# An Empirical Assessment of the Convergence Theory of the Solow Model

**Seyi Saint Akadiri**

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the Degree of

Master of Science
in
Economics

Eastern Mediterranean University
February 2015
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Serhan Cıftcıoğlu
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Master of Science in Economics.

Prof. Dr. Mehmet Balcılar
Chair, Department of Economics

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Economics.

Asst. Prof. Dr. Çağay Çoşkuner
Supervisor

Examining Committee

1. Assoc. Prof. Dr. Sevın Uğural
2. Asst. Prof. Dr. Kemal Bağzıbağlı
3. Asst. Prof. Dr. Çağay Çoşkuner

# ABSTRACT

This study empirically investigates the convergence theory based on the perceived level of diversities in the economic development within the countries of the world. he estimation method employed for this research work is the cross-sectional regression analysis to measure convergence, using data of 1980 and 2010 for 50 selected countries. Data for the study were extracted and sourced from the World Bank development indicators database.

From the empirical evidence, we discovered there is a reaction, or better put, a feedback relationship between growth and the initial GDP per capita. This implies that, country with low initial GDP per capita is farther away from their steady state and would grow faster than the countries with high initial GDP per capita but closer to their steady state. On the nexus between the growth and initial GDP per capita, the regression analysis revealed that, level of investment is a catalyst for growth. Hence, we infer that, the poor countries should enhance their level of investment (both in human and physical capital). The more the level of investment, the more would be the level of growth. The model exhibits a natural long-run relationship. This made us to know that, no matter the level of disparities and diversities between the poor countries and the richer ones today; the former would still grow and catches up with the latter.

**Keywords**: Convergence, growth, GDP per capita, investment, economic development, cross sectional.

# ÖZ

Bu çalışma değişik kalkınmışlık düzeylerindeki ülkeleri kullanarak Convergence Theoriyi test etmektedir. Bu amaçla 50 ülkeli bir Cross-Sectional regresyon kullanılmıştır. Veriler 1980 ve 2010 tarihlerini kapsamaktadır. Tüm veriler Dünya Bankası World Development Indicators verileridir.

Regrtesyon sonuçları büyüme oranları ile başlangıç kişi başı gelir düzeyleri arasında bir ilişki olduğunu göstermektedir. Başlangıçta kişi başı gelir seviyesi düşük olan ülkeler daha hızlı büyümektedir. Sonuçlar ayrıca yatırımların ekonomik büyümeyi hızlandırıcı olduğunu göstermektedir. Dolayısıyla gelişmekte olan ülkeler fiziksel ve beşeri yatırımlara öncelik vermelidirler.

Anahtar Kelimeler: Convergence, Ekonomik Büyüme, Kişi başı gelir, Yatırım, Ekonomik Kalkınmışlık, Cress-Sectional.

To My Grandma,

**MRS. OLUFUNKE OGEDEBE**

She taught me that, there is dignity in learning.

# ACKNOWLEDGMENT

I give all the glory to Almighty God for being faithful to His words in my life.

My sincere gratitude goes to my able supervisor Asst. Prof. Çağay Çoşkuner, for his encouragement, support, constructive criticism and suggestions for improvement towards the finishing of this work; and a special thanks to Prof. Glenn Jenkins for his priceless and extreme support. Special thanks to Assoc. Prof. Sevin Uğural for being a wonderful course adviser and for her esteemed support and encouragement during my program. May God reward and bless the work of your hands. (Amen).

I am indebted to my instructors for their encouragement especially Prof. Dr. Glenn Jenkins and Asst. Prof. Dr. Kemal Bağzıbağlı

Finally, my deepest gratitude goes to my family; and to friends who stood by me, in the likes of Mr. & Mrs. Onipede, Omotola Michael Awojobi, Mr. Williams Ogedebe, Marshall Valentine, Sakah Momodu, Gbenga Martins, Vıctor Festus, Abisola Obafunsho, Pastor David Odiba, Oluwashina Odukoya, and host of others that I cannot remember, may God in His infinite mercies, bless you all.

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# Chapter 1

# INTRODUCTION

## 1.1 Background to the Study

The principle of convergence theory in economics is based on the hypothesis that, the poorer economies income per capita will tend to grow at a faster rates than the richer economies. If this theory holds, then, both the rıch and the poor countries would in due course convergence in the course of per capita income.

The developing and the less developed economies have all what it takes to grow and sprout out, at a rate faster than the so called advanced (developed) economies, due to the fact that, diminishing returns (especially to capital) in the developing countries are not as strong as in the developed or capital surplus economies. Moreover, poor countries can duplicate the production techniques, methods, and procedures of developed countries.

In most of the growth literature the word “convergence” has been used with two different meanings, which are sigma convergence and beta convergence. The former refers to a reduction in the differences of income levels across different economies. On the other hand, beta convergence, come to play, when poorer countries grow faster than the rich counterparts. Economists often say that, there is a “conditional beta – convergence” when an economy experience “beta convergence” but the

conditional on all other variables being held fixed or constant. They argued that "unconditional beta convergence" or better out, "absolute beta convergence" would only exist, provided the growth rate declines, as such economy move towards its steady state.

It is equally crucial to note that, the poorer state of a country or an economy does not depict or guarantee that convergence growth will be achieved. Moses (1996) in his analysis emphasized the need for "social capabilities" to gain from the convergence growth. Among all other includes an ability to bring in new technology, employ more capital and take part in global markets. According to Moses (1996), these requirements must be in place in an economy before the convergence growth can take place and he explained why there is divergence in part of the world as of today.

One of the assumptions of the convergence theory is that, when technology is not as diffusing as assumed, then, the developing countries will be struggling to converge. The cost or unavailability of capital in these developing economies is also a factor that can prevent convergence growth from occurring, particularly, with the fact that capital is economically scarce in these developing countries. This, most of the time, traps many countries in a low-efficiency web, which is due to the fact that most efficient technology are very costly to be acquired. The productivity methods and techniques are the major differences that separate the leading developed economies from the following ones, but through a margin little enough to allow the following nations a chance to catch-up. The convergence process would proceeds as long as the following nations have tangible things to learn from the leading developed nations.

Historically, there are several lists of countries which have caught-up with the developed economies and justified the convergence theory. The East Asian Tigers in the 1960s and 1970s rapidly converged and caught-up with developed countries. These countries include Singapore, Taiwan, South Korea and Hong Kong; these countries today are regarded as developed countries and economies. West German, Japan and France, in the post war period between 1945– 1960, were able to rapidly recover their before-war position by replacing capital that was exhausted during the World War II.

However, convergence theory have been criticized by some economists, see Reinhard (1976) and Glynn (2011) they argued that, endogenous factors one of which is government policy, have much influence on economic growth compared to exogenous factors. A proposition by economics historians Sokoloff (1994) presumed that, natural resources or factor endowment are the main determinants of constitutional and systemic imbalance that shackle institutional advancement and development in some nations of the world.

## 1.2 Statement of the Problem

Therefore, going through Solow's work on "convergence theory", one would begin to wonder if it is true that the poorer countries would grow faster and catch up with the richer countries at the steady state. Why do countries have to grow at different rates? Is there convergence in growth rates between countries of the modern world, and more specifically, in what ways can countries enhance their economic growth? These are basically major questions that prompt the researchers urge. The instigator of the issue on economic growth such as Ramsey (1992), Solow (1956) and other prominent successors considered economic growth as exogenous.

It was in the 1980s that the theories of endogenous growth started to make wave and become formalized. The endogenous growth models considered the determinants of saving rates and technological progress, unlike the exogenous growth literature, thereby using microeconomics tools to build macroeconomic models.

Convergence theory and economic growth are major crucial problem. More than three quarter of the world population lives in poverty. Many do not have access to basic necessity and a decent life. Analyzing growth theories, inclusive with right economic policies, gives possible solution to these concurrent problems, at least by taking a macroeconomic glance. One thing to bear in mind is that, what really determines who lives in poverty and the ones who would manage to grow and scale through from it? Maybe, the answer to this can be gotten through assessing empirically the theory of economic convergence and the Solow model in this modern economy.

## 1.3 Objective of the Study

As the contemporary discourse on the possibility, veritable relationship and applicability of convergence between the poorer countries and the richer ones on economic growth persist, world economists are tirelessly seeking and putting together, better policies option that will sustain a vibrant relationship through efficient model that explain either conditional, absolute and club convergence theories. Implementing sound economic growth policies requires a responsive and sound understanding of the convergence theory, whether in a liberalized or repressed economy.

This study focus on the convergence theory and the Solow model in modern economy, mixing together the vital economic determinants of growth, and investigating the possibility of the convergence theory, (either conditional or absolute) between the poorer and the richer countries of today. Based on the empirical assessment that will be carried out, this study will identify the practicability and possibility of the convergence theory and growth hypothesis, to investigate if truly the poorer countries would grow faster and catch up with the richer ones at the steady state.

Other specific objectives include:

1. To highlight the various factor that boost and enhance convergence growth theory between countries.
2. To assess and investigate why countries have to grow at different rates.
3. To examine if there is convergence in growth rates between countries of the world, and lastly,
4. To analyze ways in which countries of the world can enhance their economic growth.

## 1.4 Research Methodology and Hypothesis

This study will employ the use of cross-sectional regression analysis. In order to present a vivid and clear conceptualization of issues that will be raised in the work, cross country data for 1980 and 2010 for 50 selected countries. The research will employ quantitative analytical method of econometrics for the purpose of clarity. Data shall be used to test the practicability and the possibility of the convergence theory of the Solow model, which says that, the poorer countries would grow faster

and catch up with the richer countries at the steady state. World Bank database and other relevant literature and publications shall be used as a source of data.

## 1.5 Organizational Structure

This paper is organized into eight chapters. Chapter one presents introductory part of the study, statement of the problem, objective of the study, research methodology and the organizational structure. Chapter two analyses the review of relevant empirical framework which is based on previous works on the subject matter.

Chapter three provides theoretical overview of the model, where the Solow model, meaning and types of convergence, graphical illustrations among others shall be discussed.

Chapter four focuses on research empirical specification. This comprises specification of the research regression equation, and detail discussion of the expected signs for the explanatory variables.

Chapter five analyzes the data. The countries that are sampled will be listed, while sources of these data and computation of variables will also be discussed.

Chapter six gives detailed description of the estimation technique to be used. While, chapter seven provides, estimation results, which is based on test and regression result. Chapter eight of this research shall give final conclusion of the study and policy recommendations.

# Chapter 2

# LITERATURE REVIEW

Empirical findings on convergence theory have seriously gotten the due attention of the world economists. Most of the researchers have come into conclusion that conditional convergence exists between the rich and the poor countries. The likes of Baumol (986); De-Long (1988); Eatzaz and Amber (2000); Whelan (2007); Jianyang (2011); Timakova (2011); Kui and Zhan (2011); and OIC (2013) among others, concluded that, the poor countries, *though if all things being equal* would grow faster and catch up with the richer ones. While Yatikkaya (2001) argued that, there is nothing like absolute or conditional convergence among nations. He is of the opinion that, absolute divergence rather than absolute convergence is obtainable among the world nations. Barro (1994) on the other hand, advocated for a club convergence. To him, it will be paramount and suitable to put countries into different regions and differentiate these countries base on their regions. Some of the literature works are summarized below.

One of the earliest scholars that carried out empirical work on convergence theory is Baumol (1986). He appraised convergence theory between the period of 1870 and 1979, for 16 advanced and mostly industrialized countries. The model which Baumol uses in estimating and analyzing convergence between these countries are given below;

$$\ln_i[(Y/N)_{i,1979}] - \ln_i[(Y/N)_{i,1870}] = a + b\ln_i[(Y/N)_{i,1870}] + u_i$$

From the above regression line, *ln(Y/N)* represent log of income per person, *i* indexes for different countries and $\mu$ is the error term. In his work, negative value for b indicated that, there is convergence, which means, an inverse relationship between initial income and growth. A rich country which has higher initial incomes would have a lower growth. Perfect convergence would be recorded, when the value for b is -1, while zero (0) implies that, there is no correlation between initial incomes and growth, therefore, there is no convergence.

The regression equation result suggests closely perfect convergence. The estimated value of b was closely equal to -1, which indicated that, per capita income today is uncorrelated with per capita income hundred years ago. He considered output per worker rather than output per person which reflected little effect on it findings.

De Long (1988) in his empirical findings only considered the richest countries as at 1870. He investigated 23 countries by adding seven countries to that of Baumol, between the periods of 1960 – 1985 within the zone of Communist countries. De Long considered the following regression model;

$$ln_i[(Y/N)_{i,1979}] - ln_i[(Y/N)_{i,1870}]^* = a + bln[(Y/N)_{i,1870}]^* + u_i$$

$$ln[(Y/N)_{i,1870}] = ln[(Y/N)_{i,1870}]^* + u_i$$

According to the regression estimated value, b was found to be -0.566. He demonstrated that the Baumol's findings were spurious as there is little evidence of convergence, unlike the perfect convergence coupled from Baumol's findings. Sample selection and measurement error were two inherent problems De Long discovered from Baumol's findings.

On the selection of the data problem, the Baumol's data employed an ex post sample of industrialized countries. This selection only considered countries that have previously converged, therefore not considering the rest. Thus, calls for a bias towards convergence in Baumol's analysis. The 1870 to 1979 data that was used by Baumol is prone and suffers measurement error. The 1870 data is not constant and precise and might likely prone to errors. Therefore, the OLS regression method was not the best and appropriate methodology for the analysis, because the errors were not eliminated in his findings.

Jianyang (2011) in his empirical analysis investigated whether there is any natural catch up (convergence) between the global economies of the world, by stylishly analyzing the convergence of emerging economies. Empirical studies for about 208 countries were carried out, to investigate if, conditional convergence subsists between 23 emerging economies, 28 OECD countries and 157 non-oil-producing other countries, between a period of 1970 to 2009, using a cross-sectional regression and panel data econometrics analysis. The main hypothesis of his research was to test, if convergence exists between these economies and secondly to test the impact of government intervention and trade liberalization on the growth catch up. From the findings, it was discovered that, conditional convergence subsists among all the countries, and that the emerging markets countries are catching up faster with the OECD countries, than they do with the non-oil producing countries, if the current and recent speed of population and economic growth and status of government intervention and trade openness remain unchanged. He was of the opinion that, economies that have reduced government intervention, with high trade openness

would generally experience a higher and sustainable growth rate and consequently faster convergence.

Timakova (2011) empirical evidence also supports the conditional convergence. He uses the cross country data for about 87 countries for a period of 45 years, specifically between the periods of 1960 to 2005. The Solow model was employed and used as the basis of the research analysis. From the researcher findings, it was discovered that, there is absence of absolute convergence and the existence of conditional convergence on population, investment and human capital. The inclusion of human capital strengthens further the findings and enhances the forecasting power of the model.

However, the finding seems to distinguish the assumptions that, the Solow model fails to shore up convergence. Contrarily, the Solow model was discovered to be an appropriate estimation of the convergence dynamics. After putting into consideration, based on the model description, variables and factors that determine the steady state (such as economic growth, GDP per worker, population growth, and investment and human capital) it was found that, strong evidence for conditional convergence exists. The added control (secondary) variables, (such as FDI, trade openness, government expenditure, institutions and natural resources) fails to play a considerate role in influencing economic growth, but were useful in confirming the soundness of the results.

Eatzaz and Amber (2000) in their work on convergence hypothesis used both formal and informal statistical method and techniques. Eatzaz and Amber empirical findings

was based on 54 countries within the period of 1961 to 1992. The scope of their research covers developed, less developed and underdeveloped countries. Their basic model specification is as follows:

$$\text{Log}(Y_t^i/y_{t-1}^i) = \alpha - (1 - e^{-\beta})\log Y_{t-1}^i + u_t^i)$$

According to the regression model, $Y_t^i$ depicts the real per capita output of a country; *i* in period *t* $u^t$ was used as a random disturbance term, while the β was the speed that the convergence between countries takes. They were of the opinion that, if α (the intercept term in the equation) is constant for all countries and the β is greater than zero i.e (β>0) more than what the equation specified, then the poor countries tends to grow faster than their richer counterparts.

From their findings, the value of β was found to be negative -0.0030 and statistically reliable. Contrary to their convergence hypothesis expectation which requires a positive value for β, and also a necessary condition for an absolute convergence, it was concluded that, diffusion across countries has risen over time.

However, there might be several reasons (both economics and non-economics) for this result. In fact, countries such as Canada, America, Germany, United Kingdom, etc. with high per capita incomes are more technological based and advanced in other fields of life. Less developed and underdeveloped countries are deficient in suitable technology, welfare, education, health etc. which is due to their low per capita income that can enable them to converge, such as a stable political system, good infrastructural, adequate expenditure on health and education, good governance and strong institutional structure.

Debasish (2013) in his panel data approach investigated the importance and relevance of the Solow growth model in 20 OECD countries over the period of 1971 - 2011. His work was mostly centered on Islam (1995) and MRW (1992). He estimated both augmented and textbook Solow model, where OLS along with estimation of both static panel and dynamic panel was carried out. He is of the opinion that, very few researchers on the issue of convergence have considered the dynamic panel and recent data set. To him, panel data approach to convergence analysis is more appropriate than the cross-sectional approach, because the panel data takes into consideration country effect that have been unobserved for years.

Yatikkaya (2001) carried out a cross country empirical analysis on convergence theory for 114 countries, which comprises of 85 developing countries and 29 developed countries, using a panel data approach. The research was observed for a period of 27 years, basically from 1970 to 1997. Mean growth rate of real per capita GDP was used as the dependent variable, while trade openness and capital flow were two major variables which were employed in the model to measure convergence. The model below was specified:

$$Y_{yt} = F(y_{t-1}, k_{t-1}, h_{t-1}, Z(t))$$

Where $Y_{yt}$ represent country per capita growth rate, $y_{t-1}$ the initial GDP per capital, $k_{t-1}$ was used as the initial physical capital stock per worker (person), while the variable Z in the model represent vector of control and environmental variable which are mostly determined by the government. From the result of the findings, it was discovered that, there has been absolute divergence among the nations. The empirical finding depicts strong and positive relationship between initial GDP and growth rates, which is against absolute convergence of the neoclassical.

The OIC (2013) which is popularly called Organization of Islamic Cooperation investigated economic growth and convergence across the OIC countries. A sample of 31 OIC countries was used, which covers the period of 1980 – 2009 using Ordinary Least Square (OLS) framework. The research was carried out to ascertain tendency for a regional convergence among OIC countries. The basic model specification for the research is as follow:

$$\ln(y_t/y_{i,t-1}) = \propto + \beta_0(\ln y_{i,t-1}) + \varepsilon$$

Where $\propto$ represent a constant value, $\beta_0$ the coefficient vector, $y_t$ depicts average per capita income of the country at time t. From the findings, it was discovered that, institutional quality is an integral components of growth. It was concluded that, countries that have sound institutions and property right would grow faster than the one without it. Thus, priority should be given to quality of institutions, which would have a multiplier effect on both human and physical capital and at the end, enhances economic growth.

Another cross country convergence and growth was carried out by Kui & Zhan (2011) to investigate whether the absolute convergence or conditional convergence would hold for the 164 countries sampled, over the period of 1970 to 2006. Nonparametric panel data model were used and it is specified as follow:

$$\ln_i(gdpc_{i,t}) - \ln(gdpc_{i,t-1}) = g \ln(gdpc_{i,t-1}) + u_{it} + v_{it}$$

Where $\ln(gdpc_{i,t})$ were used to represent the log of the real per capita GDP. Equation $\ln_i(gdpc_{i,t}) - \ln(gdpc_{i,t-1})$ depicted growth rate of real per capita GDP, while $v_{it}$ was used as the error term of the model. It was discovered from the findings that, conditional convergence is attainable among the economies sampled than absolute

convergence. Absolute convergence was discovered to hold better in countries with a low GDP per capita (speed ranging from 0.15 to 9 percent) and failed to hold for countries that has above 735$ GDP per capita, while conditional convergence was found to hold for most of the countries (speed ranging from 0.15 to 14 percent). Conclusively, conditional convergence was found to hold for countries that have a moderate GDP per capita.

Whelan et al (2007) in his empirical findings on convergence theory used a different method to investigate and examine conditional convergence. Samples of 104 countries were employed for a period of 1970 – 2007, using a panel data approach. Unlike the other researchers who make use of per capita or worker dynamics, Whelan make use of capital – output ratio and this put out an awesome difference in the convergence rate. Most the research and work done on convergence found 2 percent convergence rate for countries within a year. But Whelan, empirical estimation and findings revealed a different convergence rate which range from 6 – 7 percent per year. The new convergence rate among these economies was gotten, without the assumption of a constant rate of technological improvement which is known with the Solow's model. They were of the opinion that, the rate of convergence between the poor countries and rich countries would be more faster, using the capital – output ratio as a measure of convergence.

Some of the literature recently showcased and analyzed the confirmation of the absence of income convergence or presence of income convergence. This is nailed to the fact that, early scholars and studies on convergence lacks adequate data to precisely measure progress procedures of a country. Quah (1995) in his work

distinguished a coherent course. He argued that, the poor countries and rich countries, recently appears to converge around each other at a fixed rate of almost 2 per cent per year.

Moreover, Quah (1995) also advocated that, the poor countries need to have similar political atmosphere and condition, with related legal system, and technological acquisition techniques to showcase confirmation of convergence. Barro (1994) in his opinion, he proposes that, it will be paramount and suitable to put countries into different regions and differentiate these countries base on it.

Contemporary economics literatures are scrambling over the discussion concerning the issue of convergence and growth. Convergence theory has lots and several crucial effects on the developing countries of the world today. Conditional convergence was not based on the assumption of total and eventual removal of poverty unlike the absolute convergence. However, it envisages that, if the poor countries can attain the similar structural and economic characteristics as their richer counterpart, they might grow to be rich. In the area and aspect of conditional convergence, foreign aid policies appears more logical, as it can assist these countries to attain imperative structural and economic characteristics, with the right and effective policies in place.

# Chapter 3

# THE SOLOW MODEL AND THE CONVERGENCE THEORY

## 3.1 The Solow Model

The Solow-Swan (1956) model including the one augmented with human capital envisage that the poor countries income level will tend to converge towards that of the rich countries, only if the poor country possess identical saving rates for both human and physical capital (as a share of output), a procedure referred to as conditional convergence. One particular issue that has drawn the attention of the world economist in empirical work on growth is to verify, if the deficient countries tend to grow speedily than the richer countries.

Going through the Solow model, there are three basic obvious reasons one might anticipate convergence. The model envisages that countries would converge to their balance growth paths. Based on this fact, the disparities in output per worker as a result of these countries being on a divergent point relative to their balanced growth paths, it would be meaningful to expect the poor countries to grow faster and catch up with the rich countries. The model also insinuates that the rate of return on capital is much lower in a poor country that has more capital per worker. This would generate stimulus for capital to flow within these countries, which would eventually lead to convergence. Lastly, lags associated with dissemination of knowledge, income disparities can possibly arise, which is due to the fact that, some of these

countries are yet to employ the latest and best recent technologies. The poorer countries would benefit and have access to this know-how as the dissemination of knowledge and income disparities tends to diminishes.

The Solow – Swan (1956) closed economy neoclassical model is a model that explain the relationship between growth, saving and investment. It was an extension of the Harrod-Domar model. It introduces labor and technology into the growth equation inclusive with capital accumulation. The model describes the influence of saving, population growth and technology on economic growth. The Solow model revealed that, capital accumulation rely heavily on saving rate and it leads to higher level of output and faster growth. The model uses a Cobb-Douglas production function in which growth is a function of labor, capital and technology. This is given by the equation below;

$$Y_t = K_t^{\alpha}(A_tL_t)^{1-\alpha}$$

The model built an equation for capital accumulation, which is given by;

$$k^* = sY - \delta K$$

Where $\delta$ represents depreciation rate and s depicts saving rate, y represents income per capita, while K represent capital stock per capita, while k* indicates steady state value.

The relationship between population growth, saving and capital of the Solow model can be illustrated with the help of a diagram.

Let illustrate a situation when population growth decreases and its impact on capital stock and output.

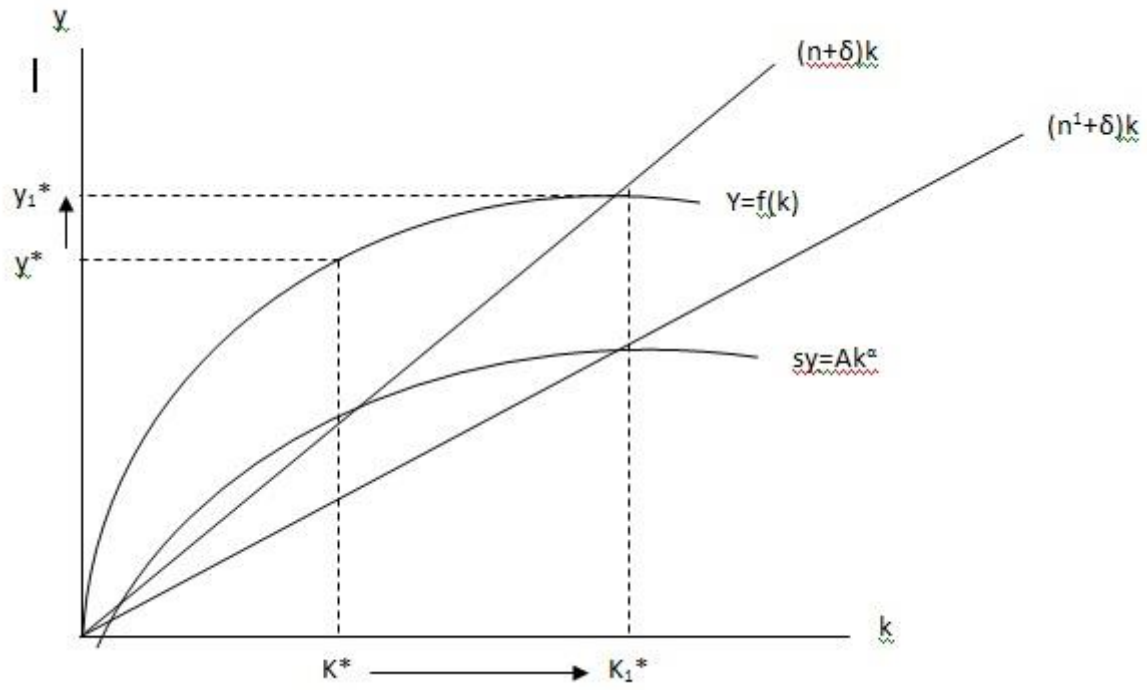


Figure 3.1 Graphical illustration of the Solow Model when population growth decreases.

From the diagram above, a decrease in population growth from (n) to ($n^1$) resulted in higher level of capital stock k* which eventually increases the level of output from y* to $y_{*1.}$ This pushes up the level of capital stock, which at the end resulted in increase in growth rate. The same analysis can be done for saving (s) and technology (A) respectively

## 3.2 The Textbook Solow Model

The textbook Solow model is a continuous model without no foreign (international) trade and government. The Robert Solow model considers population growth, technology progress, and rates of saving as delineated. By implication, they are externally procured and taken as exogenous in the contemporary structure and system. Besides, there are two basic inputs in the model, which are labor (L) and capital (K). These factor inputs received their marginal product. If a Cobb-Douglas

production function is assumed, prior to the previous information, period t production function becomes;

$$Y(t) = AK(t)^{\alpha}L(t)^{1-\alpha} \quad \text{.....1}$$

Where *t* signifies time, α (0< α < 1) is the elasticity of output to capital; *Y* denotes total output in production, *K* and *L*, capital and labor, while *A* depicts technology. As previously stated, population growth and technology are presumed to be exogenous.

Robert Solow in his model assumed that, all factor (production) inputs are completely employed, given A(0), L(0) and K(0) as its initial values. The number of labor i.e. workers and also that of technology sprout exogenously as population growth (n) and technology (g) is increased.

Where

$$L(t) = L(0)e^{nt} \quad \text{.....2}$$

$$A(t) = A(0)e^{gt} \quad \text{.....3}$$

The number of A(t)L(t) which is the effective units of labor increases at the rate of n + g, while the capital stock depreciates at a constant rate over a period of time (δ). Nevertheless, the output (Yc) is not completely consumed with 0<c<1, while the remaining (*s=1-c*) were saved for investment.

Putting Y to be the level of output per effective labor, it will be easy to demonstrate the advancement of K with the below expression:

$$\acute{K}(t) = sY(t) - \delta K(t) \quad \text{.....4}$$

The major aim of the Robert Solow prototype is on the effectual of capital intensity k: which is the capita stock per unit of effective labor.

Equation (4) above can further be simplified to account for an expression of ќ.

$$\acute{K} = [s/n+g+\delta]^{1/1-\alpha} \text{……5}$$

The implication of the equation (5) is that, the ratio of labor to capital at the steady state is negatively related to rate of population growth (n) and positively related to the savings rate (s).

This is a point where the capital stock of K and the effective labor of AL would grow at the rate of (n + g). Therefore, by assumption of constant returns, output (Y) would also grow at that same specific rate. Due to this fact, Solow – Swan growth model assumes that, an economy will converge to a balance growth path. Here, the growth of (Y) which is output per labor (worker) will be decided by technological progress. Thus, by simple explanation,

$$K(t)/Y(t)=k(t)^{1-\alpha} \text{ ……..6}$$

and at the steady state $k^{ss}$, we have

$$K(t)/Y(t) = s/(n+ g + \delta)\text{……..…… ….7}$$

Thus at steady state, the capital per output ratio, would depends solely on population growth, depreciation rate and saving. The above Solow model is an extension of the Golden Rule of saving rate.

## 3.3 Labor – Augmented Solow Model

Growth occurs in the model due to factor accumulation. It was assumed that, through population growth, labor will grow exogenously and while capital accumulation will be possible as a result of saving behavior.

For example, if the technological progress is labor augmenting;

$$Y = F(K,AL) = K^{\alpha}(AL)^{1-\alpha}$$

Where, A depicts technological level at the current time. Labor augmenting technological change is usually called "Harrod neutral" and it's related with capital – output ratio (K/Y) in a steady state.

Using Cobb and Douglas production function, labor augmenting technological change would be:

$$A(t) = A(0)e^{gt}$$

$$\ln A(t) = \ln A(0) + gt$$

Therefore, $\dot{A}/A = d\ln A(t)/dt A(t) = g$

Where, the g represents a parameter depicting the exogenous rate of technological progress.

Going back into capital accumulation equation in the Solow model

$$\dot{k}/k = Sy/k – (\delta + n + g)$$

So, y/k = Y/K must equal each other for growth rate of per capita to be constant

To derive a steady state of the Solow model with technological progress

$$Y = K^{\alpha}(AL)^{1-\alpha}$$

Dividing through by AL, the number of effective labor units would be;

$$Y/AL = (KL/A)^{\alpha}(AL/AL)^{1-\alpha}$$

$$\dot{y} = \dot{k}^{\alpha}$$

Recall that, $\dot{k}/k = d\ln(K/AL)/dt$

$$= d\ln K/dt = d\ln A/dt - d\ln L/dt$$

$$= \dot{K}/K – \dot{A}/A - \dot{L}/L$$

$$= \dot{K}/K – g – n$$

Therefore, $\dot{K}/K = Sy/k – d$

$$\dot{k}/k = Sy/k – d – g – n$$

Since, $Y/K = (Y/K)(AL/K) = y/k$

Then, $\acute{k}/k = Sy/k – (d + g + n)$

$\acute{k} = s\check{y} - (d + g + n)\acute{k}$

Substituting $\check{y} = \acute{k}^{\alpha}$

We have the Solow model labor-augmenting technological model

$$\acute{k} = s\acute{k}^{\alpha} - (d + g + n)\acute{k}$$

as earlier noted, if $\acute{k}^{*} = 0$, we can solve for the steady state levels of capital-output per unit of effective labor

$$\acute{k}^{*} = s/(d + g + n)^{1/1-\alpha}$$

As mentioned earlier, the Solow model presumes paid marginal product for the factor inputs. Therefore, the equation below can be used to forecast, not only magnitudes but the signs of the coefficients.

$$MPK = \delta Y/\delta K = \alpha A^{1-\alpha}/(K/L)^{1-\alpha}$$

If labor-augmenting technology productivity (A) is similar over the countries, the countries with less capital per labor (K/L) would have a huge marginal product, which in return, would give high returns on the capital invested. Due to this outcome, the Solow model forecast that, in a global financial capital, with open market economies, investment will proceed from the rich to the poor, till Y/L (income per worker) and (K/L) capital per worker is balance all over the countries.

The main aspect of the Robert Solow model growth analyzed above, has confirmed the discourse on the subject of convergence and growth. It was the first model that investigated convergence across countries. It envisages the existence of convergence to a balance growth path. Therefore, the model is based on the disparity that, the productivities of labor solely depends on the initial position of each country relative

to its balance growth path. If poor countries are farther away from its balanced growth path and the richer countries are closer, then the poor countries would move faster and catch up or possibly overtake the richer countries.

## 3.4 Mankiw, Romer and Weil Type of Model

MRW constructed human capital augmented type of the Solow model. The Model can be used to describe why international investment fails to flow to the poor countries. Inferring from the MRW human capital augmented model, one would see that, productivity levels in these deficient countries are negligible, because they have low level of human capital than their richer counterpart. Related to the textbook model, the following production function was used:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} A(t) L(t)^{1-\alpha-\beta}$$

Where H(t) depicts the human capital stock and it diminish at the same rate (δ) as physical capital. Taking precedence on the Solow model that save the tiny part of income over each internal, but MRW human capital model (augmented), put them into fragment, and invested part of such income in human and the order in physical capital, in a manner that we have the below;

$$S = S_h + S_k$$

Therefore, we have two distinct equations:

$$\acute{k} = S_K k^{\alpha} h^{\beta} - (n + g + \delta)k$$

$$\dot{h} = S_H k^{\alpha} h^{\beta} - (n + g + \delta)h$$

The steady state (or balanced) growth path was determined by k = h = 0, from which we can deduce that,

$$S_K k^{\alpha} h^{\beta} - (n + g + \delta)k = 0 \text{ and } S_H k^{\alpha} h^{\beta} - (n + g + \delta)h = 0$$

Summing up the above, we have:

$$\acute{k} = (S_K^{1-\beta} S_H^{\beta}/n + g + \delta)^{1/1-\alpha-\beta}$$

$$\dot{h} = (S_K^{\alpha} S_H^{1-\alpha}/n + g + \delta)^{1/1-\alpha-\beta}$$

Therefore, in steady state:

`
$$y^{ss} = (k^{ss})^{\alpha} (h^{ss})^{\beta}$$

## 3.5 Convergence Theory

The fundamentals discourse on convergence will be difficult to explore without understanding the thorough details of its basic theory. There are two basic distinct explained types of convergence; the conditional convergence and absolute convergence.

### 3.5.1 Absolute Convergence

The concept of absolute convergence takes precedence from the convergence principle. It refers to a growth idea, whereby poor countries with lower initial income per capita, would speedily grow and therefore meet up with the richer counterparts at the steady state. Absolute convergence depicts that, no matter what the condition maybe, the poorer countries, which believes to have a lower initial per capita income, would outsmart the richer counterpart. The assumption of the absolute convergence according to the Solow (1956) and Sorensen et al. (2005) is that, poor countries would grow faster to catch up with the rich countries, and all countries converge to same GDP per capita and that poverty would disappear by itself in the long-run.

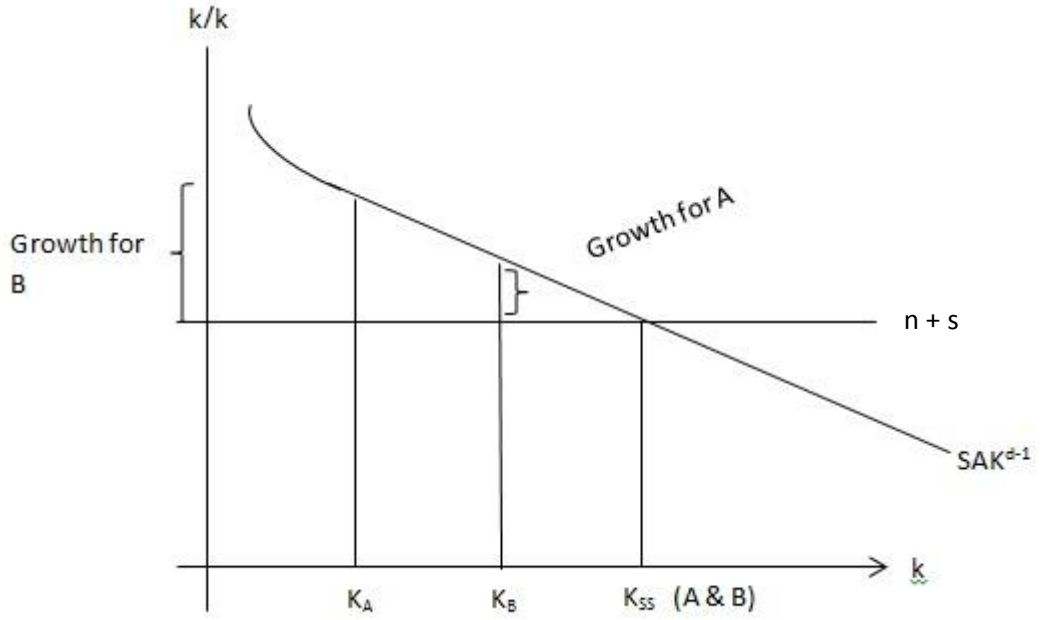

Figure 3.2: illustrate absolute convergence as depicted by the Solow model.

The diagram above depicts a case where $k_A$ and $k_B$ illustrate the initial capita per person of the rich and the poor countries respectively. The above graphical representation presumes that, both countries have the same economic characteristics (n, s, A, δ), thus same steady state. Figure 3.1 show that, the poor country growth will overshoot that of the rich counterpart, if the catch up is to be achieved. It can also be deduced from this that, the marginal product in the rich country would be lower than that of the poor ones. According to the model, the rich country A (with more $k_A$) grows slowly, while poor country B (with small $k_B$) grows faster, given that A and B has same steady state.

This growth model only refers to average consumer. Nevertheless, there are many poor people living in the rich countries. This gives room for one of the assumption of this model that poverty will disappear in the long-run. If this assumption would stand, it would have huge implication on the prevailing aid policies. The notion and

believes that poverty in the poor countries would disappear in the long-run in one hand, would hamper the rich countries political thinking and reasoning towards the aid policies packages extended to the developing countries. As it is well known that, the rate of catch up (convergence) to the universal and balance growth path is time-consuming, with the fact that influence of poverty on this developing and poor economies is frightful, which necessitate the need for rich countries aid packages. Therefore, the absolute convergence assumption solely hampers the reasoning for aid policies.

### 3.5.2 Conditional Convergence

Conditional convergence is based on the idea and notion that, each economy of the world would converge to its own steady state and the more distant they are from their own steady state value, the faster will be the speed of convergence. It is known that, an initial per capita income tends to trigger a favorable per capita growth rate, provided the economic characteristics are the same and the steady state.

Nevertheless, countries of the world are unrelated, which is due to their fundamental structural and economic features such as savings, population growth rate, technology, investment, depreciation rates etc. For an instance, it would make sense to think that, countries with higher level of saving rates would experience and have favorable level of GDP per person. According to Sorensen et al. (2005) each country income per capita (or worker) would converge to its specific long-run growth path, depending on their fundamental economic characteristics. Therefore, the lesser the countries actual level of GDP per capita (worker), the favorable would be expected future growth. By implication, countries that commence beneath their long-run growth path would probably grow faster than expected.

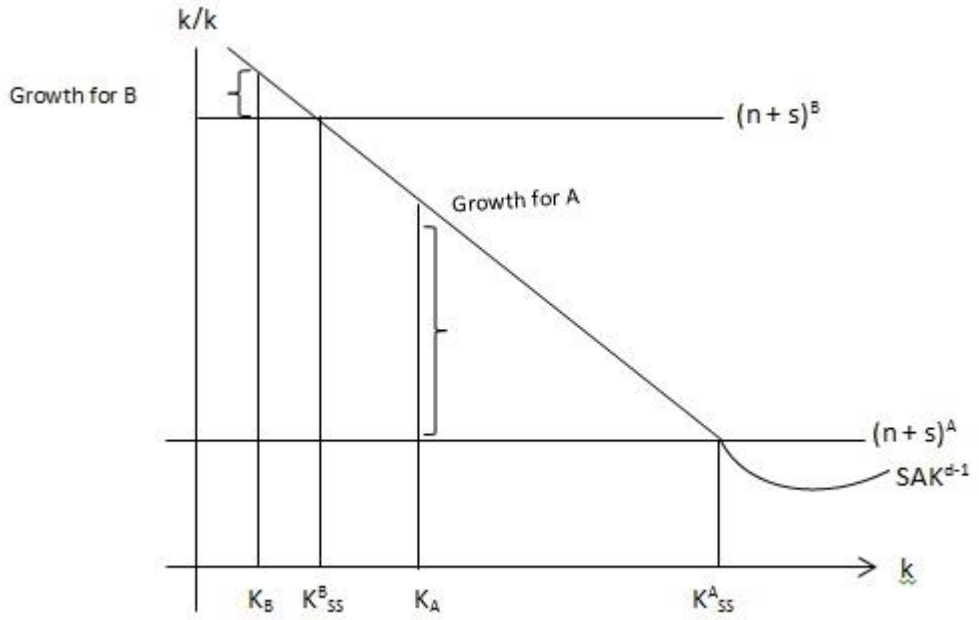

Figure 3.3: Illustrate conditional convergence as depicted by Robert Solow model.

The diagram above illustrates graphical representation of the conditional convergence assumption as stated in the Robert Solow. The assumption of the absolute hypothesis is related to that of conditional convergence that the countries converge to identical state. Nonetheless, the absolute convergence differs from the conditional convergence, because the former, necessitates that the countries should be related. Thus, until we have a control of the economic characteristics, it will be impossible to analyze the inverse relationship between the growth and the actual level of GDP per worker (capital).

# Chapter 4

# EMPIRICAL SPECIFICATION

## 4.1 The Model

The objective of the research is to assess empirically the convergence theory. That is to investigate empirically, if the poorer countries of today will grow faster and catch up with the richer ones as stated in the convergence theory. The rate of divergence between economies of the world has been a major concern; we can assume that countries with particular features are time-invariant therefore there is a need to control for such determinants to get unbiased estimators.

The empirical assessment of the convergence theory in this study would be based on growth and the initial level of GDP per capita. However, other control variables such as, investment and trade openness were employed to conduct casual effect for a cross-sectional regression model, which is formulated as:

$$ln(Y/N)_{i2010} - ln(Y/N)_{i1980} = \alpha + \beta ln(Y/N)_{i1980} + \beta_2 Invest_i + \beta_3 Openess_i + \varepsilon_{it} \quad \ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Where,

$ln_i(Y/N)_{i2010} - ln_i(Y/N)_{i1980}$ represents the GDP per capita growth from 1980 to 2010 as the dependent variable.

$ln(Y/N)_{i1980}$ – initial GDP per capita for 1980 as the main independent variable.

The control variables are as follows:

INVEST – Investment (used as a proxy for savings)

OPENNESS – Trade Openness

α- intercept term

$\beta_1, \beta_2, \beta_3,$ – the parameters coefficient to be estimated.

ε – Depicts the error term that varies over cross-sectional units and time.

The specified model is extracted from various studies with sound economic theory on the research theme. The error term ε in the model above, incorporate variables that stimulate convergence but are not covered or included in the specified model.

## 4.2 Economic Expectation of the Variables

Table 4.2: Below illustrates the apriori expectations specified in the model above.

| DEPENDENT VARIABLE | | GDP GROWTH |
|---|---|---|
| INDEPENDENT VARIABLES | THEORETICAL EXPECTATION | JUSTIFICATION |
| Initial GDP per capita | - | It is expected that the initial GDP per capita should have negative influence on the growth rate. That is, the lower the level of the initial GDP per capita, the faster would poorer countries grow and catch up. |
| Investment | + | A direct relationship is expected to exist between |

| | | |
|---|---|---|
| | | the level of investment and growth rate. This is because, the more the level of investment, the faster the growth for such economy. |
| Trade Openness | + | It is assumed that, the more an economy is open in terms of trade, the faster it would grow and catch up. It is anticipated that, trade should have a positive influence on growth. This would sprout trade flows among countries; thus, faster would be its growth. |

# Chapter 5

# DATA

The divergence in economic development between countries of the world, in relation to the convergence theory has been the motivating factor to carry out this research. The purpose of this research is to investigate and assess empirically the convergence theory, to test, if the poor countries would grow faster and catch up with the richer ones. This aspect of the research, provide details about the data and discussion of variables employed.

Fifty countries with a sufficient data are selected for this research (see table 5.1). The countries sampled consist of 21 OECD countries and 29 developing countries. This is done in order to give room for variation in the analysis on the basis of growth and the initial GDP per capita.

The research analysis period started from 1980 because, it is considered as a measure of original position of the countries. As mentioned above, this study only considered 50 countries. The basic reason for this is the availability of data, because some countries did not have the data for all the years in question. So, such countries were not sampled in order to have a strongly balanced dataset.

Table 5.1: Countries selected for econometrics analysis

| OECD Countries | Developing Countries |
|---|---|
| Australia | Algeria |
| Austria | Albania |
| Belgium | Argentina |
| Canada | Bulgaria |
| Denmark | Brazil |
| France | Bolivia |
| Finland | Colombia |
| Greece | Costa Rica |
| Germany | Cyprus |
| Hong Kong | Indonesia |
| Iceland | India |
| Italy | Iran |
| Japan | Ireland |
| Korea Republic | Morocco |
| Netherland | Malaysia |
| New Zealand | Mexico |
| Norway | Nigeria |
| Spain | Portugal |
| Sweden | Pakistan |
| United State | Romania |
| United Kingdom | South Africa |
| | Thailand |
| | Turkey |
| | Tunisia |
| | Trinidad and Tobago |
| | Uruguay |
| | Venezuela |
| | Zambia |

## 5.1 Description of Variables

The study dataset makes use of information about 50 countries over a period of 31 years (i.e.1980 to 2010). Most of the countries used in this analysis were based on the one selected by MRW (1992). Thus, the study builds on MRW analysis and extracts the data from 1980 to 2010.

### 5.1.1 The Primary Variables

***Growth***

The GDP is one crucial variable which is used to measure economic performance of a country. In my study dataset, the GDP in constant 2005 dollars is employed. The basic reason for employing this data and not the one corrected for Purchasing Power Parity (PPP) is due to the availability of data for the former. The PPP data are not available for some of the countries in my dataset.

However, using the GDP in constant 2005 dollars, the growth rate was calculated by computing the percentage change in the GDP data for 1980 and 2010 respectively. Having done this, the figure was used as the growth for the individual countries. Therefore, every country in the dataset has one figure of GDP growth, which is the percentage change of the GDP over the years captured in the analysis. The data for the GDP in constant 2005 dollars was extracted from the World Bank Development Indicators database.

***Initial level of GDP per capita***

The initial level of GDP per capita is employed and used as a proxy of the initial conditions and position of the countries. The per capita GDP in constant 2005 dollars is also employed. The variable was actually, employed to correct for the original economic position in these countries, which is assumed to play a vital role in terms of defining the growth path of the country.

Caution was taken to include only countries that have data from 1980 to 2010. In a nutshell, all the countries that were sampled have an initial level of GDP per capita. The strategy of using 1980 as the initial level of GDP per capita was chosen in other

to make the analysis much more balance and erase any time biases that might occur. If the datasets were allowed to start from different period from the one selected, it might be impossible to get enough information to examine convergence. The data for initial level of GDP per capita in constant 2005 dollars was extracted from the World Bank Development Indicators database.

### 5.1.2 The Secondary Variables

***Investment***

One crucial variable that is employed in this analysis is the level of investment. There are numerous ways in which we can measure the level of investment in a country. For this research, the data for the domestic saving as percentage of GDP was used as a proxy for investment. This is actually used as it is laid down in the Solow model that, saving is synonymous and allocated to investment. Therefore, employing domestic saving (gross) helps to eliminate any foreign investment, which makes it a good and best measure of the level of investment.

In other to get a single figure of the gross domestic saving for each country, a five years average was taken from the datasets. The data for domestic saving (gross) as a percentage of GDP, which is used to proxy the level of investment was obtained from the World Bank database.

***Trade (Openness)***

For the purpose of the analysis, trade as a percentage of GDP was employed to measure casual effect of convergence. Trade is usually accounted for by the total sum of exports and imports of goods and services. Though, there are lots of ways to do this, but the above is the standard and preferred measure of trade. This total sum of exports and imports reveals the aggregate trade flows in and out of any country.

Therefore, it can be used as one crucial measure of openness. By implication, the more the value of exports to imports as a percent of GDP, the more open such an economy would be, vice versa.

However, there are limitations in using trade as a measure of openness. For an instance, the total sum of imports and exports may not at all the time differentiate between the impacts and contributions of exports and imports in trade. In a situation where a country is specialized in importation, which makes such a country an importer, with little or no export, then the information that would be provided by this total sum will be basically more on import. By implication, this means that, the available information may not be the best information to measure the specific impact that is allocated to these components of trade. Though, this variable is not crucial in achieving the aim of this study.

In order to get a single figure of trade for each country, a five years average was taken from the datasets. The data for trade as a percentage of GDP, which is used to proxy for openness was obtained from the World Bank database.

Table 5.2: Below illustrate variables and their sources.

| Dependent Variable | Description and Source of Data |
|---|---|
| Growth | The economic performance of any country is usually measured by the growth of its GDP. The GDP growth rate was used as the dependent variable. The growth rate of GDP in constant 2005 U.S dollars is used in the study. Data on GDP growth was extracted from the World Bank Database. |
| Independent Variables | Analysis and Data Source. |
| Initial GDP per capita | This is a summation of value of goods produced per head. This is derived through division of the GDP by the entire population of the country. The GDP per capita in 1980 was used a measure of initial position of the country. The purpose of this is to allow the study to correct for initial economic position, which has a major role to play in terms of the growth path of the countries.<br>Initial GDP per capita data was extracted from the World Development Indicators database. |
| Investment | Investment is used as a proxy for the |

| | |
|---|---|
| (Control Variable 1) | gross domestic saving. This is actually used as it is laid down in the Solow model that, saving is synonymous and allocated to investment. Therefore, employing domestic saving (gross) helps to eliminate any foreign investment, which makes it a good and best measure of the level of investment.<br>Data on total investment was also extracted from the World Bank Development Indicators database |
| Trade<br>(Control variable 2) | Trade (openness) simply refers to the rate to which a country permits foreign trade. The more open an economy is, the more foreign trade will be allowed and vice versa. Trade is computed as the aggregate of exports and imports as a fraction of GDP.<br>This was also sourced for, from the World Bank Development Indicators database. |

# Chapter 6

# ESTIMATION METHOD

The estimation method employed for this research work is the cross-sectional regression analysis to measure convergence, using data for 1980 and 2010. Data for the study were extracted and sourced from the World Bank development indicators database. For a sound and reliable scientific evidence of the model, an econometrics technique of heteroscedasticity, multicollinearity, student t-test, coefficient of determination, and F-test have been carried out.

In this analysis, we designed a cross-sectional regression equation model, in which growth (as a measure of economic performance) is the dependent variable, while the major independent variable is the initial level of GDP per capita to measure convergence and other control variables, such as level of investment and trade openness for the ceteris paribus purposes. For this objective, growth is measured by computing the percentage change in GDP data between 1980 and 2010 respectively.

The initial level of GDP per capita (using 1980 value) is employed in the model as the primary independent variable, because it is assumed, following the previous studies on convergence theory, to be the best measure at which convergence can be observed. This is translated to the fact that, the lower the initial level of GDP per capita, as it was stated in the Solow model, the faster would be the level of growth.

Thus, by economic implication, inverse relationship exists amid the growth and the initial level of GDP per capita for convergence analysis.

## 6.1 The Student T-test

T-test is a measure of individual significance of the independent variable(s). The statistical significance is carried out on the parameter estimate, either at 1%, 5%, or 10% respectively. For the purpose of this research, t-test is employed to evaluate the significance of the individual parameter estimates. A two-tailed test will also be carried out at this level of significances. Comparison for a test of significance would be made between t-calculated and the t-tabulated. If the t-calculated value is found greater than the t-tabulated value, then, it will be concluded that, such parameter estimate is statistically significant and vice-versa.

## 6.2 The Coefficient of Determination

The coefficient of determination indicates how well a data point fit a statistical model – sometimes simply a line or curve.

The coefficient of determination is a statistic tool employed in the context of statistical models whose main purpose is either the prediction of future outcomes or the testing of hypotheses, on the basis of other related information. Co-efficient of determination ($R^2$) shows changes of the dependent variable that can be explained by the independent variable(s). Coefficients of determination relay information about the goodness of fit of a model. In regression, the $R^2$ coefficient of determination is a statistical measure of how well the regression line approximates the real data points. An $R^2$ of 1 indicates that the regression line perfectly fits the data.

## 6.3 F-Statistics or Joint Test

F distribution is built on relationship between the F-statistics and the F-table. F-test will be used to test the overall significance of the regression equations. The regression equation would be reliable, if the F-statistics relay a greater value than the tabulated F-statistics, vice versa. There will be two degrees of freedom for the F-test.

The rejection or acceptance of the null hypothesis would lead to the conclusion of the findings as follows:

$H_0$: that, the poor countries will grow faster and catch up with richer one at the steady state.

$H_1$: that, the poor countries will not grow faster and catch up with richer one at the steady state.

## 6.4 Heteroscedasticity Test

The Breusch Pagan/Cook-Weisberg test for heteroscedasticity was developed to identify, if there exist any true form of heteroscedasticity. This test the null hypothesis, that the model error variances are all equal, against its alternative hypothesis, that the error variances are either a multiplicative function of one or more variables. By taking this test, the chi-square value is compared with its probability value. If the chi-square value is found to be larger than the probability value, then, this would mean that, heteroscedasticity is not present in the model or vice versa. This can easily be corrected by running heteroscedascity robust regression analysis.

## 6.5 Multicollinearity Test

This is a problem that occurs in cross-sectional regression analysis, when two or more independent variables in a multiple regression model are found to be highly

correlated or related. Some scholars have suggested a means of detecting multicollinearity in a model, which is through finding the tolerance of the model or through variance inflation factor. The formula for the tolerance and the variance inflation factor are given below;

Tolerance = $(1- R^2)$, VIF = 1/tolerance.

Where, $R^2$ depicts the coefficient of determination of the model. A level of tolerance value less than 0.10 or 0.20 and a number greater than 5 or 10 for VIF means that, there is multicollinearity problem in the model.

# Chapter 7

# RESULTS AND DISCUSSION

## 7.1 Results

***Regression***

Table 7.1 below showcases the relationship between growth and the initial level of GDP per capita. Going through the analysis, we can vividly see the evidence of convergence, which is in line with many literatures. See Baumol (1986); De Long (1988); Jianyang (2011) etc.

The coefficient of initial level of GDP per capita is negative, where it is different from zero. This agrees with the study aprior expectation that, inverse relationship exist between growth and the initial GDP per capita. Though $R^2$ was found to be small, but this is always the case with simple regression analysis, and most of the time, it is not a good measure of variation. See Gujarati (2003). Thus, we can conclude that, there is a tendency for the poor countries to speedily grow and meet up with their richer counterpart.

Table 7.1: Illustrate evidence of convergence with growth and initial GDP per capita

Linear regression

Number of obs = 50
F( 1, 48) = 12.58
Prob > F = 0.0009
R-squared = 0.1627
Root MSE = 117.87

| growth | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| gdppc | -.0048946 | .00138 | -3.55 | 0.001 | -.0076692 | -.00212 |
| _cons | 219.7126 | 30.58703 | 7.18 | 0.000 | 158.2132 | 281.2119 |

It is significant at 1%, 5% and 10% respectively

The restricted regression equation for the above analysis is given below

$$ln(Y/N)_{i2010} - ln(Y/N)_{i1980} = 219.713 - 0.0049 ln(Y/N)_{i1980} :$$

s.e (30.59) (0.001)

$R^2 = 0.163$

In table 7.1, the level of investment (a proxy for domestic saving percent of GDP) was not included in the model. The inclusion of this variable, significantly improves the fit of the regression. Therefore, the new model (with investment) explains more of the variation of growth, than what was found in the previous model.

However, addition of trade openness to the regression reduces the value of the coefficient of the initial GDP per capita, but the model was still found significant. In a nutshell, the additional variable put more explanatory strength to the model. As more variable was added, the $R^2$ becomes larger than in the previous model.

Table 7.2: Evidence of Convergence (with the level of investment)

```
. reg  growth gdppc invest, r

Linear regression                               Number of obs =      50
                                                F(  2,    47) =    7.41
                                                Prob > F      =  0.0016
                                                R-squared     =  0.3093
                                                Root MSE      =  108.19

------------------------------------------------------------------------------
             |               Robust
      growth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       gdppc |  -.0052465   .0013634    -3.85   0.000    -.0079893   -.0025037
      invest |   5.540357   2.306688     2.40   0.020     .8998988    10.18081
       _cons |    93.4273   40.22553     2.32   0.025     12.50397    174.3506
------------------------------------------------------------------------------
```

Table 7.3: Evidence of Convergence (with Investment, Trade Openness)

```
. reg growth gdppc invest openness

      Source |       SS       df       MS              Number of obs =      50
-------------+------------------------------           F(  3,    46) =    7.67
       Model |  265520.764     3  88506.9214           Prob > F      =  0.0003
    Residual |  531019.468    46  11543.9015           R-squared     =  0.3333
-------------+------------------------------           Adj R-squared =  0.2899
       Total |  796540.232    49  16255.9231           Root MSE      =  107.44

------------------------------------------------------------------------------
      growth |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       gdppc |  -.0052644    .001465    -3.59   0.001    -.0082133   -.0023155
      invest |   4.636727   1.878026     2.47   0.017     .8564572    8.416997
    openness |   .4244802   .3297181     1.29   0.204     -.239208    1.088168
       _cons |   82.35269   46.45449     1.77   0.083    -11.15535    175.8607
------------------------------------------------------------------------------
```

By comparing the regression analysis in table 7.2 and 7.3, we would see that, the relationship between the growth and the initial GDP per capita still exist. The control variables maintained their aprior expectation, which was stated earlier in this study. The evidence of convergence still exists between the poor and the rich countries. The result here is very interesting, because, it shows that, the poor countries which are the low income countries, will tends to converge to a steady state level of income.

Thus, the unrestricted equation coupled from table 7.4 is presented below:

$$ln(Y/N)_{i2010} - ln(Y/N)_{i1980} = 82.32 - 0.0053ln(Y/N)_{i1980} + 4.64Invest_i + .424Openess_i$$

s.e (46.46) (0.001) (1.88) (0.32)

$R^2 = 0.333$

However, trade openness agrees with the aprior expectation, but was found to be statistically insignificant (though not crucial for the analysis) at 1%, 5% and 10% respectively. One out of many reasons for having this result could be that, the poor countries (developing countries) are presently far from their respective steady state. Therefore, the influence of trade openness has not yet had its full impact on their level of growth.

For overall significance of the model, the F-statistics value for both restricted and unrestricted regression equation should be compared with its probability value. See Wooldridge (2009). In the regression analysis above, the F-statistics (12.58, 7.67) value was found to be greater than it probability value (0.0009, 0.0003) for both the restricted and the unrestricted model. Thus, we accept the hypothesis that, there is tendency for convergence.

***Testing for Heteroskedasticity***

The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity was also carried out on the model. It was discovered that, the model had a constant variance. The chi-square value was found greater than the probability value. Therefore, the result of the test was not different from zero.

Table 7.5: Presents Breusch-Pagan / Cook-Weisberg test for heteroskedasticity

```
. hettest

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
        Ho: Constant variance
        Variables: fitted values of growth

        chi2(1)      =    16.85
        Prob > chi2  =   0.0000
```

***Testing for Multicolinearity***

It is also paramount to carry out test for multicolinearity. From the regression analysis, it was discovered using the tolerance and the variance inflation factor techniques that the model is free of multicollinearity problem. The tolerance value of the model, which was calculated as $(1-R^2)$ i.e. (1-0.33) was found to be 0.67 which is greater than 0.1 or 0.2. Thus, we can conclude that, the model is multicollinearity free.

Table 7.6: Test for Multicollinearity

```
. vif
```

| Variable | VIF | 1/VIF |
|---|---|---|
| invest | 1.17 | 0.855408 |
| openness | 1.16 | 0.859130 |
| gdppc | 1.01 | 0.994206 |
| Mean VIF | 1.11 | |

From the VIF perspective, checking through the table above, the VIF values for the variables are all less than 5. This is a standard measure for testing multicollinearity

(see Wooldridge, 2009) Therefore, we conclude that, the variables are not in any way correlated or related.

## 7.2 Economic Implication of the Results

The results obtained from the regression analysis carried out seem to be in line with several empirical literatures on the presence and possibility of convergence theory. The coefficient of $\beta_1$ which is the parameter estimate for the initial GDP per capita, in the unrestricted mode, was found to be -0.0053. This vividly confirms the existence of convergence between the poor and the rich countries. If the initial GDP per capita for the richer countries increases by 1 percent, their growth rate would declines by 0.53 percent. Therefore, the poorer country at this pace grows and catches up with them at the steady state, vice versa.

The inclusion of investment further empowers the result and makes better the explanatory power of the model. The coefficient for investment $\beta_2$ (4.64) was found to be elastic. This implies that, a 1 percent change in the level of investment would bring about 4.64 percent changes in the level of growth.

The trade openness seems not to play a significant role in observing convergence. Though, in the results, it was discovered that, a change in trade openness as positive impact on the level of growth. The trade openness expresses inelastic impact on growth. The coefficient $\beta_3$ value is about 0.424 respectively. This indicates that, a 1 percent change in trade would results in 0.42 percent changes in the level of growth.

However, much emphasis is not place on it. The trade openness was only employed to pull ceteris paribus effect. One out of many reasons for having this control

variable result not to be statistically significant could be that, the poor countries (developing countries) are presently far from their respective steady state. Therefore, the influence of trade openness has not yet had its full impact on their level of growth. Moreover, the variable is much useful in affirming the robustness of the model.

Conclusively, the heteroscedasticity test also shows that, the model had a constant variance. The chi-square was found to be greater than the probability value, thus, the result of the test was not different from zero. On the other hand, through the variance inflation factor and tolerance test carried out for multicollinearity, it was discovered that, the variables are not in any way correlated or related.

# Chapter 8

# CONCLUSION

## 8.1 Conclusion

The recent diversities in the level of economic development within the countries of the world have been the motivating factor to carry out this research. Some countries keep growing and getting richer, while some are getting poorer. For example, the level of disparities in economic development between United State, Canada, Denmark, and Japan etc. with the likes of Nigeria, Cyprus, India, and Indonesia etc. are enormous that one would start to think, if these developing economies would ever grow to be like their richer counterparts. Despite all this perceived level of diversities, there is convergence theory, which says that, these poor countries would grow faster and catch up with the richer ones. This cast a shadow on the validity of the convergence theory, which this study will investigate.

The aim of this study is to investigate the presence and possibility of the convergence theory. That is, to investigate whether the poor countries would grow faster and catch up with the richer ones as the convergence theory advocated. This study tries to investigate, if it will be possible for the poor countries of today, despite the level of diversity in the growth and development between the world economies to grow faster and catches up with the rich countries. Cross-sectional data is used to show the

tendency of convergence between the periods of 1980 – 2010 for 50 selected countries.

From the regression, it was discovered that, a negative relationship exists between growth and initial GDP per capita for the period. This is in accordance with the aprior expectation set for the study. Other control variables signs from the regression results were also in line with the stated economic expectations. The level of investment and openness all had a positive relationship with growth, but it was discovered that, trade openness is statistically insignificant, though it was useful in estimating the robustness of the model.

From the empirical evidence, we discovered there is a reaction, or better put, a feedback relationship between growth and the initial GDP per capita. This implies that, country with low initial GDP per capita is farther away from their steady state and would grow faster than the countries with high initial GDP per capita but closer to their steady state. On the nexus between the growth and initial GDP per capita, the regression analysis revealed that, level of investment is a catalyst for growth. Hence, we infer that, the poor countries should enhance their level of investment (both in human and physical capital). The more the level of investment, the more would be the level of growth.

Conclusively, the model exhibits a natural long-run relationship. This made us to know that, no matter the level of disparities and diversities between the poor countries and the richer ones today; the former would still grow and catches up with the latter.

# REFERENCES


Baumol, W. J. (1986). “Productivity Growth, Convergence and Welfare: What the Long Run Data Show” American Economic Review. 76, 5.

Barro, R. (1995). Economic Growth. Mc Graw. New York.

De Long, J. B. (1988). “Productivity Growth, Convergence and Welfare: Comment: American Economic Review. 76, 5.

Debasish, O. (2013). Growth Empirics: A Panel Data Approach. Quarterly Journal of Economics. 110, 1139-70

Eatzaz, A., & Amber, N. (2000). “An Empiric Analysis of Convergence Hypothesis” Pakistan Development Review. 39, 729–740

Jianyang, H. (2011). New Empirical Evidence on Economic Convergence. Journal of Cambridge Studies. Visiting Scholar at Harvard University.

Timakova, M. V. (2011). Conditional Convergence and the Solow Model: an Empirical Study. Rotterdam School of Economics. Master Thesis.

Quah, D. T. (1995). “Convergence Empirics across Economies with Capital Mobility” Journal of Economic Growth.

Quah, D. T. (1996). “Convergence Empirics across Economies with Capital Mobility” Journal of Economic Growth (Ed.).

Moses, A., & Paul, A. D. (1996). “Convergence and Deterred Catch Up, Productivity Leadership and the Waning of American Exceptionalism. Stamford University. All Soul College. Oxford and MERIT.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). "A Contribution to the Empirics of Economic Growth". The Quarterly Journal of Economics. 2, 407–437.

Solow, R. M. (1956). "A Contribution to the Theory of Economic Growth”. *Quarterly Journal of Economics.* 70 (1), 65–94.

Sorensen, P. B. (2005). *Introducing Advanced Macroeconomics: Growth and Business Cycles*. Berkshire. UK: McGraw Hill.

Solow, R. M. (1956). "A Contribution to the Theory of Economic Growth”. *Quarterly Journal of* Economics. 70 (1), 65–94.

Sokoloff, K. L, & Engerman, S. L. (1994). "History Lessons: Institutions, Factor Endowments, and Paths of Development in the New World". *The Journal of Economic Perspectives*. 14, 217-232.

Solow, R. M. (1956). "A Contribution to the Theory of Economic Growth”. Quarterly 70 (1), 65–94.

Sachs, J. D., & A. M. Warner (1995). “Economic Convergence and Economic Policies” NBER Working Paper. 5, 5039

Ramsey, F. P. (1992). Convergence in Growth Rates. The Role of Capital Mobility and Accumulation in the Theory of Long Run Growth.

Romer, D. (2006). *Advanced Macroeconomics*. The McGraw Hill. Third edition.