countries with a low level of income. For low-income countries or undeveloped countries the neoclassical growth theory that is based on capital accumulation should be applied. In other words, governments should implement policies that increase the investment rate.

The other part of the results explains the sources of difference across countries. In the above discussion we conclude that the rate of convergence, when applying new growth regression, is faster in middle-income and high-income countries, and we relate it to the nature of new growth theory in which the main source of growth is technological change. The results of the determinants of growth support this idea. This means that if we take a look at the signs and significances of the variables in the new growth regression for middle-income and high-income countries it is clear that they are stronger and more effective than the NCG regression. For example, when we compare the results of neoclassical growth regression with new growth regression in high-income countries, it can be seen that research intensity is more productive in new growth regression than in the neoclassical growth regression. This is also true for globalization indicators and governance indicators. Comparing the results for middle-income countries provides the same conclusion; the productivity of the variables is more when we apply the new growth theory. We can say that the effectiveness of variables is deeply related to the level of their development, and, therefore, level of income. However, what about low-income countries?

For low-income countries that are not developed or in the initial stages of development, the interpretation of the results is a little different. As the results show, physical and human capital formation is effective and significant on growth in both classes of model, especially in the NCG model. However, for the other explanatory variables we can see that when applying the NG model, none of the explanatory variables are significant. When applying the NCG model, the most effective variable amongst others are the globalization indicators, which remain significant and positive. One explanation for this is that globalization, innovation and institutions have no immediate/direct impact when applying the new growth theory in which these variables are considered as sources for technological change. However, among them, globalization may work and remain important in the neoclassical growth model. This is consistent with economists like Charles Jones (1998) who argued that although creation and innovation are not happening in all countries, we can see that some countries can still grow; being globalized and opening up the borders not only brings foreign investment to these countries but also brings technology. Therefore, we can see that there is also growth in these classes of countries, although at a slower pace. The results of this study provide further evidence for what he claimed. It is true that these countries do not have a sufficient level of human capital to take advantage of the output of R&D activities and creation, but by working on their political stability, which is positive and significant across them, they can provide a safe environment for foreign countries to invest in their country. Therefore, they can take advantage from technology spillovers and so increase their GDP growth rate. Furthermore, this is an interesting result because we can conclude that reaping the benefits of technology is not possible for low-income countries until they reach a certain income threshold.

8.3 Contributions of the Study

The primary contribution of this study to the literature is reconciling the neoclassical growth model based on the new aspects of growth like the effects of R&D, institutions and globalization. In the previous studies, researchers may take a look at these variables in the neoclassical growth model, but they only add them as controlling variables to the model for controlling the steady state of the growth path in the economies. In contrast, this study adds them to the model as components of human capital accumulation, which facilitate and accelerate the accumulation of capital, rather than just simple independent variables.

Second, this study also focused on the imitation and innovation as components of knowledge growth for examining the new growth theory rather than focusing on innovation based models. Furthermore, for imitation, factors like institutions and globalization are considered as variables that can have a direct effect on the speed of technology transfer, and, therefore, affect the imitation rate, and, ultimately, economic growth.

Third, the study provides an analysis of convergence from a political economic point of view. Most of the studies focused on the political view or economic points of view separately, while in this study we consider both of them to analyse economic growth and convergence. For doing that, this study incorporates variables like political stability, regulatory quality and other institutional factors as well as economic factors like FDI, initial GDP per capita, and school enrolment ratio as both groups of variables have an influential effect on economic growth.

Finally, in this study we extended the analysis of economic growth and convergence to the year 2010 for all of the variables.

8.4 Limitations of the study

One of the greatest limitations of this study is availability of the data for low-income and middle-income countries. Despite the fact that the World Bank database provides an extensive source of data for almost any kind of world activity, data are not available for some of the low-income and lower middle-income countries.

Another limitation of this research is the choice of proxies for institutional factors in economies. For measuring institutions, the governance indicators were the most comprehensive ones that could be found in databases, which have their own shortcomings.

Furthermore, the same thing happened for globalization. For measuring Globalization, the KOF index was the only one that covers other dimensions of integration besides the economic aspects, which has its own shortcomings. However, it is the most comprehensive among the others.

8.5 Policy Recommendations

A number of policy recommendations can be made based on the findings of this research. First, government should not follow blindly the policies implemented in developed countries. The results of testing convergence in both classes of growth models reveals that countries that are at the initial level of development or those that are not developed yet should still follow capital deepening models that focus on increasing the saving rate, and, therefore, lead to an increase in the investment in the economy. Implementing policies that lead to more investment in the R&D sector to have more creation and innovation does not have an outcome in these countries, since they do not have the fundamentals like sufficient level of human capital and physical capital. The findings of this study suggest that governments should take the existence of the income threshold seriously.

Second, more attention should be paid to how the globalization phenomenon can affect economic growth and convergence in countries, especially low-income countries. Although many aspects of this phenomenon are difficult to measure and can be considered as part of the unobserved variables, recently, Dreher (2003), by introducing the KOF index, provided a better measurement for globalization. The effect and impact of globalization could be greatly increased if policies are capable of improving low-income countries' globalization efficiency and work harder within the confines of the political system. The findings of this study show that low-income countries could not benefit from R&D outputs so investing in these activities may not confer immediate tangible benefits; however, implementing policies that increase the speed of technology transfer through globalization could make it possible for these undeveloped countries to improve their culture through the Internet and other infrastructure, so that step-by-step they can speed up the imitation rate and increase the productivity and economic growth in their countries.

Third, building strong institutions is not an ideal policy for countries that do not have the fundamentals. The findings show that for low-income countries, having strong institutions can even have a negative effect on economic growth. For example, controlling corruption in low-income countries might even slow down the convergence rate. The explanation is very simple, for example, if in an undeveloped country the way to get driving licences illegally is very easy and is not costly, and there is no need for lots of paperwork, people in that economy are able to obtain them, and, so, the transportation of goods and services will become easier and cheaper and lead to economic growth(Heckelman & Powell, 2008; Mironov, 2005). However, this should not continue in the system after reaching a certain level of development, because it could have a negative effect on growth.

8.6 Suggestions for Further Research

Studying economic growth and convergence is a very dynamic issue and many scholars have attempted to figure out the effects of different determinants on economic growth by applying different methods that could consider unobserved effects as well. In this study we applied the dynamic system GMM since we had little time and a large number of units. However, the one suggestion for further research is to extend the time series, by focusing on other determinants of growth for which the data are available and use Pooled Mean group estimators or Mean group estimators to gain more robust results. However, applying a long time series has its own difficulties, for example, for large T, Kevin Lee et al. (1997) estimators, like GMM fixed effect, instrumental variables can produce inconsistent and potentially misleading estimates of the average values of the parameters in the dynamic panel data model. Furthermore, when the pooling assumption does not hold, the panel is referred to as a heterogeneous panel (some of the parameters actually vary across the panel). Therefore, for solving the problem of heterogeneity bias K. Lee, M. H. Pesaran, and R. P. Smith (1997) suggest two other estimators – pooled mean group or mean group estimators. In the GMM estimator, since first difference is taken, the differences between countries are eliminated from the regression, while for long time period we consider these differences by applying pooled mean group or mean group estimators.

The other suggestion for further research is testing the convergence hypothesis by examining multiple dependent variables that present different aspects of economics, such as labour productivity and investment per worker. The reason for this is that economic growth is complex and the concern of countries is not only to increase their GDP per capita, but also productivity. Therefore, we suggest applying alternative factors, in addition to GDP per capita, for testing convergence among countries and making a comparison among them.

Finally, further research can classify countries based on the distance to the leader, for example, US can be picked as a leader based on the greatest TFP that it has in 2012 amongst countries, and then test the convergence hypothesis with other explanatory variables to see whether the results are the same as when we classify countries based on their income.

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Appendix

Table 1: KOF Index of Globalization by details (2012)

	Indices and Variables	Weighs
A.	Economic Globalization	[36%]
	i) Actual Flows	(50%)
	Trade (percent of GDP)	(21%)
	Foreign Direct Investment, stocks (percent of	(28%)
	Portfolio Investment (percent of GDP)	(24%)
	Income Payments to Foreign Nationals (percent	(27%)
	ii) Restrictions	(50%)
	Hidden Import Barriers	(24%)
	Mean Tariff Rate	(27%)
	Taxes on International Trade (percent of current	(26%)
	Capital Account Restrictions	(23%)
B.	Social Globalization	[37%]
	i) Data on Personal Contact	(34%)
	Telephone Traffic	(25%)
	Transfers (percent of GDP)	(4%)
	International Tourism	(26%)
	Foreign Population (percent of total population)	(21%)
	International letters (per capita)	(25%)
	ii) Data on Information Flows	(35%)
	Internet Users (per 1000 people)	(33%)
	Television (per 1000 people)	(36%)
	Trade in Newspapers (percent of GDP)	(32%)
	iii) Data on Cultural Proximity	(31%)
	Number of McDonald's Restaurants (per capita)	(44%)
	Number of Ikea (per capita)	(45%)
	Trade in books (percent of GDP)	(11%)
C.	Political Globalization	[26%]
	Embassies in Country	(25%)
	Membership in International Organizations	(28%)
	Participation in U.N. Security Council Missions	(22%)
	International Treaties	(25%)

Source:

Dreher, Axel, 2006, Does Globalization Affect Growth? Empirical Evidence from a new Index, Applied Economics 38, 10: 1091-1110.

Updated in:
Dreher, Axel; Noel Gaston and Pim Martens, 2008, Measuring Globalization - Gauging its Consequence, New York: Springer.

Pairwise correlation coefficients for governance indicators from 1996 to 2010 in high income countries.

	G1	G2	G3	G4	G5	G6
G1	1.0000					
G2	0.9236*	1.0000				
	0.0000					
G3	0.4697*	0.4707*	1.0000			
	0.0000	0.0000				
G4	0.7729*	0.7739*	0.3910*	1.0000		
	0.0000	0.0000	0.0000			
G5	0.9515*	0.9219*	0.5151*	0.7815*	1.0000	
	0.0000	0.0000	0.0000	0.0000		
G6	0.8185*	0.8085*	0.6475*	0.7544*	0.8250*	1.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	

Pairwise correlation coefficients for governance indicators from 1996 to 2010 in middle income countries.

	g1	g2	g3	g4	g5	g6
g1	1.0000					
g2	0.8405*	1.0000				
	0.0000					
g3	0.6650*	0.5699*	1.0000			
	0.0000	0.0000				
g4	0.6902*	0.8187*	0.4333*	1.0000		
	0.0000	0.0000	0.0000			
g5	0.8669*	0.8448*	0.7410*	0.7176*	1.0000	
	0.0000	0.0000	0.0000	0.0000		
g6	0.6378*	0.6066*	0.5371*	0.6520*	0.6543*	1.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	

Pairwise correlation coefficients for governance indicators from 1996 to 2010 in low income countries.

	g1	g2	g3	g4	g5	g6
g1	1.0000					
g2	0.6164*	1.0000				
	0.0000					
g3	0.5219*	0.5614*	1.0000			
	0.0000	0.0000				
g4	0.4649*	0.7370*	0.5024*	1.0000		
	0.0000	0.0000	0.0000			
g5	0.7468*	0.7878*	0.7013*	0.6575*	1.0000	
	0.0000	0.0000	0.0000	0.0000		
g6	0.4189*	0.5552*	0.6461*	0.6504*	0.5813*	1.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	

Pairwise correlation coefficients for Globalization indicators from 1996 to 2010 in high income countries.

	fdi	kof
fdi	1.0000	
kof	0.0293	1.0000

World Governance Indicators (WGI) Aggregation Methodology:

Each of six aggregate WGI measures is constructed by averaging together data from the underlying sources that correspond to the concept of governance being measured. This is done in the three steps described below.

STEP 1: Assigning data from individual sources to the six aggregate indicators. Individual questions from the underlying data sources are assigned to each of the six aggregate indicators. For example, a firm survey question on the regulatory environment would be assigned to Regulatory Quality, or a measure of press freedom would be assigned to Voice and Accountability. A full description of the individual variables used in the WGI and how they are assigned to the six aggregate indicators, can be found by clicking on the names of the six aggregate indicators listed above. Note that not all of the data sources cover all countries, and so the aggregate governance scores are based on different sets of underlying data for different countries.

STEP 2: Preliminary rescaling of the individual source data to run from 0 to 1. The questions from the individual data sources are first rescaled to range from 0 to 1, with higher values corresponding to better outcomes. If, for example, a survey question asks for responses on a scale from a minimum of 1 to a maximum of 4, we rescale a score of 2 as (2-min)/(max-min)=(2-1)/3=0.33. When an individual data source provides more than one question relating to a particular dimension of governance, we average together the rescaled scores. The 0-1 rescaled data from the individual sources are available interactively through the WGI website here, in the country data sheets, and in the data files for each individual source. Although nominally in the same 0-1 units, this rescaled data is not necessarily comparable across sources. For example, one data source might use a 0-10 scale but in practice most scores are clustered between 6 and 10, while another data source might also use a 0-10 scale but have responses spread out over the entire range. While the max-min rescaling above does not correct for this source of non-comparability, the procedure used to construct the aggregate indicators does (see below).

STEP 3: Using an Unobserved Components Model (UCM) to construct a weighted average of the individual indicators for each source. A statistical tool known as an Unobserved Components Model (UCM) is used to make the 0-1 rescaled data comparable across sources, and then to construct a weighted average of the data from each source for each country. The UCM assumes that the observed data from each source are a linear function of the unobserved level of governance, plus an error term. This linear function is different for different data sources, and so corrects for the remaining non-comparability of units of the rescaled data noted above. The resulting estimates of governance are a weighted average of the data from each source, with weights reflecting the pattern of correlation among data sources. Click here for the weights applied to the component indicators.

The UCM assigns greater weight to data sources that tend to be more strongly correlated with each other. While this weighting improves the statistical precision of the aggregate indicators, it typically does not affect very much the ranking of countries on the aggregate indicators. The composite measures of governance generated by the UCM are in units of a standard normal distribution, with mean zero, standard deviation of one, and running from approximately -2.5 to 2.5, with higher values corresponding to better governance. We also report the data in percentile rank term, ranging from 0 (lowest rank) to 100 (highest rank).