Competing theories of growth models and their forecast ability of actual output growth

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A dissertation submitted to the Faculty of Commerce, Law and Management (CLM) University of the Witwatersrand Johannesburg School of Economic and Business Sciences (SEBS), in fulfilment of the requirements for the degree of Master of Economic Science

30 March 2020

Declaration

I Dembe Netshipale, declare that this dissertation, competing theories of growth models and their forecast ability of real output growth which I hereby submit for the degree of Master of Economic Sciences at the University of Witwatersrand is my own work and has not been submitted before for any degree at any other University.

Signed…………………………………………….

Name of Student: Dembe Netshipale

April 2020

Dedication

This dissertation is devoted to the following people: Masindi Maluta Mbulaheni "Shamula", Todani Ndou, Eric Ndifheleni Netshipale, Ndorovheni Netshipale, Mulamuleli Randima, Mutondiwa Netshipale, Rolamulelwa Ritshidze Netshipale, Nthungeni Ndou, Avhafunani Netshipale, Mashudu Netshipale, Ndavhelelo Netshipale, Magondo M.E. & M, Maanda Magondo, Louisa Netshipale, Thimaliswi Netshipale, Azwianewi Netshipale, Ndamulelo Netshipale, Mulisa Nenzhelele, Emmanuel Mudzanani, Bongani Senyolo, Breezman Chabalala, Mpfunzeni Makhanya, Ramilane Mohlakoane, Aaron Alovokpinhou, Bonga Mdletshe, Ntsieni Thanyani, Aluwani Mulovedzi, Rotshidzwa Nedzingahe, Phalandwa Rendani, and Mafanywa Given.

Iwe Dembe Netshipale! "Dzulani zwanu MuDzanani, mukhwa vhusuto, mukhwa mulavhu, mukhwa govha, mutaulu muila gumbo. Songozwi thavha ya Dzanani". Shamula!!!!!!!! UF Jema!!!!!!!!!!!!!!!!!!!

Acknowledgements

I thank God, and my supervisor Dr. Tshepo Mokoka for his critical feedback, kind support and guidance in the process of writing this dissertation.

Abstract

This dissertation examines correlation between real output growth and projected output growth for diverse schools of thought. In this research study, we measure projected output growth of Australia, Brazil, France, Germany, South Korea, South Africa (S.A.), the United Kingdom (U.K.) and the United States (U.S.), using the Domar model, Solow model, extended Solow model, Goodwin’s model, AK model, Lucas model and Romer model for the period from 1970 to 2017, then compare it to the actual output values to see if there exist a co - movement between the two variables and the correlation.

We use both the ordinary least squares (OLS) regression and root mean square error (RMSE) to compare the performance of projected output growth for the above-mentioned period. The OLS results show that the Solow model, the extended Solow model, Goodwin’s model, and Lucas model the impact of projected output growth on real output growth is positive for all the countries and statistically significant. For the Domar model, the parameter term is significant, and the model predicts a positive impact on projected output growth, except for SA.

We also present the graphic representation of real output growth and projected output growth for seven growth models. The results show a strong co-movement between real output growth and projected output growth for extended Solow, Solow and Domar model. The RMSE estimate of real output growth and projected output growth for Solow model and extended Solow model provides superior estimate ability.

Lastly, we use in-sample and out-of-sample forecasts, by utilizing RMSE, to determine which model possess the most superior forecasting ability for the one year, two year and three year time horizon. The in-sample results illustrate that, generally, the Goodwin model outperforms other models followed by extended Solow model then The AK and Lucas models. The out-of-sample results yield the following results: The extended Solow model generally outperforms the other models, followed by Solow model then Domar and Lucas models.

Keywords: projected output growth, actual output growth and forecasting ability

Table of Contents

List of Figures

List of Tables

1. Introduction

1.1 Background of the study

Throughout the history of economics, since its advent in the late 15th century, there has been the development of many diverse schools of economic thought. Many have arisen due to the needs and economic crises of their times, and how well they cope and explain the said crises. A predominant amount of the theories was influenced by the question, if the growth rate of a country the right instrument to measure the standard of living? However, the schools' ability to be effective over differing periods (to their period of genesis) is what determines how fundamentally accurate or strong the prevailing theories and assumptions of that time are. A school of thought that functions for only a twenty-year period is not nearly as valuable as one that can be used to determine trends over a century. As different models have different underlying theories, it is also important to compare diverse schools over a common topic - to this end, the following study will analyse and contrast the diverse schools over the common topic of long-term growth.

The economic growth review and models paper by Piętak (2014) outlines economic growth critics as follows: Firstly, not embodying the "black market" on the extracted output data from all different sources. Secondly, the welfare of the society measurement excludes the effort spent on work. Thirdly, the economic growth rate calculations exclude negative economic activities - notably air and environmental pollution. Regardless of the critics, the economic growth theory and models remains crucial for measuring a country living standard.

Before developing the main idea of this study, the development of the economic growth theory is worth highlighting. The concept of economic growth emerged in the 15th century by Mercantilism, whereby a country's wealth is stored using precious metals (gold and silver etc.) and maintaining a trade surplus. Where the government encouraged trade surpluses through subsidy incentives in exports and the imposition of tariffs on imports. The Mercantilist theory is a "zero sum" game where the two countries trade against each other in such a manner that if country A gains country B loses and vice-versa (Berhani, 2015). The Marxian theory pointed out the weakness of

Mercantilism theory as being exclusive of industrial and non-agriculture labour from determining this wealth.

The Mercantilist economic theory was replaced during the 18th century by Physiocrats who believed that wealth is dependent on the agricultural land and products worth - where the growth in agricultural production is proportional to technological changes. The Adam Smith theory criticized the mercantilist belief of holding precious metals and Physiocrats belief of agricultural land and product. Furthermore, Adam Smith pronounces that the wealth of a country is determined by its industrial and agricultural production and views trade as "winning sum" game by incorporating the absolute advantage concept (Berhani, 2015).

The following economist: A. Smith, T. Malthus and D. Ricardo discovered the theory of classical growth, where the theory suggests that changes in real output per capita are determined by the population growth (Çalışkan, 2015). In his influential book "An Inquiry into the Nature and Causes of the Wealth of Nations" Adam Smith (1776) professed the classical growth theories, which point out that the wealth is generated through trading not holding of precious metals. Furthermore, he argues that enhancement of peoples' wealth is related to factor inputs (i.e. land, labour, and capital) that produce output which results in a higher labour productivity. The book emphasizes on the key role played by population growth to extensive growth.

However, Smith believed that the capital accumulation and population growth are constant at the equilibrium state. The comparative advantage theory discovered by Ricardo (1821) is viewed as one of the most influential works under the classical growth economics. Piętak (2014) identifies that the trade of goods and services transacted through money which Ricardo just viewed it as a medium of exchange. Contrary to the absolute advantage in Smith theory, Ricardo's theory of the corporative advantage postulates that free trade can be mutually beneficial to all participant countries (Berhani, 2015). In addition, Ricardo advanced Smith by considering the effects of diminishing marginal returns from input on Smith's growth model.

Malthus (1959) on his "Essay on the principle of Population" opposes Smith's idea to say that the relationship between population growth and production tends to be negative (Sharipov, 2015). Thus, the food supply grows slower than the population growth as it grows arithmetically whereas population is geometrically (Berhani, 2015). Lastly, the classical growth theory got summed up by Keynes (1936) who argues about long term economic trend - the long-term population growth is stimulated by an increase in capital. Joseph Schumpeter (1934) introduced the innovative growth theory, which is driven by business and entrepreneur innovator competition for economic long run development (Nijkamp & Poot, 1998).

The Keynesians theory of economic growth was developed by J.M. Keynes (1936), to provide a better understanding of economic activity of an economy. Keynes believed that factor demand determined economic growth, existing solely because of the development and processes around a macroeconomic steady state. An impediment of Keynes' theory is that the tools of analysis are focused on the short-run, subsequently, Harrold and Domar examined the outcomes of growth theory for the long-run. Harrold, (1939) establishes that output growth is determined by the growth rate of labour and capital productivity whereas Domar, (1946) emphasizes more on the role of the marginal propensity to save (MPS) and average productivity of investment. Consequently, the combination of Harrold-Domar is extensively used in the recent literature because the two methods yield the same conclusion regarding a country's continuous sustainable development.

The neoclassical economists were against the idea of Keynes that during recessions a government should intervene to enhance business activity. The study by Sharipov (2015) points out three weaknesses of Keynesian and Post-Keynesian growth theories as follows: Firstly, economic growth being only determined by investment growth - excluding factors like technological progress. Secondly, the lack of an ability to interchange between the share of capital and labour - the neoclassical school of thought proves output can be achieved by different combination of inputs. Lastly, Inability of achieving a market mechanism for automatic rebalancing - only believe that stability is brought by government rather than competitive market system.

The Solow (1956; 1957) model show that output per capita growth is determined by the combination of, technological progress, labour, and investments. Solow's theory puts considerable emphasis on technological progress as a main determinant of sustainable economic growth - measured by per capita income. Furthermore, the countries with a high population experience a lower capital per labour which means low incomes.

During 1980s the issue of imperfect competition, research and development (R&D) theory and the role of possible changes in the profit rate became of interest by Paul Romer (1986, 1987&1990) and Robert Lucas (1988). This resulted from the neoclassical critics of diminishing marginal productivity of capital, from taxation and government spending not being able to affect long term economic growth. Sharipov (2015), shows the impact of economic growth as the savings rate only. The endogenous growth models believe that technological progress is not the only determinant of long-term economic growth, it emphasizes that the following factors need to be considered: Human capital, government intervention for science, technology development and protection in terms of property rights.

1.2 Motivation for the study

Following Parente (2001), examines the endogenous and exogenous growth theories to see which one best explain the evolving income distribution of all countries. However, the endogenous growth theory fails to encapsulate the following: It is unable to explain the growth miracles which occurred restrictively in poor countries and is unable to explain that the modern economic growth for late entrants that have the ability to double their respective income than that of early entrants. Therefore, endogenous growth theory is not a convenient tool to measure economic development. This influenced the chosen variables through assessing which models best project the actual output through the better-known models of economic growth such as Solow, the extended Solow, Domar, Goodwin, The AK, Lucas and Romer models. Following Boldeanu and Constantinescu (2015), the issues of enhancing active population, human capital investment, natural resources and research and development advancement impact on economic growth led to assessment of this variables impact on economic growth which are directly impacted. Furthermore, the assessment of the factors that affect the economic growth indirectly such as institutions, saving rates and investment rates, fiscal policies and the efficiency of government and financial systems etc. This influenced the study to consider both the variables that have a direct and indirect impact on economic growth when projecting the actual output growth.

In most studies, authors have focused on the issues of determinants and sources of economic growth; world income distribution; convergence of the countries and their long run impact. Firstly, the study is driven by the lack of consensus in the literature for exogenous and endogenous growth theory on examining the relationship between real output growth and projected output growth. The study by Adak (2009) examined the causality between total factor productivity (TFP) growth and economic growth using the Solow model for Turkey. The author’s finding shows a significant linear relationship between TFP growth and economic growth rates. Furthermore, the study by Khan (2005) analyses the co-movement and the correlation between real output growth and projected output growth for Pakistan. Where the author's finding shows the identical behaviour between real output growth and projected output growth for the entire period of analysis and a high degree of correlation.

The second motivation that influenced the study originates from the crucial role played by macroeconomic variables such as unemployment, Gross Domestic Product (GDP) and inflation in the considerations of politicians and central banks when forecasting the future (Pilström & Pohl, 2009). We examine these long run growth models of Domar, Solow, extended Solow, Goodwin, the AK, Lucas and Romer models to see which model best predict the economic growth. GDP is a significant macroeconomic variable used by politicians, central banks, consumers, and firms to make future economic decisions. Uncertainty about macroeconomic fluctuations induces challenges for the economic ecosystem, consequently a thorough understanding of each respective model provides value for each economic agent. The comparisons of all the 7 models using 8 diverse countries to see which one best predict real output growth rate will assist in remedying the issue of uncertainty. The debate on which model best predict real output growth among above mentioned models has not been settled in the literature.

We conduct this study for Australia, Brazil, France, Germany, South Korea, South Africa, United Kingdom, and the United States. The chosen diverse group of countries were chosen from the stand point of different levels of research and development, productivity growth and economic activity, their monetary policy mandate to achieve price stability in the economy this is a crucial part of their monetary policy conduct when forecasting the actual output growth.

1.3 Objective of the study

The objective of this study is to revisit the importance of economic growth models in the following ways: Firstly, study the importance of both endogenous and exogenous growth models and their limitation. Secondly, examine the relationship between projected output growth and real output growth. Lastly, examines which of the considered economic growth models best forecast economic growth. Pilström and Pohl (2009), pointed out that this information is crucial for central bank when it comes to managing interest rate and prices which affect economic growth of a country. Therefore, it is crucial to identify a general model that best forecast the economic growth. To this end, the analysis will cover the period from 1970 until 2017 across the above-mentioned countries. Such an analysis not only provides insight through comparable nations, such as the first world developed France and Germany, but also through contrasting very distinctly different nations, such as SA and the US. As there is a clear range in the types of economies analysed. The analysis allows greater discernment and interrogation of the models - under what circumstances are they most accurate? And to what lengths of time?

1.4 Problem statement

The problem statement emanates from the following studies Adak (2009), Khan (2005) and Liu, Li, and Tan (2012) where their studies examines the correlation between the TFP and the actual output growth from the standpoint of the Solow growth model. Their results show a Significant relationship between the TFP and the actual output growth. This brought the argument to examine the correlation and the co-movement between the TFP and the actual output growth using other exogenous growth models such as Domar model and the Goodwin model and also the main endogenous growth models such as the AK, Lucas and Romer Model.

Furthermore, the study by Diebolt and Monteils (2000) analyses the sources and the policy implications of the endogenous growth models, through deriving projected output growth of the AK, Lucas and Domar model. The Solow model were already derived by Solow (1957) study then, this stimulated us to derive the Domar model using Domar (1947) and Lianos (1979), and the Goodwin model using the Goodwin (1982). Therefore, this led to a question of comparison and contrasting long term growth models from the competing schools of thought.

The following studies emphasizes on the importance of GDP growth role which plays an important indication role for the central banks, world banks, companies etc. to forecast the future (Pilström & Pohl 2009, Andersson 2007 and Monokroussos 1999). This stimulated the question to know which outperforms the others under a different time horizon. To this end, the analysis will cover the period from 1970 until 2017 across the above-mentioned countries. Such an analysis not only provides insight through comparable nations, such as the first world developed France and Germany, but also through contrasting very distinctly different nations, such as SA and the US. As there is a clear range in the types of economies analysed. The analysis allows greater discernment and interrogation of the models - under what circumstances are they most accurate? And to what lengths of time?

1.5 Research questions

The research problem outlines three main questions:

I. Between the economic growth models, which one best explains real output growth?
II. Is there a significant relationship between projected output growth and economic growth?
III. Which economic growth model best forecast real output growth?

1.6 Contribution of the study

Firstly, the study derives the projected output growth from endogenous and exogeneous growth models, then compares them to the actual output growth to examine the relationship between the two variables. The issue of economic growth is a major challenge for developing countries, it is either there is a negative growth, or the country is growing at a very slow rate. This results from the issue of economic delinquency were the level of growth is not sufficient to address the issue of poverty and inequality (Bhorat and Tarp, 2016). This has important implications on long run growth rate to alleviates poverty and inequality through enhancing employment opportunities and labour productivity. Therefore, the projected output growth and the actual output growth plays a crucial role in determining the rate at which the economy will expand in the long run and also provides the implications for the outlook of inflation and economic growth. This also offers a significant information on stock market by the investors as they attention to the fluctuations of projected and the actual output growth. Lastly, the study compares the performance of competing growth theories in forecasting the actual output growth to test which one produces the best forecasting of actual output growth one, four and eight years ahead, respectively. This is crucial for monetary policy since the actual output growth is one of the main variables used by the central banks and other institutions to predict the future.

Most of the existing studies focus mainly on addressing problems such as convergence, income distribution and inequality. We contribute to the existing knowledge by shedding light on the best growth models that explain real output growth better. This allows us to point out the gap between the models and which model describes best the dynamics of the economy. This is the current gap in economic knowledge as there is no literature that covers such a wide spread of cross-sectional data nor models in terms of determining which model most accurately depicts long term growth.

Furthermore, we need to distinguish between policies that can be effective for decades and implemented from the short, medium and long run effects as this is noted to have no impact on the needs of development economics by Hicks (1965) study. This results from inadequate exploring of exogenous growth model (Solow model and the extended Solow model). On the other hand, for endogenous growth models this study examines the dynamics of the long run growth effect of the economy as it have been neglected - majority of the studies mainly focuses on the long run growth effect of the policy. However, for a developing country endogenous with optimising agents. This is due to complexity of the parameter's derivation and non- linearity structure of the model estimation using a time series for a country specific (Rao and Cooray, 2012). This also shades light as the study examines the long run dynamics of endogenous and exogenous growth models, mainly concentrated on the projected and actual output growth and link them with the policies that can have a positive impact on the development of a country in the long run.

2. Literature review

2.1 Introduction

The issue of economic growth has become a subject of interest in the past 50 years because of the industrial revolution and subsequent two world wars. There have been competing models of growth from diverse schools of thought, with each trying to explain economic growth. The mercantilists argue that the accumulation of gold and silver as the engine of country's state of wealth. However, The Wealth of the Nations book by Adam Smith (1776) favours the labour force productivity as an appropriate measure of wealth rather than the holding of precious metals (Parente & Prescott 1993). In addition, after the industrial revolution, output growth has overtaken population growth, but these models lack growth path comparisons between different countries over lengthy periods of time (Grossman and Helpman, 1994).

A recent study by Pietak (2014) re-emphasizes that majority of the growth models were developed in the 20th century. Furthermore, Sharipov (2015) documents the economic growth models and theory through outlining the evolution of the literature on growth theories. The study by Çalışkan (2015), defines economic growth as a rise in the number of tools and products required to meet human needs in any country, where it is primarily determined by capital accumulation, technology advancements, a rise in population and work force. Isaksson (2007) outlined that the TFP enhances the welfare of the people in the economy. This stimulated many authors to focus on recent contributions of TFP growth on economic growth.

During the 19th century the issue of economic growth became of interest by many neoclassical economists, especially after the World War II. However, Economic historians have recommended industrialization based on historical experience. Grossman and Helpman (1993) point out that the industrial revolution that facilitated an output expansion that superseded population growth from 19th to 20th century and diverse growth path for over a relative longer period among the countries.

This stimulated many economists to focus on recent contributions of economic growth. During the 20th century Harrod (1939) "An essay in dynamic growth" discovers the concept of warranted rate growth, actual (geometrical) rate of growth and natural rate of growth, which influenced many economists to analyse the causes of economic growth; which saw the emergence of two problems.

Firstly, the savings rate determines the actual growth rate and labour determines the natural growth rate. The assumptions of fixed wages, labour and capital consumption in the identical ratio resulted in the actual growth to equal the natural growth. Secondly, the Harrod model exhibited unstable economic growth consequently, this had the potential of explosive growth occurring when real output growth slightly deviated from natural rate growth, with a stagflation as a possible outcome (Hagemann, 2009). The assumption of the fixed proportion of labour and capital became a major criticism of the Harrold-Domar model. The Solow (1956) model of economic growth relaxes the assumption of fixed wages, labour and capital consumption. The Solow's model focuses on the capital accumulation and his findings shows that the opposition among the unwarranted and natural growth rate of capital is not easily achievable if the constant returns to scale and variable proportions holds under neoclassical assumptions. This means that the knife edge case, found in Harrod-Domar economic models, is not attainable.

Swan (1956) studies the relationship between the capital accumulation and the output growth using two diagrams based on theory of Adam Smith, Stuart Mill, Lewis and Ricardo. Abramowitz (1956) answers questions relating to the resource and output trends (the net increase in aggregate output per capital, evidence of change in the output per labour growth and fluctuations that affect the growth rate of output) in the U.S. for the periods of 1870 to 1953: Firstly, Abramowitz (1956) find that the population tripled and the net national output per labour in constant prices quadrupled. Secondly, growth rate of total output and output per capita shows no significant trends in rates. Lastly, he finds uniform change of the output growth rate. Additionally, these points outline the fact that capital should be broadened to include the following categories: health, education and training and research. One may therefore attribute the founding ideas of endogenous technological change to Abramowitz (1956), just that he did not present it in a formal way.

Romer (1986) challenged the exogenous growth theory, where they discovered the endogenous growth models which emphasize on contribution by researchers and entrepreneurs as the engine of economic growth. Furthermore, Jones (2019) considered Romer (1990a) paper as a turning point in economic growth as it provided a key insight to nonrivalry of ideas and the rival of standard goods in classical economics, and clarity on the implications for economic growth. This key turning point led authors into publish papers under the key topic endogenous growth theory.

The literature review next sections are as follows: section 2.2 discuss the evolution of growth theories and growth facts, section 2.3 discuss convergence as a whole, section 2.4 provides sources of economic growth, section 2.5 diverse schools of thought and lastly Section 2.6 the role of potential output.

2.2 The evolution of growth theories and growth facts

2.2.1 The importance of long run economic growth

The long run economic growth plays a crucial role in explaining the factors that determines economic growth within a specified country of interest and explains the cross country differences in income and growth rates (Soylu, Çakmak, and Okur, 2018). The standard of living determines the economic growth which is the productive capability of an economy, measured by the quantity of goods and services (Palmer, 2012). The long run economic growth theory state that the higher level of investment and savings rate results in temporarily increase in output growth (Kahn, 1992).

2.2.2 Growth miracles and disasters

The growth miracle occurs when the income inequality of a country is higher than the actual position at a steady state (Jones 1997). Young, 1995 argues that the capital growth rate explains “growth miracles”, whereas for most of the economists may have considered to be driven by the higher TFP growth. During 1960 to 1990, South Korea average yearly growth rate of output per labour rose to 6.1 percent. Hlavac, (2010) point out that the South Korea economy recovered after the Second World War through encouragement of inflow of foreign capital, international trade, and international completion among powerful countries. Furthermore, Singapore, Hong Kong and Japan reported similar growth miracles from 1960 to 1980 where there was an improvement by 40 percent from the initial start of 20 percent in the year 1960 (Jones, 1997). The South Korean income rose, relative to the US GDP per capita, from 11 percent in 1960 to 38 percent in 1988, where the average yearly growth rate of output per labour rises to 6.1 percent, average yearly growth rate of capital amount to 10.8 percent, with the average yearly growth rate of labour and TFP growth amount to 2.6 and 2.3 percent, respectively (Lui, 2007).

The other countries that reported a relative high-income growth are as follows: Botswana (from 5 to 20 percent), Romania (from 3 to 12 percent) and Lesotho (from 2 percent to 6 percent). Although, the countries’ modest growth attribute to a large change, they did not catch the attention of economists', for the period same period as South Korea. Contrastingly, during the same period Venezuela faced a crucial period where their income of 84 percent U.S. income fell dramatically to only 55 percent. Chad is the other country that experience growth disaster from 8 percent to 3 percent in relative income (Jones 1997).

2.2.3 The question of why the whole world is not rich?

Following Wolla (2017), GDP measures the value of final goods and services produced within a year. As mentioned under the importance of long run economic growth it measures a country standard of living. The difference between the poor country and the rich country, determined by the level of income, wealth, goods, and services. The whole world is not rich because GDP per capita is used to measure the country's standard of living (Economic well-being of a country). This question got addressed by the following models Harrold (1939) and Domar (1946) model, Solow model (1956) and endogenous growth models (Barro and Salai-i-Martin, 1995 and Aghion and Howitt, 1998)

Following Felipe, Kumar, and Abdon (2014), outlines three reasons why the whole world is not rich question. Firstly, the low level equilibrium trap which is formalised by Nelson (1956) – occurs when the capital stock and population is growth at a similar rate which mean a constant change in capital per worker, were this change also impact per capita income as it result in a constant economic growth of a country. This shows the interdependence of the three mentioned variables. Therefore, low level equilibrium trap occurs when the population super pass the per capita income.

Secondly, the issue of economic development under the structural transformation literature which occurs when new ideas replace the old ones, their impact on economic activity and their interactivity (Felipe, Kumar, and Abdon, 2014). Following Chenery, Robinson, Syrquin, (1986), Kuznets (1966) or Kaldor (1967) the structural changes focuses more on industry such as composition of demand, the occupation of the labour force and international trade unlike agriculture sector only.

Lasty, the issue of higher real wage earnings which makes a country to become rich (Sutton, 2001). The Sutton argues that the source of growth is through a gradual build-up of "scarce capabilities" which is through network of firms which contrasts from that of the neoclassical model that capital per labour ratio results in higher real wages (Felipe, Kumar, and Abdon, 2014). Furthermore, Hidalgo et al (2007) argues that the production and exports of technology, capital, skills, and institutions as a product progress enhance countries growth.

2.2.4 The world income distribution

Sala-i-Martin (2003) examines the issue of how income spreads vary amongst countries by means of a microeconomic survey and aggregate GDP data for the period 1970 to 2000. The author's findings show that the world per capita GDP progressed to 95 percent[1]. During 1970 to 1978, the total population rises by more than 1.6 billion whereas number of poor people increased by 20 million. This shows that the population growth offset the poverty rate - this rate decreased by a factor of 3 during this period since 1970. Therefore, growth plays a significant role in eliminating the world poverty (Barro and Salai-i-Martin, 2004, pa.8).

The issue of income distribution in the future under the new growth theories assumption of technological progress as the engine of economic growth shows in the long run that the creation of ideas stimulates the output per capita (Jones, 1997). Since ideas are non-rival this means that the other countries can share the ideas, therefore, this implies that the countries that can catch up with each other and growth at the equivalent rate of world knowledge (Eaton and Kortum, 1994).

2.2.5 Determinants of economic growth

Following Barro and Salai-i-Martin (2004), the issue of economic growth plays a significant role in standard of living, income levels of individuals and world poverty. Their study stresses on the importance of determinants of economic growth both theoretically and empirically. Barro (2003) examines initial levels of state variables, policy variables and national characteristics as a determinant of economic growth using a panel empirical study. The author's findings show that holding GDP per capita and high human capital constant, the fertility rate, the inflation rate and the ratio of government consumption to GDP affects growth rate negatively whereas rule of law and the international openness stimulates growth and the effect of democracy being ambiguous. This effect of democracy consists of political models-which impact democracies negatively as it

[1] The world per capita is equivalent to GDP of 126 countries then divided by world population.

influences the transfer of political power and private sector capital accumulation expropriation - henceforth a democracy becomes productive when government does not expropriate.

The following inputs: R&D, capital stock and human capital have been proved to be the main sources of growth. The issue of investment in physical capital shows that the Solow-Swan model in the long run is expected to be independent of the investment rate, because of the diminishing returns. This shows that the there is a correlation that appears in the data between the investment rates and growth rate (Temple, 1999). The issue of human capital on MRW analysis raises two problems, firstly the issue of output per person being overstated by fluctuations in human capital (Benhabib & Spiegel, 1994), lastly the data set shows that the growth rate of educational capital shows no effect on the growth rate output per labour (Pritchett, 2001).

The study by Dieckmann (1996), examines the effect of cultural determinants on economic growth under endogenous growth model using theoretical and empirical analysis. The theoretical part found cultural determinants to provide a country with a highest growth rate whereas the effect of empirical study still needs clarity. Also, the effect of cultural determinants cannot be examined under neoclassical growth model since the competitive equilibrium methods under growth accounting is not adequate.

2.3 Convergence

During 1980s the questions were asked about the degree of income distribution changes across countries. If there exist absolute convergences or not in future decades? These led to the convergence debate to be of an interest among economists.

Following Romer (1996, pa.30), the reasons for economists to study convergence got influenced by the Solow model when forecasting that countries tends to converge to their own equilibrium state, which indicates that the rate of return of capital is low for rich countries and delays in the spread of knowledge. Furthermore, Barro and Sala-i-Martin (2004, pa.47) point out that the neoclassical growth models plays an important role in the prediction of conditional convergence, which occurs when we have heterogeneity (group of countries) across the countries and different steady states.

Baumol (1986) and Abramovitz (1986) observe the level of output per labour and growth in the long period after the world-war II, they found that there exists an inverse relationship in the estimation among the poor and rich countries. The catch-up hypothesis further shows that the level of technology includes a country's capital stock acts as a catalyst, where the latecomer's country performance (which is initially backward) accelerates with leading country. The diminishing returns in capital yields high rates of return, under the neoclassical model of growth in a closed economy, which is the reason why it led to absolute convergence (Barro & Sala-i-Martin, 1990).

2.3.1 Concepts of convergence hypothesis

Following Barro and Sala-i Martin (2004, pa.462), the absolute convergence hypothesis holds when poor countries tends to grow faster than the rich countries - implies a catch-up effect with the rich ones. They assume the following parameters to be identical: population growth, depreciation rate, savings rate, and factors of production. The absolute convergence hypothesis depends on the structural attribute namely, "technologies, preferences, population growth, government policy and factor market structure" which are significant for the attainment of a country's long run steady state (Galor, 1996). Barro (2003) examines the relationship between the output per capita growth rate and log output per capita in 1965 for sample of 113 countries for the period 1965 to 1995. The author's outcomes show that the no relation between absolute convergence and cross section of countries.

During 1870 to 1979, the study by Maddison (1977) examined the absolute convergence for OECD countries for 13 advanced countries and found strong evidence that support this convergence after World War II period. However, Martin and Sunley (1998) criticized the findings and argue that the study consists of countries that are the same - in the sense that the cross-section of countries is rich before thus are subjective to convergence. The authors suggest that they should have used ex ante sample countries that are expected to be industrialized in 1870, which when combined with ex post, provides evidence of convergence. However, for the relationship between annual growth rate for the period 1880 to 2000 and log personal income per capita in 1880 across U.S. states as well as the relationship between log of GDP per capita in 1960 and growth rate from 1960 to 2000 all support the hypothesis of absolute convergence (Barro & Sala-i Martin 2004, pa.462). Barro (1991) and Quah (1996) validates that the absolute advantage hypothesis is wrong in their empirical studies built on cross - country regression and dynamics of income distribution across countries, respectively.

The other concept of convergence is conditional convergence hypothesis ($\beta\ Convergence$), which occurs when we drop all the assumptions that the parameters in the absolute convergence are the same across countries (Barro & Sala-i Martin 2004, pa.464). The study by Barro (1996), postulates that for conditional convergence to occur when initial real GDP per capita is less than equilibrium state position, the lower the real GDP per capita infers the higher the likelihood of a higher growth rates. In other words, given the identical structural characteristics across countries except for the initial real GDP per capita, the countries are anticipated to converge to the equivalent equilibrium state position of real GDP per capita (Galor, 1996). Therefore, the conditional convergence is a necessary condition however not a sufficient condition for absolute convergence (Martin & Sunley, 1998; Nelson, 1981).

The conditional convergence and club convergence are the two types of unconditional convergence, which were studied by Fischer and Stirböck (2006) who examine two key developments of basic convergence regression that resulted from the analysis of a constrained group of richer OECD countries that support hypothesis of absolute convergence. According to Martin and Sunley (1998), the existence of club convergence result from testing of multiple equilibrium state through adding successive powers of log (y_{it}) in the basic growth regression. Following Islam (2003), unconditional convergence occurs when there is only one steady state amongst all countries, while conditional convergence occurs when each country has its own equilibrium state. The club hypothesis convergence - arises when per capita income of regional countries is the same in both structural features and initial conditions converge to one another in a long run (Galor, 1996).

Further, Baumol (1986) introduce the unconditional convergence, where the author examines the long run growth and convergence among 16 advanced countries using Maddison (1983) data for the period 1870-1979. The author’s findings illustrate a high coefficient of correlation which infers that, with a higher initial income per person in 1870 then the growth rate changes at a slower rate until 1979 denoting perfect convergence and support the evidence of unconditional convergence. However, the author findings were criticised for being mostly dubious which results from the sample selection - the countries used are utmost developed and measurement error - the estimated real output per worker in 1870 is vague (DeLong 1998). Azariadis and Drazen (1990) argue that club convergence occurs when there exists a multiple equilibrium state in the Diamond model.

Furthermore, the club convergence may also occur when the cross country reaches steady state given that they have identical location. Therefore, these different concepts of convergence depend on the initial position and some other factors. Following Islam (2003), condition of technological change under the neoclassical growth models requires the following assumptions: technological innovation not driven by resources, it should benefit everyone equally and benefits should be for free. Therefore, if all these assumptions hold, these yield a growth rate that satisfies the convergence hypothesis. If the assumption of production functions being identical in all countries holds then this yields the income level convergence.

2.4 Sources of Economic convergence

Rassekh (1998) identifies three main sources of conditional convergence and find its past origin. Firstly, diffusion of technology for poor countries the transfer of technology and low wages results in a faster growth than the rich countries. Secondly, the neoclassical growth model argued that the assumption of diminishing returns to capital results in conditional convergence. Lastly, the role of globalisation - where the terms of trade favours the developed countries and widens the income gap. According to Elmslie (1994), David Hume and Josiah Tucker established the convergence hypothesis during the mid-18th century. Hume’s view is that during economic development, growth experienced a natural inclination of convergence across countries while Tucker’s view is in line with the existence of international economic inequality forever. In addition, Hume discussed the following factors low wages and transfer of technology as the driving force for absolute convergence (Irwin, 1996 and Rassekh, 1998). Gerschenkron (1952) promoted and clarified on the suggestion that there is an advantage in being technologically backward country. Abramovitz (1986) uses Maddison data to hypothesize that being technological backward carries a potential for faster growth, which occurs when a leading country abandons old stock and change it.

During 17th and 18th centuries, the two classical economists John Stuart and Adam Smith has suggested the possibility of limit to growth. During 1776, Smith in his "Wealth of the Nations" forecasts that real GDP per capita reaches a maximum state for each country and does not touch on convergence. In addition, Smith criticizes Hume's theory of technological transfer and low wages in poor countries. Furthermore, Rassekh (1998) shows that Smith argues that higher productivity in developed economies benefit them to lead over deprived countries regardless of having to pay higher wages. Mills (1998) in his "Principles of political economy" emphasizes concentrating on a spread of wealth instead of focusing on increasing it for rich countries, which makes poor countries catch up - convergence applies.

Solow (1956) points out that even if the countries are not trading to each other, the neoclassical growth model forecasts income convergence across countries with similar initial per capita GDP. However, Rassekh (1998) argues that international trade is a determining factor of convergence/divergence process. This is because more trade benefits the incomes of the trading partners. Whether more trade leads to convergence of countries is dubious. There are several empirical works that concentrate on examining the relationship between income convergence and international trade. The study by Ben-David (1996) uses a sample of major trade partners and found a positive relationship between convergence and trade - through a decline in the sample of countries income discrepancies overtime. The author clarifies that an increase in trade openness instead of the volume of trade that leads to equalisation of incomes.

2.5 School of thoughts

2.5.1. Keynesian School (Domar's model)

Domar's model, in isolation, has a fundamental issue with regards to unemployment and inflation (Aricó, 2003). The derivation of equilibria is defined as, "on a knife's edge," where any slight deviation results in prolonging or growing of either of these ills, due to the lack of stabilising forces.- the model is not stable (Sato, 1964). The model assumes fixed and equal proportions of factors of labour and capital which is extremely problematic and at the core of the criticisms. Swan (1956) began this critique of long-term growth theory, that capital and labour were key determinants, and such assumptions were misleading and inaccurate. This was in accordance with neoclassical theory, reinvigorated by the development of Solow's model in the same year (Solow, 1956).

Domar's model, while claiming to refute the original Marxian Reproduction Scheme only serves to rediscover and reinforce the arguments Marx made in a modern context. Domar begins with an analysis of the investment process, declaring a dual nature to the function. Specifically, that investment initially as, spending in the economy that creates income for others, as well as an increase to the productive capacities of the system (Lianos, 1979). Domar (1947) originally stated that, "investment is at the same time a cure for the disease (of unemployment) and the cause of even greater ills in the future."

The parallels between Domar and Marx's models extend further beyond the definition of investment - the same rate of growth of investment must equal the MPS multiplied by the average productivity of investment. That is, the underlying fundamentals, if their economic reasoning in both models are equivalent. Domar's implementation of the Keynesian savings rate should not be misinterpreted, it is equivalent to Marx in that the savings rate is estimated in a class society where labourers have no marginal or average propensity to save. This means that the savings rate constructed is the same as Marx's Capitalists saving's function. These stark similarities continue into the determination of long-term growth - the income growth rate must be equivalent to the MPS multiplied by the average productivity of investment. These realisations are exactly those of Marx, whose model preceded these revelations by eighty years.

2.5.2. Neoclassical School (Solow and extended Solow models).

The neoclassical economists were against the idea of Keynes stating that during the recession the government should intervene to enhance business activity. Firstly, the theory of new neoclassical growth theories was discovered in the article economics of growth by Abramovitz (1952) through his basic notations. However, this was neglected since those basic notations were not articulated formally. The difference in the new neoclassical models assumes perfect foresight, this helped to overcome neglecting or misspecification of important parts of technological change and economic growth. Chandler, *et al* (2009) and Lazonick and Lazonick(1990) articulate the finding that, during end of 19th century and the start 20th century, the US exceeded the UK in economic performance because of differences in management and organizational structure among both countries firms. Furthermore, Womack et al. (1990) shows that after World War II the Japanese economic growth performance increased unexpected, this resulted from organization of Japanese firms.

The Solow growth model is the fundamental model for estimation in growth theory. Solow (1957) studies, US technological change that isolate shift of the output per labour from the movements of the available capital per labour, for the period 1900 to 1949. The findings show that technological change is neutral on average, it accounts for an average of 1 percent in the first half and an average of 2 percent in the remaining half-this results from the upward shift in the production function and increase in technological change approximately double by contributing 87.5 percent of gross output per labour. Since the Mankiw, Romer and Weil (MRW) (1992), MRW going forward, empirical study focused on the rate of growth rather than variation of the income levels, Jones and Hall (1997) study point out that the importance of income levels for 133 countries lies in the differences in output per labour which is basically connected to differences in institutions and government policy (social infrastructure). This is a result of MRW failing to account for income in the cross-country differences through endogenous variables such as lack physical infrastructure.

Sachs and Warner (1997) use a cross-country regression to examine geographical factors and economic and international framework factors that affect the slow growth in Sub-Saharan Africa. The authors' finding shows that the factors mentioned above influenced slow growth, where the GDP per capita accounts for 65 percent in 1965 then dramatically falls to 35 percent in 1990. This is a fall by 25 percent over 25 years. For several years, the issue of whether the growth models with multiple equilibria outline the differences in the long-term income levels were left unaddressed. The Benhabib and Gali (1995, pa.195) study addresses this by coming up with "model based, and conditional on a number of auxiliary hypothesis" method, where their evidence supports multiple equilibria role in explaining the difference in income levels.

The study by Klenow and Rodriguez-Clare (1997) examines how the human capital and international productivity difference are measured, by re-estimating the MRW methodology incorporating primary schooling by running a Mincer regression. The findings show that 50 percent or more of 1985 GDP per worker at level difference result from the productivity difference. The MRW calculation of school enrolment data experiences difficulties since it was not clear which proxy is represented amid investment in human capital and investment stock. This is a result of population or labour force data on average schooling being currently accessible which means that it is going to be a poor (Temple, 1999).

2.5.2.1 Technology progress as the Engine of Growth

The neoclassical growth theory founded by Solow (1956) focuses on method of capital formation with the assumptions of constant returns to scale (CRTS) and fixed technology, where a country that begins with a low capital per labour ratio drive a high marginal product of capital. However, Grossman and Helpman (1994) criticize the neoclassical growth theorist as being unable to anticipate undesirable outcome of long run forecasts for the aggregate economy.

The original Solow growth model influenced researcher to review the issue of growth in different ways. Some, such as MRW (1992) using a sample of 98 countries investigate the difference between the Solow growth model and the augmented Solow model - includes human capital, are consistent in international variations and speed of convergence in the standard of living, for the period 1960-85. The findings show almost 80 percent of international variations in income per unit of labour are generated by the augmented Solow model which shows improvement in the performance variations of income per labour than in the Solow model. The results were influenced by the correlation of human capital accumulation with the savings and population growth, which solves the bias results of the coefficient of savings and population growth.

Furthermore, Nonneman & Vanhoudt (1996) study shows that the augmented Solow models best explains the international variations in the income per labour through savings, education, and population. The results show a 60 percent accuracy than of original Solow model. Romer (2006) identifies Solow model as the current foundational base of long-term growth theory.

The other key issue that economist encountered under neoclassical growth theory is what TFP change measures? The study by Lipsey and Carlaw (2004) solves the different interpretation of what TFP change exactly measures. This resulted from different conclusion of what it measures where studies; Barro (1991) and Young (1992) show that it measures the rate of technological progress. However, Hulten (2001); Jorgenson and Griliches (1967) believes that it measures the super normal benefits (R&D, and externalities) of technological progress. The findings support the super normal benefits preposition as a measure of technology progress since this is based on investing in new technology rather than investing in an existing technology, which represent an imperfect measure of returns. Hulten (1975, 1978), Rymes (1971), and Cas and Rymes (1991), show that if the Solow conditions hold, the TFP is measured as a shift in the production function. They further clarify that; marginal propensity to invest under capital accumulation should contribute to economic growth. However, in the growth process the TFP residual model “overstate” the role of capital and “understate” the role of innovation as results of exogenous capital assumption (Chen, 1997.).

The Solow model of growth has been contrasted against the Domar model in Sato’s 1964 paper. In it, is a note made of the relative strength of the two models, and that Solow’s model is superior as long run instability, with regards to unemployment and inflation, is improbable. This is due to neoclassical assumptions on variable proportions and constant returns to scale. However, latter assumption is criticised by Shaikh (1974) for making the model “infallible” - that is, the model functions on the mathematics of the production function, and not on underlying economic theory. It is a coincidence of the mathematics. Furthermore, For Industrialized and developing countries the neoclassical growth model were criticized for being unable to address the divergent growth paths issue, where this led to economists coming up with an endogenous growth model which address the differences in growth rates and output per person (Morana, 2003).

2.5.3. Marxian School (Goodwin’s model)

Goodwin’s model of long-term growth is formulated around considerations of distribution and growth in the economy. From his analysis, there is a clear instability in the capitalist framework and system. This is due to the struggle of all economies to distribute value. This results in perpetual disequilibrium as the economy oscillates between varying levels of employment and wages. The author states that the economy is disaggregated into two classes: the capitalist class and the working class (Goodwin, 1965). The core issue is that value is constantly absorbed from the system at large by the capitalist class from the poor working class, in a manner that is not unlike the gravitational pull from a black hole. This simile of the rich eating the poor is only broken by Volterra’s uneasy predator-prey relation that Goodwin’s model has been contrasted against

(Volterra, 1926). As the rich require the poor, there is a need for sustainability in the system, otherwise it collapses. This "collapse" is seen throughout history through mass revolt and/or mass starvation. To sustain the system the economy needs to grow, through an increase in employment and wages, until the point of overheat and implosion. Then wages start to diminish, and employment levels drop, and such the system begins anew. Throughout this cycle, the capitalist class are rarely the afflicted group, that burden is left to the working class. This has changed slightly in the modern economic era, where the rate of brutality has reduced, however the rate of exploitation has increased.

Goodwin's model too has received criticism, as the labour share and proportion of employed labourers in the economy can exceed the value of one - violating core a priori expectations making the model estimation nonsensical. However, modern adaptations of the model have accounted for these issues, but as we are estimating Goodwin's original model, these issues still lie in the underlying fundamentals of the framework (Desai, et al., 2006).

2.5.4. New Growth School - [NGT - The AK, Lucas and Romer models]

During 1980s a large body of economic research analysis focused on studies into endogenous growth which is one of the crucial research areas on causes of economic growth (Gualerzi, 2002). In addition, the disregard of determinants and subsequent impact of technological progress by neoclassical model stimulated the new growth models (Belloumi, 2014). This is due to neoclassical economic growth failing to consider R&D, public expenditure, and education as a critical input in the production. The above-mentioned input variables were incorporated into research by Romer (1986) and Lucas (1988) who discovered the theory of endogenous growth. This was done through the relaxing of the neoclassical growth model and theory assumption of exogenous technological change. Furthermore, the NGT value of capital which currently includes human capital and knowledge.

Lucas (1988) examines models that place emphasis on; "physical capital accumulation; technological change, human capital through schooling; and human capital accumulation through learning by doing" and evaluate if the variables are sufficient for economic development. The author's findings for physical capital accumulation model portray that convergence occurs in the income and asymptotically for the rate of growth levels equally for countries that have identical technology and preferences. The accumulation of capital models through schooling shows a consistent cross-country difference in the income per capita that is permanent education. Romer's model in the seminal work "increasing returns and the long-run growth" shows that the knowledge is an input in production of endogenous technical change model and exhibit increasing returns in marginal product (Romer, 1986).

Gilson and Roe (1993) as well as Nelson (1993), outlined how the difference in national institution as a factor that influence the country growth performance: the financial sector and the universities. The critique about new neoclassical growth model is that it hardly deals with institutions, and firms are treated in an extremely simplified manner. Romer (1990) outlines, the reason why the new growth theories formalized certain thoughts for understanding technological advances and economic growth, the ideas include uncertainty. The reason being that the NGT model's agenda is to be as close as possible to the principles of general equilibrium theory.

According to Hulten (2001), the important assumption of NGT is the constant marginal product. However, the human capital and research are important determinants of economic growth. Furthermore, Gualerzi (2002), points out that the growth per capita in capital is the engine for the neoclassical growth model. However, the problem with the assumption of diminishing return to capital is that the Solow (1956) model fails to consider the continuing improvement in technology as a result the per capita growth comes to an end (ceases). Cuñado *et al,* (2009), points out that the convergence hypothesis is the important difference between the neoclassical and endogenous growth model prediction. In addition, convergence hypothesis outlines that the per capita outcome in an economy for endogenous growth models and finds that it's unlikely for income to converge. However, the neoclassical growth model will converge at equilibrium state growth rates of output per capita. Thus, the growth of neoclassical model is determined by technological change which is exogenous in nature (Gualerzi, 2002).

Rabelo (1991), formulated the AK model based on human capital as well as R&D as the engine for endogenous growth. This model assumes that fixed factors are not re-producible and can't be accumulated so they don't form part of the model, the factors can be land, labour and raw materials etc. However, Lucas (1988); Azariadis and Drazen (1990) stress the importance of education as the engine for the economic growth and in Lucas (1988) model the self-maintained process as the engine of growth. Following Diebolt and Monteils (2000), the production and the education sector in Lucas model occurs simultaneously. The process occurs as follows: goods are produced from human capital and capital stock, then through some part of human capital in production sector not utilised and human capital through itself.

According to Barro and Lee (1993), the level of education positively affects the gross national product (GNP) growth rate directly. This study was conducted for the period 1960 to 1985; it examines levels of adult population at primary, secondary, uneducated, and higher education stochastic rate of success. The NGT is supported by Charlot (1997) and Barro (2003), who pointed out that the returns on the education are cumulative and positively impact on output growth rate. However, Benhabib and Spiegel (1994) show that the effect on growth rate of per capita output is not significant by the growth rate of human of the working population (calculated as number of years of education). This indicates that the human capital is no longer considered as factor of production since it only enhances rate of income per capita rather than growth rate, this study contradicts with the endogenous growth theory. The abovementioned contradicting conclusions are due to endogenous growth hypothesis not directly tested (Monteils, 2002).

Hulten (2001) point out that the economic growth in the TFP model cannot be explained only by the production function and marginal productivity conditions, since it does not describe how the inputs and technology changes over time. The Solow (1956) overcomes the change over time problem by assuming that labour and technology are exogenous, and investment is a constant fraction of the output. Furthermore, they investigate the importance of technological change in the neoclassical economic growth which shows that the long run growth is not explained by the capital formation. This arises since capital is endogenous and dependent on technological innovations that enhance output which further lead to an increase in the investment and the result being an increase in capital stock. According to Hulten (2000), the TFP models derived from production function are based on a view that productivity growth occurs through advancements in the “transforming of input into output”. However, no clarity on the TFP models’ view about the dimension of innovation.

Grossman and Helpmann (1991) point out that the production of better goods contributes a lot to welfare gains that the production of new goods in terms of innovation, where this is referred as increasing the quality ladder. However, the better goods outcome of innovation is not part of the

TFP residual; it only measures the production of more goods. Solow (1956) and Johansen (1959) shows that the efficiency approach solves the problem of the two types innovation (the introduction of new goods and quality of products developments) - through the model of capital embodied technological change.

According to Nelson (1997), during 1950s the technological advance remains acknowledged as the engine for "formal" neoclassical models of economic growth. However, many studies on the "formal" neoclassical models inarticulate the sources of technological advance. This resulted in the establishment of the new formal neoclassical growth model (Aghion and Howit, 1990; Grossman and Helpman, 1989 and Romer 1990). A distinguishable contrast between the neoclassical growth models is that the new formal neoclassical growth model includes R&D and assumes the imperfectly competitive markets whereas in the "informal" neoclassical growth model assumes the perfectly competitive market. The technological advance in endogenous models has been considered differently as some models take it as a creative destruction and some as externalities: research, and development investment and education activities.

2.5.4.1. Research and Development (R&D)

In the AK models the permanent changes in the capital growth rate leads to a temporary effect on the output growth rate rather than permanent changes. This led to NGT to consider the R&D as a significant source of growth for industrial economics. The R&D models got influenced by AK models because of their inconsistency with regards to long run growth time series test and cross-sectional empirical literature (Jones, 1995). In the NGT, the R&D models in the long run concentrates on technological progress and R&D, where the technological progress is an outcome from the search for innovations through discoveries ideas. R&D considers the significance of externalities, spillover and increasing returns for growth theory (Griliches, 1991). The study by Griliches (1979) examines the effect of R&D on economic growth, using the historical case studies and the econometric production function approach-where the aggregate inputs variables also embodies the R&D investment. However, the historical case study is difficult to implement due to data and time expensiveness.

Following Parente (2001), R&D is costly, and it excludes poor countries from participating forcing these countries to enhance their output per person through implementing the existing technological developments of rich countries. After World War II, Japan and South Korea are examples of poor countries that implemented existing R&D then became rich countries as the output per person largely increased. Solow (1994) criticize that the R&D activity is affected less by product improvement and cost reduction, where the author shows that it is mainly affected by production labour, process engineers, and even customers. Furthermore, enhancing productivity through resources is not sufficiently measured by the R&D expenditure.

2.5.4.2 The issue of measurement

Following Griliches (1979), this issue arises as result of output being measured in terms of inputs and does not account for improvement in productivity through R&D investments - which is consistent of defence, space, and health subdivisions. This implies that the data for R&D sectors were totally unmeasured and mis-measured as it is problematic to trace it out. The following have been the main issues for measurement of capital: R&D of capital may not impact economic growth since its process takes time and its adjustment takes place after several years; the previous R&D investment losses value and becomes out of date; and the level of knowledge of R&D Investment being rival among industries (Griliches 1979).

2.5.4.3 Econometric problem

Griliches (1979) outlines multicollinearity and simultaneity as econometric analysis problems for estimation of measured capital and output in R&D to economic growth. The multicollinearity occurs because numerous series focused more on moving observations which are jointly correlated for a given period. The possible remedy for multicollinearity uses micro-time series data “at the individual firm”. The simultaneity occurs because of causality between R&D and output, where the possible solutions are the use of instrumental variables and assumptions of independent relationship between error term and independent variables.

2.6 The role of potential output

Slevin (2001); Fedderke and Mengisteab (2017) and Butler (1996), defined the potential output as the maximum level of output that the country can sustain if all the resources (labour, technology and technology) are used efficiently and while inflation held constant. In addition, the output gap is defined as the percentage deviation between real output growth and the potential output growth - an indication of supply and demand pressures of a country at a given time (Kemp, 2011 and De Brouwer, 1998). The GDP is measured by the level of Real GDP - the demand over the business cycle (Slevin, 2001). Therefore, the positive output gap suggests an excess demand which may result in inflationary pressure. On the contrary, the negative output gap suggests a shortage of demand which may results in declining inflationary pressure (Fuentes, *et al* 2007).

Most central banks have a common mandate to achieve consistent price stability. Therefore, the output gap represents a variable provide a significant information in economic policy formulation by policy makers when measuring a country macroeconomic performance, setting inflation targets and fiscal policies. (Fedderke & Mengisteab, 2017; Kemp, 2011 and Arora & Bhundia, 2003). However, these variables are unobservable - becomes a challenge to quantify.

In the literature there are various methods of calculating potential output growth such as: a production function, Univariate and Multivariate and structural vectors. This section focuses on the production function approach to evaluate potential output like the Solow model approach used to project output growth. Musso and Westermann (2005), point out that the growth accounting method plays an important part in the medium to long run growth, as the output growth and the supply side factors (where the aggregate supply of the country can be represented by the potential output growth (Slevin 2000). Furthermore, the key benefit of using this method is that it does not rely on forecasting but the actual results.

In a monetary policy sense the unemployment is defined as output level that is steady with the constant rate of inflation in the short run (Butler, 1996). The derivation and the results of potential output and output gap are shown in Appendix A.

3. Methodology

3.1 Introduction

The economists during the 20th century examine the issue of economic growth due to rapid changes in the US economic growth post - World War II. This section focuses on deriving the projected output growth rate of different school of thoughts and compares it to real output economic growth of each school. Harrold and Domar had revised Keynes's analysis of general theory consider the full capacity utilization and full employment of an economy in the long run. However, the problem of enormous stability in Domar model brought the neoclassical growth theory as Solow model (Hagemann, 2009). Temple (1999) point out the engine of growth in neoclassical growth model as technological change.

The neoclassical growth which is the most fundamental for economic growth mainly assumes that the technologies "production function" are the same across countries. This assumption raises a question of whether the large difference in productivity per capita for developed countries is considered by TFP? (Felipe McCombie, 2007). According to Velupillai (1983), during the period 1970-1980 economists came up with Goodwin model as an alternative for Solow model which examine the class struggle between the share of wages and employment ratio. Though, the problem of enormous instability in the Goodwin model remains mysterious (Sportelli, 1995).

However, the neoclassical growth theory assumption of constant returns to capital were criticized and this led economist to derive the endogenous growth models. Then the Rebelo (1991) study derived the AK model by excluding all the constant inputs that are not accumulated such as land, labour etc. This were followed by the Lucas (1988) model which emphasize on acquiring the knowledge as a category of human capital as a driver for economic growth. Lastly, the Romer model (1990) which incorporate the knowledge in the category of R&D as a driver for economic growth.

The section will begin by deriving the Keynesian School model in section 3.2, focuses on the Domar school model; the neoclassical school's model in section 3.3 and subsequently the Marxian school in section 3.4. Section 3.5 will look at the models within the school of NGT. The succeeding sections of 3.6 and 3.7 will review the diagnostic procedure of the analysis looking at the RMSE Error (used for forecasting), followed by the variable construction.

3.2 Keynesian School: Domar model

Following Domar (1947) and Lianos (1979), both models stress the importance of the duality nature of investment process: where it enhances productive capacity and generate income. The model assumes. Firstly, the savings rate is proportional to investment. Secondly, the ratio of change in income over change in output is contending. Thirdly, investment is a function of capital and depreciation. (Sharipov, 2015 and Berhani, 2015).

The model is derived as follows:

$$I = \alpha Y \quad (1)$$

Where I and Y, denote investment and income, respectively and α denote the MPS. The increase in income ΔY is determined by an increase in investment ΔI as

$$\Delta Y = \frac{1}{\alpha}\Delta I \quad (2)$$

Where $\frac{1}{\alpha}$ denote the multiplier. Let us specify the average productivity of investment as follows:

$$\sigma = \frac{\Delta Y}{\Delta K} = \frac{\Delta Y}{I} \quad (3)$$

Where σ denote the average productivity of investment and Eq. (3) denote the average productivity of investment. Assume: full employment in an economy, therefore the change in productive capacity is equivalent to change in income, that is:

$$\frac{\Delta I}{\alpha} = \sigma I \quad (4)$$

Where σI denotes the increase in the productive capacity and $\frac{\Delta I}{\alpha}$ denote the increase in actual income. It thus follows that:

$$\frac{\Delta I}{I} = \alpha\sigma \quad (5)$$

Combining Eq. (1) and Eq. (3) yield the output growth equation as follows

$$\hat{g}_{yt} = \alpha\sigma \tag{6}$$

The projected output growth in Eq. (6) is the product of the average productivity of investment and the inverse of income multiplier.

3.3 Neoclassical School: Solow model

Following Kendric (1961); Barro (1999); Solow (1957); Liu, Li and Tan (2012), Kim and Lim (2004) and Aghion and Howitt (2007), TFP is measured using the labour augmenting aggregate production. Where the TFP growth denote the output growth rate "not explained" by the growth rate of inputs (labour and capital). The model assumes: CRTS; diminishing returns to inputs; perfect competition and that the share of capital and labour sums to one. Therefore, the production function is as follows:

$$Y(t) = A(t)\, K(t)^{\alpha} L(t)^{1-\alpha} \qquad (0 < \alpha < 1) \tag{7}$$

Where $Y(t)$,$K(t)$ and $L(t)$ denotes real output, capital stock and quantity of labour, respectively. And $A(t)$ denote the level of technology-represent the shift in the production function, and $L(t)$ denote the.

We then log-linearize Eq. (7)

$$ln\, Y(t) = ln\, A(t) + ln\, f\big(K(t), L(t)\big) \tag{8}$$

Differentiate Eq. (8) with respect to time:

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A(t)}}{A(t)} + \frac{\partial f(K(t),L(t))}{\partial K(t)} \frac{\dot{K(t)}}{f(K(t),L(t))} + \frac{\partial f(K(t),L(t))}{\partial L(t)} \frac{\dot{L(t)}}{f(K(t),L(t))} \tag{9}$$

Where, $\frac{\dot{Y}(t)}{Y(t)}$ and $\frac{\dot{A(t)}}{A(t)}$ denote the output growth and the technological change, respectively. Note that $f\big(K(t), L(t)\big)$= $\frac{Y(t)}{A(t)}$ then Eq. (9) becomes:

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A(t)}}{A(t)} + A(t) \frac{\partial Y(t)}{\partial K(t)} \frac{\dot{K(t)}}{Y(t)} + A(t) \frac{\partial Y(t)}{\partial L(t)} \frac{\dot{L(t)}}{Y(t)} \tag{10}$$

Rearranging Eq. (10) yield the capital share as $\alpha = \frac{\partial Y(t)}{\partial K(t)} \frac{K(t)}{Y(t)}$, also the labour share as (1-α) = $\frac{\partial Y(t)}{\partial L(t)} \frac{L(t)}{Y(t)}$. Then Eq. (10) becomes:

$$\frac{\dot{Y}(t)}{Y(t)} = \frac{\dot{A(t)}}{A(t)} + \alpha \frac{\dot{K(t)}}{K(t)} + (1-\alpha) \frac{\dot{L(t)}}{L(t)} \quad (11)$$

Where g_Y denote real output growth, g_K[2] denote growth rate of capital, g_L denote growth rate of labour and g_A denote the Solow residual (TFP growth).

The growth rate of capital per labour is derived as follows:

$$g_{kt} = s\left(\frac{y(t)}{k(t)}\right) - \sigma \quad (13)$$

Where s denote savings rate and σ denote depreciation rate.

In per capita terms output growth becomes:

$$g_{yt} = \hat{g}_{At} - \alpha g_{kt} \quad (12)$$

Where g_{yt} and g_{kt} denote growth of output per labour and growth of capital per labour, respectively. Then $\hat{g}_{At}$ denote the estimate of the TFP growth.

3.4 Neoclassical School: Extended Solow model

Following MRW (1992) extended Solow model through incorporating human capital as an input in a production function denoted by the following:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (A(t)L(t))^{1-\alpha-\beta} \quad (14)$$

Where $Y(t)$ denotes output, $K(t)$ and $L(t)$ denote capital stock and labour, respectively and $H(t)$ denote the human capital. Romer (2001) outlines the human capital as consisting of skill through

[2] Where $\dot{K}(t) = sY(t) - \sigma K(t)$

education, training, and experience. Then Eq. (14) can be written in the log form to present labour productivity as:

$$ln\,(y_t) = (1 - \alpha - \beta)ln(A_t) + \alpha ln(k_t) + \beta(h_t) \quad (15\,)$$

Where y denote output per labour, k denote capital per labour, h denote human capital per labour and $(1 - \alpha - \beta)ln(A)$ denote the residual which present the level of technology. Therefore, differentiate Eq. (15) with respect to time to get projected output growth becomes:

$$g_{yt} = \hat{g}_{At} + \alpha g_{kt} + \beta g_{ht} \quad (16)$$

Where g_{yt} denote real output growth and $\hat{g}_{At}$ denote projected output growth (TFP growth), g_{kt} denote capital per labour growth and lastly, g_{ht} denote human capital per labour growth.

3.5 Marxian School: Goodwin model

Following Desai (1973), Harvie (2000), Sportelli (1995), Desai, *et al*. (2006) and Goodwin (1965 & 1982), "the growth cycle 1967" shows that Goodwin model address the problem of (un) employment and wages (labour share). The derivation is organized as follows each assumption will be followed by an equation.

A3.31 Technological progress grows at a steady rate of α

$$\frac{Y}{L} = a = a_0 e^{\alpha t} \qquad \alpha > 0 \quad (17)$$

Where Y and L denotes output and labour, respectively and a denote the average labour productivity

A3.32 Labour force grows at a steady rate of β

$$N = N_0 e^{\beta t} \qquad \beta > 0 \quad (18)$$

Where N denote the labour force

A3.33 Assume labour and capital as only factors of production.

$$v = \frac{L}{N} \tag{19}$$

Where v denotes the employment rate

$$\phi = \frac{WL}{Y} = \frac{W}{a} \tag{20}$$

Where W denote the real wage and ϕ denote the labour share of national income

A3.34 All Profits are saved and invested.

$$\dot{K} = \left(1 - \frac{W}{a}\right)Y - \mu K \tag{21}$$

Where $\dot{K}$ denote the change in investment and μ denote the depreciation rate.

A3.35 There is a constant capital/output ratio σ

$$\sigma = \frac{K}{Y} \tag{22}$$

Where K denote the capital stock.

By linearizing Eq. (22) we get

$$ln\sigma = lnK - lnY \tag{23}$$

Then differentiate Eq. (23) with respect to time

$$\frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} \tag{24}$$

Substitute Eq. (21) into Eq. (24) we get

$$\hat{g}_{yt} = \frac{(1 - \phi)}{\sigma} - \mu \tag{25}$$

Eq. (25) $\hat{g}_{yt}$ denote the projected output growth rate.

3.6 New growth theories

3.6.1 The AK growth model

The AK model relaxes the assumption of diminishing return to capital to constant returns to capital. Following Cuñado, *et al* (2009) and Li (2002), the AK models is derived using the production function as follows:

$$Y(t) = A\, K(t)^{\alpha} L(t)^{1-\alpha} \tag{26}$$

We divide Eq. (26) by the labour to express it in per capita terms as

$$y = Ak^{\alpha} \tag{27}$$

Where A denote a constant technology, y and k denotes output per labour and capital per labour, respectively. Since the assumption is based on constant returns to capital. Therefore, $\alpha = 1$. The expression in Eq. (27) becomes:

$$y = Ak \tag{28}$$

Quinn and Hoag (2013), shows that the growth rate of capital per labour is as follows

$$\frac{\dot{k}}{k} = sA - (n + g) \tag{29}$$

Where s denotes an exogenous savings rate, A is a constant assumed to be positive[3], n denote the population growth and g denote the depreciation rate

Differentiate Eq. (28) to with respect to time to get[4]

$$\hat{g}_{yt} = sA - n - g \tag{30}$$

Eq. (30) shows that the $\hat{g}_{yt}$ projected growth rate of output per capita is positively related to savings rate and the output - capital ratio, negatively related to the population growth and depreciation rate.

[3] $A = \frac{Y}{K}$ where $\frac{\dot{K}}{K} = s\frac{Y}{K} - (n + g)$

[4] $g_y = g_k$ (the growth rate of factors of production are equal)

3.6.2. Lucas model

According to Lucas (1988), education is the engine for the self-maintained process of growth. The model uses the following production function:

$$Y(t) = AK(t)^{\beta}H(t)^{1-\beta}h^{\gamma}h_a(t)^{\gamma} \qquad \gamma \geq 0 \qquad (31)$$

Where $H(t)$ denote the human capital, A denote a positive constant level of technology, $h_a(t)$ denote external effects of human capital $K(t)$ and $L(t)$ denote capital stock and labour, respectively and lastly, $Y(t)$ denotes output.

Following Diebolt and Monteils (2000) the "production sector and education" sector in Lucas model occurs simultaneously. The process occurs as follows, goods are produced from capital stock and some part of human capital, then through some part of human capital in production not utilised and human capital through itself. Therefore, the human skills in the production sector are as follows:

$$H = uhN \qquad (32)$$

Where h is the allocation effects in productivity and in the level of human capital, N denote the workers (assumed to be identical agents with the same skill) and u is the production fraction of non-leisure time. Furthermore, considering the two effect of human capital (internal and external factors) the production good technology is of the form:

$$Y \ = NC + \dot{K} \qquad (33)$$

Where C denote per capita consumption. The production good technology is further simplified to be of the form

$$Y = AK^{\beta}[uhN]^{1-\beta}h^{\gamma} \qquad (34)$$

The human capital through education model assumes that human capital produces itself, the growth of human capital is as follows

$$\frac{\dot{h}}{h} = \varphi(1-u) \qquad (35)$$

Assume that the production is determined by the labour and capital inputs and the level of technological change:

$$\dot{K} \;= AK^{\beta}N^{1-\beta} - NC \qquad (36)$$

The real per capita consumption is formulated on assumption of constant population n and a closed economy, is given by

$$\int_0^{\infty} e^{-\rho t}\left(\frac{{c_t}^{1-\sigma}-1}{1-\sigma}\right)\ N(t)dt \qquad \rho,\sigma > 0 \qquad (37)$$

Where ρ denote preference rate and σ denote coefficient of risk aversion. We set up Hamiltonian function as follows

$$H(K,h,Q_1,Q_2,c,u,t) = \frac{N}{1-\sigma}(c^{1-\sigma}-1) + Q_1\left[AK^{\beta}(uNh)^{1-\beta}h^{\gamma} - NC\,\right] + Q_2[\delta h(1-u)] \qquad (38)$$

The first order conditions are given as

$$\frac{\partial H}{\partial c}: \qquad C^{-\sigma} = Q_1 \qquad (39)$$

$$\frac{\partial H}{\partial u}: \qquad Q_1(1-\beta)AK^{\beta}(unh)^{-\beta}Nh^{1+\gamma} = Q_2\varphi h \qquad (40)$$

The prices Q_1 and Q_2 rate is derived by[5] as follows:

$$\dot{Q}_1(t) = \rho Q_1 - \ Q_1\,\beta A\big(K(t)\big)^{\beta-1}\big(u(t)h(t)N(t)\big)^{1-\beta}h(t)^{\gamma} \qquad (41)$$

$$\dot{Q}_2(t) = \rho Q_2 - \ Q_2\,(1-\beta+\gamma)A\big(K(t)\big)^{\beta}\big(u(t)N(t)\big)^{1-\beta}h(t)^{\gamma-\beta} - Q_2\varphi\,\big(1-u(t)\big) \qquad (42)$$

[5] The following price rate condition is as follows $\dot{Q}_i(t) = \ \rho Q_i(t) - \frac{\partial}{\partial x}H(K(t),Q_i(t),C(t),t\,)$

We differentiate Eq. (38) with respect to time, this leads to:[6]

$$\frac{\dot{Q}(t)}{Q(t)} = -\varphi k \tag{43}$$

Let $\frac{\dot{Q}(t)}{Q(t)} = -\varphi k$ and this result in a condition of marginal productivity of capital.

$$\beta A(K(t))^{\beta-1}\big(u(t)h(t)N(t)\big)^{1-\beta} h(t)^{\gamma} = \rho + \varphi k \tag{44}$$

We differentiate Eq. (39) with respect to time, which yields:

$$(\beta - 1)\frac{\dot{K}(t)}{K(t)} + (1-\beta)\frac{\dot{u}(t)}{u(t)} + (1-\beta)\frac{\dot{N}(t)}{N(t)} + (1-\beta-\gamma)\frac{\dot{h}}{h} = 0 \tag{45}$$

Therefore, Eq. (45) becomes[7] the engine of growth as follows:

$$\hat{g}_{yt} = \frac{\varphi(1-\beta+\gamma)(1-u)}{(1-\beta)} \tag{46}$$

Eq. (46) shows that the $\hat{g}_{yt}$ projected output growth is determined by the efficiency of human capital, externality (γ) and time assigned to knowledge accumulation (1-u).

3.6.3 Romer model

Romer (1990) model is made up of three sectors: R&D sector, an intermediate sector and final output sector.

R&D sector production side is based perfect competition of design therefore, new technology as follows

$$\dot{A} = \tau H_A A \tag{47}$$

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[6] $\ln c(t)^{-\sigma} = ln\, Q(t)$

[7] $\frac{\dot{K}}{K} = k + \tau$, where τ denote population growth $\frac{\dot{u(t)}}{u(t)} = 0$ (since the time allocation is constant) and $\frac{\dot{h(t)}}{h(t)} = \varphi(1 - u(t))$ as given in Eq.(35)

Where A is the knowledge stock, H_A[8] is the number of researcher and τ is scale and productivity parameter. The equation shows that new knowledge depends on quantity of labour assigned to research and the number of new capital goods designed.[9]

An intermediate sector production side number of firms is assumed to be on a monopolistic competition. The capital good affect the second sector through new discovery of production. Therefore, the aggregate capital is explained by the non-consumed fraction in production.

$$K = \eta \sum_{i=1}^{A} x_i \tag{48}$$

Where η denote the creation of one unit of each type is produced and x_i is the availability of each type of capital. This equation implies that the capital stock results are further used in production of final goods since it yields intermediate goods. Therefore, there is a one to one relationship between capital and labour supply.

Final output sector production side is based perfect competition-the returns are constant. Therefore, the production is outlined by a single competitive industry.

$$Y(H_y, L, x) = H_Y^{\alpha} L^{\beta} \int_{i=1}^{\infty} x_i^{1-\alpha-\beta}\, di \tag{49}$$

Where $Y(H_y, L, x)$ denote the output that is saved or consumed as new capital, x_i denote the units of durable good, L denote labour supply, H_Y denote the production of final output of human capital.

After deriving the three sectors what follows is to determine the equilibrium profits, price of a design, wage for human capital and lastly production side equilibrium

The maximum problem requires that the aggregated demand to meet the following condition

$$\max_x \int_0^{\infty} \left[H_Y^{\alpha} L^{\beta} x(i)^{1-\alpha-\beta} - p(i)x(i)\right] di \tag{50}$$

[8] $H_A = H - H_Y$, Where H_Y determine the production of final output of human capital.

Differentiating with respect to $x(i)$ yields inverse demand function

$$p(i) = (1-\alpha-\beta)H_Y^{\alpha}L^{\beta}x(i)^{-\alpha-\beta} \quad (51)$$

Therefore, the price of a blueprint is as follows[10]

$$P_A = \frac{1}{z}\pi = \frac{\alpha+\beta}{z}(1-\alpha-\beta)H_Y^{\alpha}L^{\beta}\bar{x}^{1-\alpha-\beta} \quad (52)$$

Where π and z denotes the profit rate and interest rate, respectively. The wage is derived from marginal product of labour supply[11]

$$w_H = \alpha H_Y^{\alpha-1}L^{\beta}A\bar{x}^{1-\alpha-\beta} \quad (53)$$

Where w_H denote human capital rental rate. Then substituting Eq. (52) into Eq. (53) yield the following:

$$H_Y = \frac{\alpha * z}{\sigma(1-\alpha-\beta)(\alpha+\beta)} \quad (54)$$

The Romer model economic growth is determined through acquiring of knowledge, this implies that an economy that assigns more quantities of human capital to research will yield a faster growth than others. Therefore, Romer concludes that consumption, output, capital, and research technology growth rate are equal.

$$\hat{g}_{yt} = \frac{\dot{C}}{C} = \frac{\dot{Y}}{Y} = \frac{\dot{K}}{K} = \frac{\dot{A}}{A} = \tau(H - H_Y) \quad (55)$$

The equation shows that production grows at equivalent rate as A when one considers L, H_Y, and $\bar{x}$. Capital grows at the same rate as A: because it depends on the A$\bar{x}$ η. Romer concludes that a little human capital is devoted to research and subsidising activity requires the appropriate economic policy.

Eq. (56) below show that the $\hat{g}_{yt}$ projected output growth rate of economy can be simplified as[12]

$$\hat{g}_{yt} = \tau H - \theta z \quad (56)$$

[10] $\pi = \bar{p}\bar{x}$

[11] Note that $w_H = P_A \frac{\partial Y(H_Y, L, x)}{\partial H_y}$

[12] $\theta = \frac{\alpha}{(1-\alpha-\beta)(\alpha+\beta)}$

3.7 The Root Mean Square Error (RMSE)

Chai & Draxler (2014), define the RMSE as a standard statistical tool used to "measure the performance of the model". Where the RMSE is derived as difference between the actual data and a hypothetical model predicted values, which measures the goodness of the fit of generalized regression models. The Mean Square Error (MSE) helps in knowing whether the average error results from the model or from the randomness of the model. The outcomes of MSE represent the "absolute fit of the model" - represent the standard deviation of unexplained variance. This standard deviation derived is used for error forecasting in the model (Müller, 1987). In this section, we use RMSE since it represents prediction errors in the same units as the data whereas the MSE represent errors in the squared units.

There are three steps to compute RMSE. Firstly, the Error series which is determined as follows:

$$\vartheta_t = \left(g_t - g_t^f\right) \tag{57}$$

Where g_t andg_t^f, are real output growth and forecasted output growth, respectively and ϑ_t denote the standard error of the forecast error of the model. Secondly, the MSE which is the error series squared is determined as follows:

$$\vartheta_t^2 = \left(g_t - g_t^f\right)^2 \tag{58}$$

Eq. (58) is the estimated variance between real output growth and forecasted output growth. Therefore, the RMSE is as follows:

$$\vartheta_{mt} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(g_{t+i} - g_{t+i}^f)^2} \tag{59}$$

Where ϑ_{mt} denote the standard deviation of the RMSE for a specific model.

3.8 Models variables and data sources

3.8.1 Collective Data

The study uses the following variables: GDP, capital stock, interest rate, the depreciation rate, R&D and the population growth. The GDP is constructed as real GDP and capital stock is constructed as capital stock both at national constant prices and are extracted from St. Louis Federal Reserve Database for all the models.

The depreciation rate is extracted from World Bank - WDI data as consumption of fixed capital which denote "replacement value" of the capital stock used in the production function. The data used is in time series for the period of 47 years collected starting in 1970 to 2017, which uses annual data. The database used are: The World Bank - The World Bank Development Indicators (WDI), Organisation for Economic Cooperation and Development (OECD) and Federal Reserve Bank of St. Louis (FRED)

3.8.2 Models variables

3.8.2.1 The Domar model

The savings rate data is extracted as a gross domestic savings which is the difference between GDP and consumption expenditures from the WDI data.

3.8.2.2 The Solow model

The share of capital as a "share of gross capital formation at current purchasing power parities" and the labour share as "the share of labour compensation in GDP at current national prices" both from FRED data. The labour is extracted as the number of people involved in production measured in millions.

3.8.2.3 The extended Solow model

The human capital is extracted from FRED data as an “Index of human capital per person”, which is made up of: Barro & Lee (2013) uses “years of schooling” and Psacharopoulos (1994) uses “returns on education”. Following MRW (1992), the share of human capital is assumed to be equivalent to one third.

3.8.2.4 Goodwin model

The real wage is extracted for OECD Data as a gross wages and salaries paid in any kind and employee’s contributions.

3.8.2.5 The AK Growth model

The population growth is extracted for FRED data as a total population considering their country of origin.

3.8.2.6 Lucas and Romer model

The share of human capital is assumed to be equivalent to 0.87 for all the countries following the study by Nguyen (2009) “Sources of Economic Growth”. We use the fraction of total labour time spent working to denote the fraction of time allocated to knowledge accumulation which is extracted from OECD data as labour force participation rate. The real interest rate is extracted from FRED data as short-term interest rate 90-day rates and Yields Bank Bills. H_A Is extracted from OECD data as number of researchers. The knowledge stock is extracted from OECD data as spending on R&D. Due to incomplete data for interest rates, knowledge stock and number of researchers we do not have results for Brazil and SA - results from a lack of educational data being precise for the developing countries (Greiner, Semmler and Gong, 2016).

4. Results

This examine the relationship between projected output growth and real output growth for the period 1970 to 2017 using the annual data. Firstly, in section 4.1 we run the OLS regression, then in section 4.2 present and examine the parameters of the OLS regression results. In section 4.3 examine the robustness of the regression results in a narrowed sample period 1970 to 2007, in section 4.4 examine the co-movement between the variables using the graphic analysis, in section 4.5 forecast real output growth for in-sample and out-of-sample for one year, two year, and three year forecast time horizons. Lastly, in section 4.6 examine the significance of the standard deviation between model one and model two.

4.1 The Analysis

Following Adak (2009), the econometric analysis depends on linear OLS method. Granger and Newbold (1974) argues that if the OLS regression is ran by non-stationary stochastic process it produces spurious estimates with no economic meaning this occurs when the R squared, and t-ratios are very high. Thus, the OLS model - using a coefficient covariance matrix HAC (Newely-West) will thus be:

$$g_{yt} = \alpha_0 + \alpha_1 \hat{g}_{yt} + e \quad (60)$$

Where g_{yt} denote real output growth (output per capita growth) - defined as dependent variable and $\hat{g}_{yt}$ denote projected output growth (TFP growth) - defined as explanatory variable and e is the error term. In this dissertation series stationarity tests have been implemented using Augmented Dickey Fuller test statistic with Schwartz info Criteria, using the trend and intercept. For all the countries considered the actual output growth, Solow model, Extended Solow model and Domar model test were found to be stationary at level I (0). Therefore, the regression analysis shows that the output is consistent in the long run. The AK model results were consistent except for South Korea were stationarity found at level I (1). Refer to Appendix A.3. for Unit root test and stationarity test.

The regression of real output growth rate on projected output growth rate uses “HAC standard errors and covariance Bartlett kernel, Newey-West fixed” for all the models.

4.2 The Table

4.2.1 Domar model results

Table 1.Estimated parameters of the Domar model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.001	0.01^{***}	0.002	0.01^{*}	0.01^{**}	0.004	0.01^{*}	0.005
	(0.55)	(2.62)	(1.33)	(5.42)	(4.79)	(0.57)	(2.53)	(1.95)
α_1	0.41^{*}	0.62^{*}	0.06^{*}	0.13^{*}	0.06	0.68^{*}	0.43^{*}	0.36^{*}
	(32.19)	(7.71)	(8.02)	(8.38)	(1.34)	(10.99)	(6.19)	(6.97)
R^2	0.92	0.65	0.73	0.59	0.12	0.74	0.70	0.78
SE	0.00	0.02	0.01	0.01	0.02	0.01	0.01	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 1 provide the results of the estimated parameters for Domar model. The impact of projected output growth on real output growth is positive for all the countries for all the countries. Therefore, for Australia if projected output growth increase by 1 percent this leads to an increase in real output growth by 0.41 percent. The same procedure applies to remaining countries. The impact of projected output growth on real output growth is higher for Brazil and South Korea. The value of the coefficient of projected output growth is greater than 0.60 in those countries. The t-statistics reported in parentheses are greater than 2 for a parameter term. As per the rule of thumb if the absolute value of t statistic is greater than 2, therefore it is statistically significant for all the countries except for SA. The standard error of regression is low - which is good for the accuracy of predictions. While the intercept term is statistically significant except for Australia, France and South Korea and the US.

The probabilities in this model is significant at 1 percent for all countries for parameter term and for intercept term only for Germany and the UK, for SA is significant at 5 percent and for Brazil is significant at 10 percent.

The R-squared measures the variance of the real output growth that is explained by a projected output growth. The R-squared results show a good fit of the model with the highest R-squared value of 92 percent for Australia. For all other countries it can be concluded that projected output growth has a high explanation capability on the real output growth, except for SA where it shows the poorest fit of the model of 12 percent.

4.2.2 Solow model results

Table 2.Estimated parameters of the Solow model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.002	-0.001	-0.00003	-0.002	-0.001	0.01^{*}	0.001	-0.001
	(1.59)	(-0.61)	(-0.01)	(-0.89)	(-0.71)	(2.52)	(0.27)	(-0.29)
α_1	0.76^{*}	0.91^{*}	0.86^{*}	0.97^{*}	0.87^{*}	0.78^{*}	0.92^{*}	0.96^{*}
	(11.54)	(40.56)	(12.07)	(9.36)	(11.84)	(9.45)	(8.63)	(7.23)
R^2	0.73	0.96	0.77	0.82	0.80	0.69	0.70	0.73
SE	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 2 provide the results of the estimated parameters for the Solow model. The impact of projected output growth on real output growth is positive for all the countries and statistically significant with a coefficient close to 1. While the intercept term is only statistically significant for South Korea. The probabilities in this model is significant at 1 percent for all the countries parameter term and intercept term is significant at 1 percent for South Korea.

The standard error of regression is low - which is good for the accuracy of predictions. The impact of projected output growth on real output growth is higher for all the countries. The value of the coefficient of projected output growth is greater than 0.75 in those countries. Further, in most of the selected countries, the model fit the data well. This is because the measure of the goodness of fit is greater than 68 percent in all the countries.

4.2.3 Extended Solow model results

Table 3.Estimated parameters of the extended Solow model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.003	0.00^{*}	0.001	-0.001	0.002	0.01^{***}	0.003	-0.001
	(1.98)	(3.49)	(0.73)	(-0.75)	(0.98)	(2.03)	(0.86)	(-0.63)
α_1	0.80^{**}	0.88^{*}	0.91^{*}	1.05^{*}	0.86^{*}	0.71^{*}	0.93^{*}	1.12^{*}

	(11.05)	(34.51)	(12.34)	(13.01)	(10.62)	(5.23)	(8.20)	(15.79)
R^2	0.76	0.95	0.77	0.87	0.78	0.45	0.69	0.91
SE	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 3 provide the results of the estimated parameters for extended Solow model. We also find positive and significant impact of projected output growth on real output growth for all the countries. As for Germany and USA if projected output growth increase by 1 percent this leads to an increase in real output growth by 1.05 percent and by 1.12 percent, respectively.

The impact of projected output growth on real output growth is higher for all the countries. The value of the coefficient of projected output growth is greater than 0.79 in those countries. The probabilities in this model is significant at 1 percent for all countries for parameter term, except Australia which is significant at 5 percent. For intercept term is significant at 1 percent for Brazil and significant at 10 percent for South Korea.

The R-squared results show that projected output growth has a high explanation capability of real output growth. Except, for South Korea were the value is 45 percent. The standard error of regression is low - which is good for the accuracy of predictions.

4.2.4 Goodwin model results

Table 4.Estimated parameters of the Goodwin model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.03^*	0.02^*	0.02^*	0.02^*	0.02^*	0.05^*	0.02^{**}	0.02^*
	(24.12)	(7.72)	(7.80)	(7.44)	(6.80)	(9.49)	(7.87)	(11.81)
α_1	1.57^*	4.92^*	1.93^*	2.30^*	0.70^*	1.33^*	2.46^*	2.23^*
	(8.43)	(9.25)	(6.04)	(8.94)	(3.60)	(4.48)	(10.03)	(19.91)
R^2	0.67	0.80	0.38	0.66	0.12	0.57	0.71	0.80
SE	0.01	0.01	0.01	0.01	0.02	0.03	0.01	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 4 provide the results of the estimated parameters for Goodwin model. The model coefficients are positive and statistically significant. We see that if projected output growth increase by 1 percent this leads to an increase in real output growth by more than 1 percent, except for SA were real output growth increase by 0.70 percent. The impact of projected output growth on real output growth is higher for all the countries. The value of the coefficient of projected output growth is greater than 0.70 in those countries. The probabilities in this model are significant at 1 percent for all countries for both parameter term and intercept term.

The R-squared results shows a good fit of the model - except for France with 38 percent and SA with 12 percent which has the lowest explanatory capability on the economic growth. The standard error of regression is low - which is good for the accuracy of prediction.

4.2.5 The AK model results

Table 5.Estimated parameters of the AK model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
$\boldsymbol{\alpha_0}$	0.01^{**}	0.04^{*}	0.003	-0.01	0.02^{*}	0.04^{*}	0.01^{*}	0.004
	(2.04)	(3.72)	(0.57)	(-0.67)	(4.38)	(3.09)	(2.19)	(-0.93)
$\boldsymbol{\alpha_1}$	0.21^{**}	-0.23^{***}	0.49^{*}	0.54^{*}	0.20^{*}	0.32^{**}	0.38^{*}	0.72^{*}
	(1.84)	(-1.25)	(3.99)	(3.64)	(2.86)	(2.31)	(3.52)	(12.46)
$\boldsymbol{R^2}$	0.17	0.03	0.24	0.33	0.15	0.18	0.24	0.69
$\boldsymbol{SE}$	0.01	0.04	0.01	0.02	0.02	0.03	0.02	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 5 provide the results of the estimated parameters of the AK model. We also find significant impact of projected output growth on real output growth except for Australia and Brazil - only the intercept term is significant. The estimated responses of real output growth to projected output growth for Brazil has a negative coefficient of -0.23 -means no explanatory power. The impact of projected output growth on real output growth is low except for France, Germany, and USA. The probabilities in this model for parameter term are significant at 1 percent for France, Germany, SA, the UK, and USA, at 5 percent for Australia and South Korea and at 10 percent for Brazil. For intercept term the probabilities in this model are significant at 1 percent for Brazil, SA, South Korea, and the UK and at 5 percent for Australia. The R-squared results shows poor fit of the model overall - except for USA with 69 percent. The standard error of regression is low - which is good for the accuracy predictions.

4.2.6 Lucas model results

Table 6.Estimated parameters of the Lucas model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.03^*	0.03^*	0.02^*	0.02^*	0.02^*	0.07^*	0.02^*	0.03^*
	(17.43)	(4.75)	(6.48)	(6.74)	(7.03)	(8.57)	(5.47)	(12.83)
α_1	2.20^*	7.36^*	2.07^*	1.83^*	2.41^*	1.76^*	3.21^*	4.18^*
	(4.68)	(4.02)	(2.74)	(3.23)	(5.87)	(4.62)	(3.82)	(16.19)
R^2	0.47	0.40	0.17	0.18	0.24	0.25	0.29	0.67
SE	0.01	0.03	0.02	0.02	0.02	0.03	0.02	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 6 provide the results of the estimated parameters for Lucas model. The model coefficients are positive and significant. We see that if projected output growth increase by 1 percent this leads to an increase in real output growth by more than 1 percent for all the countries. The impact of projected output growth on real output growth is high for all the countries. The value of the coefficient of projected output growth is greater than 1.75 in those countries - this is the greatest impact compared to other models. Furthermore, intercept term and the parameter term are significant at 1 percent and the standard error of regression is low.

The model fit the data well for Brazil with 40 percent, Australia with 47 percent, and USA with 67 percent only. The Lucas model predicts positive impact in all the countries and when compared to the AK model and fits the data much better than the AK model.

4.2.7 Romer model results

Table 7.Estimated parameters of the Romer model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.03^*	-	0.02^*	0.02^*	-	0.04^*	0.02^*	0.03^*
	(15.79)	$(-)$	(6.89)	(5.10)	-	(9.41)	(5.08)	(7.52)
α_1	-0.16	-	-0.33	-0.02	-	0.57	-0.13	-0.33
	(-1.13)	$(-)$	(-1.16)	(-0.36)	-	(1.23)	(-0.60)	(-1.58)
R^2	-0.004	-	0.04	-0.03	-	0.17	-0.01	0.04

SE	0.01	-	0.01	0.02	-	0.03	0.02	0.02

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 7 provide the results of the estimated parameters for Romer model. The impact of projected output growth on real output growth is negative for all the countries and not statistically significant on the sample data. However, for South Korea the impact is positive. We see that if projected output growth increase by 1 percent this leads to a decrease in real output growth by, except for South Korea which increases real output growth 0.57 percent. The probabilities in this model for parameter term is significant at 10 percent for all the countries. Where, the number of observations for Australia amount to 46, France amount to 35, Germany amount to 35, South Korea amount to 22, the UK amount to 37 and US amount to 35. However, the parameter term is insignificant. For intercept term the probabilities in this model are significant at 1 percent for all the countries considered and the standard error of regression is low

In all the countries, the explanatory power of the model is near zero. This implies that the model does not fit the data. Therefore, it can be concluded that Romer model performs poor than the other models.

4.2.8 Summary of the table results

This section briefly summarizes the results for the estimated parameters for seven growth models namely: Domar, Solow, extended Solow, Goodwin, the AK, Lucas and Romer models. The results show that Solow model, the extended Solow model, Goodwin's model, and Lucas model all predict positive and significant impact of estimated growth rate of output on real output growth rate of output. For Domar model, the parameter term is significant, and the model predict a positive impact on projected output growth, except for SA.

The AK model also predict positive and significant impact of projected output growth except for insignificant impact (Australia and Brazil) and negative impact for Brazil. While the coefficients of determination are high for the, Solow, the extended Solow, Goodwin, and Lucas models, they are very low for the AK and Romer models with the lowest coefficient of determination of -0.23 for Brazil when the AK model is considered and -0.33 for France and USA when Romer model is considered.

The Romer model predict in most cases negative impact of projected output growth on real output growth and the AK only predict a negative case for Brazil but the coefficient is not significant. The only positive impact that is observed with the Romer model was in South Korea, but the coefficient is not significant.

If we were to rank these growth models, the top three models that describe better the impact of projected output growth on real output growth are the extended Solow model, Solow model and Goodwin model. Domar model and Lucas model perform better than the AK model and Romer model.

4.3 Robustness checks

The robustness check uses equation Eq. (60) for the pre - global financial crisis sample period from 1970-2007 before the great recession impact to examine the sensitivity of the parameters. Following the study by Masanjala and Papageorgiou, (2004) in their study replaced the production function with constant elasticity of substitution for Solow model and the extended Solow model, their robustness checks attempt to validate the reliability of the results on the extended period of the original sample by a decade. We examine the robustness of the parameters after the sample reduction for Domar, Solow and the extended Solow, Goodwin, the AK, Lucas and Romer models.

4.3.1 Domar model results

Table 8.Robustness Check: Estimated parameters of the Domar model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.001	0.01^{***}	0.002	0.01^{*}	0.02^{*}	0.00^{***}	0.00	0.001
	(0.99)	(2.17)	(0.67)	(2.37)	(4.05)	(2.56)	(1.10)	(1.05)
α_1	0.41^{*}	0.63^{*}	0.51^{*}	0.26^{*}	0.05	0.65^{*}	0.59^{*}	0.46^{*}
	(31.75)	(6.07)	(5.88)	(3.52)	(1.24)	(13.05)	(7.47)	(31.70)
R^2	0.94	0.56	0.67	0.54	0.10	0.83	0.74	0.95
SE	0.00	0.03	0.01	0.01	0.02	0.02	0.01	0.00

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 8 provide the robustness results check of the estimated parameters for Domar model. The result for the pre-financial crisis still shows that the model is significant for the parameter term and with a high projected output growth has a high explanation capability on the economic growth except for SA. Therefore, the significant and explanatory capability of variables in the robustness checks yield the same outcomes to that of the full sample period. The results show a slight difference at t-static for the intercept and parameter term and the R squared.

4.3.2 Solow model results

Table 9.Robustness Check: Estimated parameters of the Solow model

	Aus	Bra	Fra	Ger	SA.	SK.	UK	USA
α_0	0.002	-0.001	0.002	0.0002	-0.001	0.02^*	0.003	-0.002
	(1.36)	(-0.42)	(1.19)	(0.09)	(-0.34)	(3.02)	(0.54)	(-0.62)
α_1	0.79^*	0.91^*	0.80^*	0.87^*	0.86^*	0.72^*	0.85^*	1.04^*
	(11.28)	(37.43)	(15.79)	(7.78)	(10.96)	(7.39)	(5.67)	(5.82)
R^2	0.74	0.96	0.75	0.77	0.79	0.65	0.60	0.50
SE	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 9 provide the robustness results check of the estimated parameters for Solow model. The impact of projected output growth on real output growth is positive for all the countries and statistically significant with a coefficient close to 1.

4.3.3 Extended Solow model results

Table 10.Robustness Check: Estimated parameters of the extended Solow model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA

α_0	0.003	0.003^{***}	0.003	0.0005	0.002	0.02	0.005	-0.001
	(1.80)	(2.49)	(1.89)	(0.24)	(0.68)	(1.87)	(1.02)	(-0.75)
α_1	0.82^{*}	0.87^{*}	0.84^{*}	0.95^{*}	0.86^{*}	0.64^{*}	0.84^{*}	1.13^{*}
	(11.00)	(33.66)	(16.12)	(11.78)	(10.02)	(3.61)	(5.51)	(15.28)
R^2	0.78	0.95	0.74	0.81	0.77	0.32	0.59	0.92
SE	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01

* Significant at 1%, ** Significant at 5%, *** Significant at 10% and () denote t-statistics

Table 10 provide the robustness results check of the estimated parameters for extended Solow model. We also find significant impact of projected output growth on real output growth, for USA if projected output growth increase by 1 percent this leads to an increase in real output growth by 1.13 percent.

4.3.4 Goodwin model results

Table 11.Robustness Check: Estimated parameters of the Goodwin model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
α_0	0.03^{*}	0.02^{*}	0.03^{*}	0.02^{*}	0.02^{*}	0.06^{*}	0.02^{**}	0.03^{*}
	(22.21)	(4.12)	(8.02)	(7.48)	(5.61)	(9.56)	(8.47)	(20.03)
α_1	1.70^{*}	2.74^{*}	1.63^{*}	2.12^{*}	0.65^{*}	1.19^{*}	2.26^{*}	2.22^{*}
	(10.41)	(2.13)	(6.31)	(6.49)	(3.44)	(3.54)	(11.14)	(31.63)
R^2	0.75	0.16	0.28	0.52	0.11	0.54	0.69	0.90
SE	0.01	0.02	0.01	0.01	0.02	0.03	0.01	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 11 provide the robustness results check of the estimated parameters for Goodwin model. Projected output growth coefficient is positive and statistically significant for both the intercept term and the parameter term. We see that for 1 percent increase in projected output growth increases real output growth by more than 1 percent. However, for SA real output growth increase by 0.65 percent. The intercept term and the parameter term are still significant at 5 percent.

4.3.5 The AK model results

Table 12.Robustness Check: Estimated parameters of the AK model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
$\boldsymbol{\alpha_0}$	0.01	0.04^{*}	0.01^{*}	0.001	0.02^{*}	0.05^{*}	0.02^{*}	0.0002
	(1.41)	(3.80)	(3.11)	(0.16)	(3.82)	(3.43)	(3.15)	(0.06)
$\boldsymbol{\alpha_1}$	0.24	-0.18	0.35^{*}	0.48^{*}	0.21^{*}	0.33^{***}	0.33^{**}	0.70^{*}
	(1.60)	(-1.12)	(4.66)	(3.18)	(2.74)	(2.22)	(3.16)	(13.96)
$\boldsymbol{R^2}$	0.18	0.01	0.12	0.26	0.16	0.23	0.21	0.78
$\boldsymbol{SE}$	0.01	0.04	0.01	0.01	0.02	0.03	0.02	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 12 provide the robustness results check of the estimated parameters for the AK model. We also find significant impact of projected output growth on real output growth except for Australia (includes the intercept term) and Brazil. The estimated responses of real output growth to projected output growth for Brazil has a negative coefficient-no explanatory power.

4.3.6 Lucas model results

Table 13.Robustness Check: Estimated parameters of the Lucas model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
$\boldsymbol{\alpha_0}$	0.03^{*}	0.03^{*}	0.03^{*}	0.02^{*}	0.03^{*}	0.08^{*}	0.02^{*}	0.03^{*}
	(13.85)	(3.79)	(8.26)	(7.23)	(6.33)	(10.82)	(6.28)	(9.99)
$\boldsymbol{\alpha_1}$	2.23^{*}	7.00^{*}	1.79^{*}	1.47^{*}	2.47^{*}	1.81^{*}	2.92^{*}	3.99^{*}
	(4.12)	(2.77)	(2.14)	(3.26)	(6.28)	(4.17)	(3.69)	(9.84)
$\boldsymbol{R^2}$	0.46	0.30	0.18	0.18	0.26	0.33	0.29	0.58
$\boldsymbol{SE}$	0.01	0.03	0.01	0.02	0.02	0.03	0.02	0.01

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 13 provide the robustness results check of the estimated parameters for Lucas model. The impact of projected output growth on real output growth is positive for all the countries and statistically significant and even for intercept term. We see that if projected output growth increase by 1 percent this leads to an increase in real output growth by more than 1 percent for all the countries. Furthermore, intercept term and the parameter term are significant at 1 percent.

4.3.7 Romer model results

Table 14.Robustness Check: Estimated parameters of the Romer model

	Aus	Bra	Fra	Ger	SA	SK	UK	USA
$\boldsymbol{\alpha_0}$	0.03^*	-	0.02^*	0.02^*	-	0.05^*	0.02^*	0.03^*
	(14.53)	$(-)$	(7.73)	(5.30)	$(-)$	(8.99)	(10.14)	(9.41)
$\boldsymbol{\alpha_1}$	-0.23	-	-0.10	0.12	-	0.60	0.07	-0.27
	(-1.69)	$(-)$	(-0.73)	(0.85)	$(-)$	(1.15)	(0.37)	(-1.01)
$\boldsymbol{R^2}$	0.01	-	-0.03	-0.02	-	0.19	-0.03	0.03
$\boldsymbol{SE}$	0.02	-	0.01	0.02	-	0.03	0.02	0.02

***, **, * denote significant at 10%, 5% &1% and () denote t-statistics

Table 14 provide the robustness results check of the estimated parameters for Romer model. The impact of projected output growth on real output growth is negative for Australia, France, and USA and positive for Germany, South Korea, and the UK. However, the parameter term is insignificant for all the considered countries. In full sample regression, South Korea is the only country where impact of projected output growth on real output growth is negative. The intercept term is statistically significant except for all the countries. In all the countries, the explanatory power of the model is near zero. This implies a bad fit of the model data.

4.3.8 Summary of the table results

For the pre global financial crisis period 1970-2007, the standard error remains low as in the full sample size, the R-squared relative change by a smaller percentage relative to the full sample size. In Goodwin model for Brazil we noticed drastic change in R-squared from 80 percent for the full sample period to 16 percent for the pre global financial crisis whereas amounts to the level of significant remains the same for almost all the models. The results show that Solow model, the extended Solow model, Goodwin's model and Lucas model all predict positive and significant impact of estimated growth rate of output on real output growth rate - the same results to that of the full sample size. However, for Romer model the results show that the impact of projected output growth on real output growth is negative for Australia, France, and the US and positive for Germany. Whereas for full sample the negative impacted the US, the UK, Australia, Germany, and France, and therefore, for Germany the negative impact on the full sample is not robust.

4.4 Output growth rate and projected output growth rate

4.4.1 Domar model

Figure 1. Projected output growth of the Domar model results

Figure1 provide a graphic interpretation of real output growth rate against projected output growth rate using Domar model in 8 diverse countries. The results show that real output growth and projected output growth trails the same manner for the entire period of analysis. Furthermore, if projected output growth rises, real output growth also take impetus and conversely.

In 1971, Australia reported 9.9 percent in projected output growth which resulted in relatively lower 3.8 percent of real output growth. However, in 1982 projected output growth dipped into -5.9 percent which drug down real output growth to -2.3 percent - found to be lowest growth for the successive period of analysis The great recession (2007 to 2009) also affected projected output growth from 7.5 percent to 4.3 percent then followed by real output growth from 3.6 percent to 1.9 percent. The relationship among projected output growth and per capita growth pattern amounts to 50.62 percent, which implies a moderate degree of correlation.

In 1971, Brazil reported 7.3 percent in projected output growth which resulted in relatively higher 10.7 percent of real output growth. During 1985, they reported 14.50 percent of projected output growth followed by the relatively lower 7.60 percent real output growth- found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 10.90 percent to -0.2 percent then followed by real output growth from 5.90 percent to 0.02 percent. The relationship among projected output growth and per capita growth amounts to 80.80 percent, this implies a high degree of correlation.

In 1971, France reported 6.17 percent in projected output growth which resulted in relatively lower 5.18 percent of real output growth. During 1998, they reported 9.61 percent projected output growth which resulted in relatively lower 3.53 percent of real output growth - found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 5.51 percent to -8.66 percent followed by real output growth from 2.40 percent to -2.92 percent - was found to be lowest growth for the successive period of analysis. The coefficient of correlation between projected output growth and per capita growth amounts to 85.50%, this indicates high degree of correlation.

In 1971, Germany reported 4.5 percent in projected output growth which resulted in the same percentage of real output growth. The great recession (2007 to 2009) affected projected output growth from 18 percent to -58 percent then followed by real output growth from 3 percent to -6 percent - found to be lowest growth for the successive period of analysis. During 2010, they reported 6.8 percent projected output growth which resulted in 7 percent higher real output growth-projected output growth found to be highest growth for the successive period of analysis. The correlation coefficient between projected output growth and per capita growth amounts to 77.57 percent, which implies a high degree of correlation.

In 1971, SA reported 5 percent in projected output growth which resulted in the same real output growth. Then the great recession (2007 to 2009) affected projected output growth from 0.8 percent to -2 percent then followed by real output growth from 5 percent to -2 percent - real output growth found to be lowest growth for the successive period of analysis. The relationship among projected output growth and per capita growth amounts to 37.85 percent, which implies a low degree of correlation.

South Korea, in 1971 they reported 9 percent in projected output growth which resulted in relatively higher 9.9 percent of real output growth. During 1998, they reported -11.5 percent projected output growth which resulted in relatively 5.6 percent lower real output growth - found to be lowest growth for the successive period of analysis because of the Asian financial crisis. Then the great recession (2007 to 2009) affected projected output growth from 9.9 percent to 1.5 percent then followed by real output growth from 5.3 percent to 0.7 percent. The coefficient of correlation between projected output growth and per capita growth is 86.60 percent, which implies a high degree of correlation.

For the UK, in 1971 they reported 3 percent in projected output growth which resulted in relatively higher 3.4 percent of real output growth. During 1997, they reported 9.7 percent of projected output growth which resulted which resulted in relatively lower 4.2 percent of real output growth - found to be highest growth for the successive period of analysis. The great recession (2007 to 2009) affected projected output growth from 4.8 percent to -16.3 percent then real output growth then followed by real output growth from 2.5 percent to -4.3 percent. The relationship among projected output growth and real output growth pattern amounts to 83.92 percent, which implies a high degree of correlation.

For USA, in 1971 they reported 6.4 percent in projected output growth which resulted in relatively higher 3.2 percent real output growth. During 1984, they reported 13.9 percent projected output growth followed by the relatively lower 7 percent real output growth - found to be highest growth for the successive period of analysis growth for the successive period of analysis. The great recession (2007 to 2009) affected projected output growth from 4.4 percent to -13.2 percent then real output growth then followed by real output growth from 1.9 percent to -2.6 percent. The relationship among projected output growth and real output growth pattern amounts to 88.31 percent, which implies a high degree of correlation.

Therefore, the great recession affected both the per capita output and projected output growth badly in 2009 since most countries reported a negative growth in both. The degree of correlation in this model shows a great interdependence of real output growth and projected output growth. However, for SA the variables are weakly linearly related.

4.4.2 Solow model

Figure 2. Projected output growth of the Solow model results

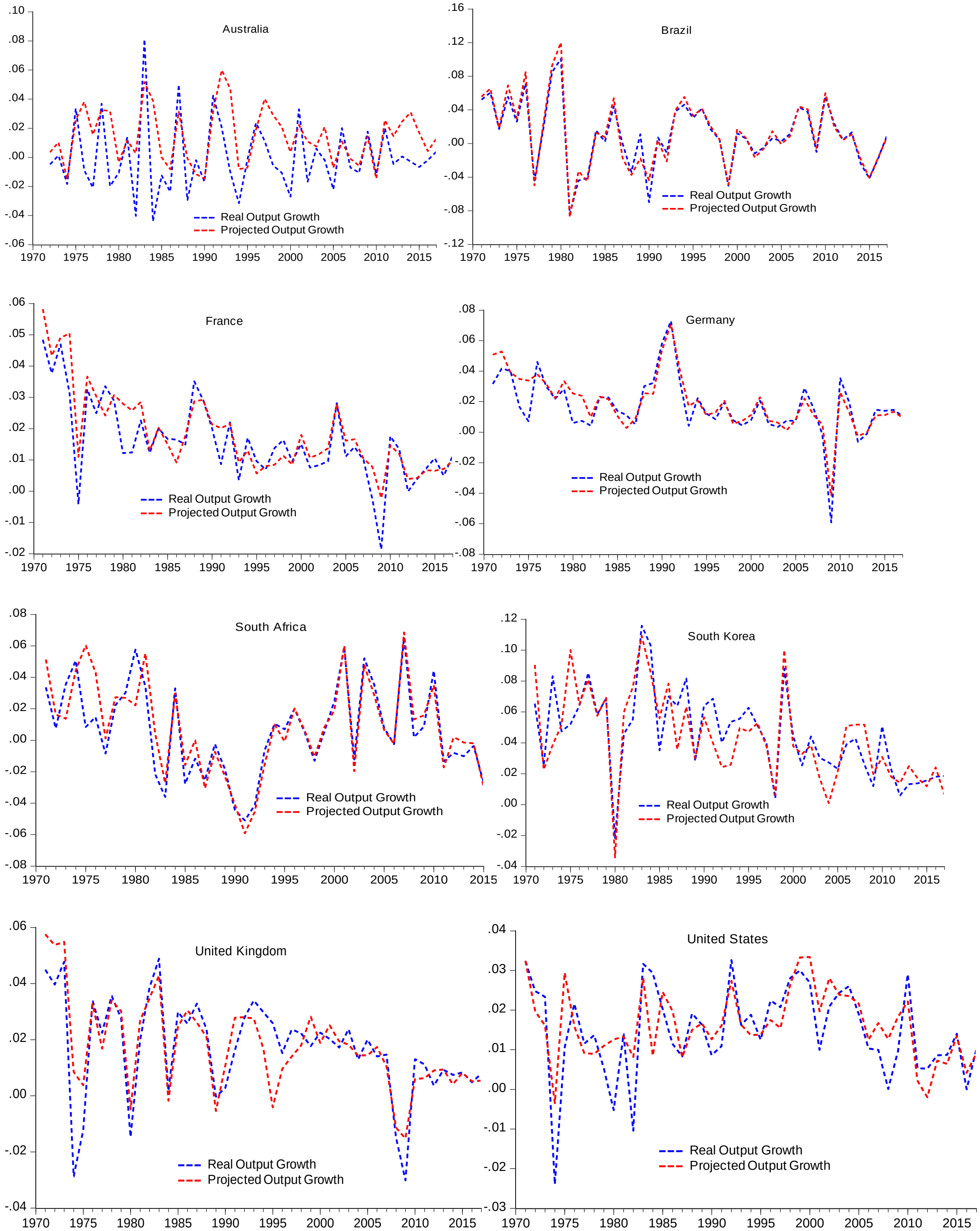


Figure 2 provide a graphic interpretation of real output growth rate against projected output growth rate using Solow model in 8 diverse countries. The results show that real output growth and projected output growth trails the same manner for the entire period of analysis. Furthermore, if projected output growth rises, real per capita GDP growth also takes impetus and conversely.

In 1972, Australia reported 0.4 percent in projected output growth which resulted in relatively lower -0.5 percent of real output growth. During 1983, they reported -5.2 percent of projected output growth which resulted in relatively highly 8.1 percent of per capita output - found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from -0.1 percent to 1.5 percent which followed by real output growth from -0.1 percent to 1.8 percent which made real output growth. The relationship among projected output growth and the per capita growth pattern amounts to 85.75 percent, which implies a high degree of correlation.

In 1971, Brazil reported 5.6 percent in projected output growth which resulted in relatively lower 5.2 percent of real output growth. During 1980, they reported -12 percent of projected output growth which resulted in relatively highly 10.1 percent of per capita output - found to be highest growth for the successive period of analysis. However, in 1981 they reported a huge drop to -8.8 percent of projected output growth which resulted in relatively highly 8.4 percent of per capita output - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 4.4 percent to -0.5 percent which resulted in the same percentage change for real output growth. The relationship among projected output growth and the per capita growth amounts to 97.99 percent, which implies a high degree of correlation.

In 1971, France reported 5.8 percent in projected output growth which resulted in relatively lower 4.8 percent of real output growth - found to be highest growth for the successive period of analysis. However, in 1974 projected output growth dramatically fell to 1.2 percent followed by relatively lower -0.3 percent of projected output growth, then recovered in 1976 to 3.7 percent followed by 3.3 percent, respectively. Then the great recession (2007 to 2009) affected projected output growth from 10 percent to -0.2 percent resulted in real output growth from 10 percent to -1.9 percent - found to be lowest growth for the successive period of analysis. The relationship among projected output growth and the per capita growth pattern amounts to 87.92 percent, which implies a high degree of correlation.

For Germany, in 1971 they reported 5.1 percent projected output growth which resulted in relatively lower 3.2 percent real output growth. During 1991, they reported 7.3 percent projected output growth followed by relatively lower 7.1 percent real output growth- found to be highest growth for the successive period of analysis. However, the great recession (2007 to 2009) affected projected output growth from 1.1 percent to -4.2 percent then followed by real output growth and from 1.1 percent to -5.9 percent. Furthermore, year 2009 - found to be lowest growth for the successive period of analysis. The relationship among projected output growth and the per capita growth pattern amounts to 90.58 percent, which implies a high degree of correlation.

For SA initially in 1971, reported 5.1 percent in projected output growth which resulted in relatively lower 3.4 percent of real output growth. During 1991, they reported -5.9 percent growth of estimated GDP resulted in higher -5.1 percent real output growth- found to be lowest growth for the successive period of analysis. Contrary, during 2007 they reported 6.9 percent growth of projected output growth which resulted in the same percent real output growth- found to be highest growth for the successive period of analysis. The Great Recession (2007 to 2009) affected projected output growth from 6.9 percent to 1.6 percent then followed by real output growth from 6.9 percent to 0.9 percent. The relationship among projected output growth and the per capita growth pattern amounts to 89.54 percent, which implies a high degree of correlation.

In 1970, South Korea reported 9 percent in projected output growth which resulted in relatively lower 6.5 percent of real output growth. However, during 1980, they reported -3.4 percent growth of projected output growth resulted in lower -2.2 lower percent real output growth- found to be lowest growth for the successive period of analysis of projected output growth. Contrary, during 1983, they reported 10.9 percent projected output growth followed by the relatively higher 11.6 percent real output growth- found to be highest growth for the successive period of analysis of estimated output growth. Then the great recession (2007 to 2009) affected projected output growth from 5.2 percent to 2 percent then followed by real output growth and from 4.3 percent to 1.2 percent. The relationship among projected output growth and the per capita growth pattern amounts to 83 percent, which implies a high of correlation.

In 1971, the UK reported 5.8 percent in projected output growth which resulted in relatively lower 4.5 the same percent of real output growth - found to be highest growth for the successive period of analysis. However, the great recession (2007 to 2009) affected estimated output growth 10 percent to -1.5 percent then followed by real output growth and from 15 percent to -3 percent, found to be lowest growth for the successive period of analysis. The relationship between projected output growth and real growth per capita pattern amount to 83.48 percent, which implies a high degree of correlation.

In 1973, the US reported 3.2 percent in projected output growth which resulted in in the 2.4 lower percent of real output growth - found to be highest growth for the successive period of analysis for projected output growth. However, in 1974 projected output growth dipped to -0.3 percent which dragged real output growth down to -2.4 percent - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 1.7 percent to 1.8 percent then followed by real output growth from 1 percent to 1 percent. The relationship between projected output growth and per capita growth pattern amounts to 73.07 percent, which implies a high degree of correlation.

Therefore, it can be said that great depression affected both the per capita output and projected output growth badly in 2009 since all the countries reported a negative or the lowest growth in projected output growth and real output growth in all eight countries. The relationship between projected output growth and per capita growth pattern for all the countries shows a high degree of correlation.

4.4.3. The extended Solow model

Figure 3. Projected output growth of the extended Solow model results

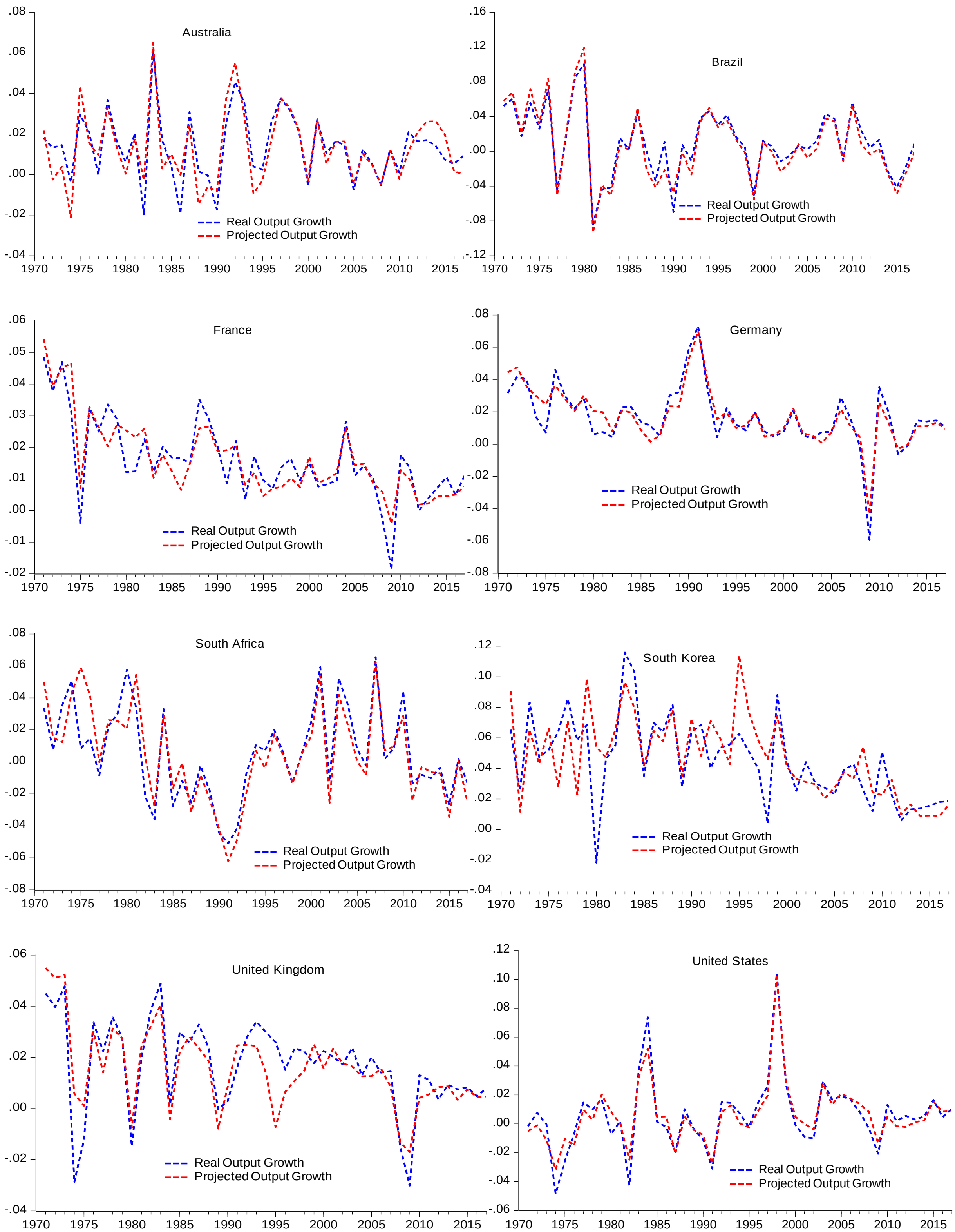


Figure 3 provide a graphic interpretation of real output growth rate against projected output growth rate using extended Solow model in 8 diverse countries. The results show that real output growth and projected output growth trails the same manner for the entire period of analysis. Furthermore, if projected output growth rises, real per capita GDP growth also takes impetus and conversely.

In 1971, Australia qualified 2.2 percent in projected output growth which resulted in relatively lower 1.8 percent of real output growth. During 1983, they reported 6.5 percent growth of projected output growth followed by 6.1 percent real output growth- found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 0.5 percent to 1.2 percent which resulted in the same percentage change of real output growth. The relationship between projected output growth and the per capita growth pattern amounts to 87.29 percent, which implies a high degree of correlation.

In 1971, Brazil reported 5.8 percent in projected output growth which resulted in relatively lower 5.2 percent of real output growth. During 1980, they reported 11.9 percent growth of projected output growth followed by relatively lower 10.9 percent real output growth- found to be highest growth for the successive period of analysis. However, in 1981 they reported -9.3 percent growth of projected output growth followed relatively higher -8.4 percent real output growth- found to be lowest growth for the successive period of analysis.

Then the great recession (2007 to 2009) affected projected output growth from 3.5 percent to -10 percent which followed by real output growth from 4.3 percent to -10 percent which made real output growth. The relationship between projected output growth and the per capita growth pattern amounts to 97.62 percent, which implies a high degree of correlation.

For France, in 1971 they reported 5.4 percent in projected output growth which resulted in relatively lower 4.8 percent of real output growth - found to be highest growth for the successive period of analysis. However, the great recession (2007 to 2009) affected projected output growth from 10 percent to -0.4 percent resulted in real output growth from 10 percent to -1.9 percent - found to be lowest growth for the successive period of analysis. The relationship between projected output growth and the per capita growth pattern amounts to 88.07 percent, which implies a high degree of correlation.

For Germany, in 1971 they reported 4.4 percent projected output growth followed by the relatively lower 3.2 percent growth of per capita output. During 1991, they reported 7 percent projected output growth followed by relatively higher 7.3 percent real output growth- found to be highest growth for the successive period of analysis. However, the great recession (2007 to 2009) affected projected output growth from 1.1 percent to -4.3 percent then followed by real output growth and from 1.1 percent to -5.9 percent. Furthermore, year 2009 - found to be lowest growth for the successive period of analysis. The relationship between projected output growth and the per capita growth pattern amounts to 93.44 percent, which implies a high degree of correlation.

For SA, in 1971 they reported 5 percent in projected output growth which resulted in relatively lower 3.4 percent of real output growth. During 1991, they reported -6.2 percent projected output growth followed by the relatively lower -5.1 percent real output growth- found to be lowest growth for the successive period of analysis. However, the Great Recession (2007 to 2009) affected projected output growth from 6.2 percent to 0.7 percent then followed by real output growth and from 6.5 percent to 0.9 percent - the year 2007 is found to be highest growth for the successive period of analysis. The relationship between projected output growth and the real output growth pattern amounts to 88.57 percent, which implies a high degree of correlation.

For South Korea, in 1971 they reported 9.1 percent in projected output growth which resulted in relatively lower 6.5 percent of real output growth. During 1983, they reported 9.8 percent projected output growth followed by the relatively higher 11.6 percent real output growth- real output growth found to be highest growth for the successive period of analysis. However, during 1980, they reported -8.9 percent projected output growth followed by the relatively -2.3 percent real output growth- found to be lowest growth for the successive period of analysis of projected output growth. Then the great recession (2007 to 2009) affected projected output growth from 4.3 percent to 2.4 percent then followed by real output growth and from 4.3 percent to 1.2 percent. The relationship between projected output growth and the per capita growth pattern amounts to 68.31 percent, which implies a high degree of correlation.

For the UK, initially in 1971 they reported 3.4 percent in projected output growth which resulted in the same percent of real output growth - projected output growth found to be highest growth for the successive period of analysis. During 1983, projected output growth rose to 4.1 percent which dragged real output growth up to 4.9 percent - real output growth found to be highest growth for the successive period of analysis. Contrary, then the great recession (2007 to 2009) affected projected output growth from 0.9 percent to -1.7 percent then followed by real output growth and from 1.5 percent to -3 percent - found to be lowest growth for the successive period of analysis. The relationship between projected output growth and per capita growth pattern amount to 83.25 percent, which implies a high degree of correlation

For the US, initially in 1971 they reported -0.5 percent in projected output growth which resulted in relatively lower -0.2 percent of real output growth. During 1974, projected output growth dipped to -3.2 percent which dragged real output growth down to -4.8 percent - found to be highest growth for the successive period of analysis. Contrary, in 1998, they reported 10.1 percent projected output growth followed by the relatively higher 10.4 percent higher real output growth- found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 1.4 percent to -1.3 percent then followed by real output growth from 0.8 percent to -2.1 percent. The relationship between projected output growth and per capita growth pattern amounts to 95.58 percent, which implies a high degree of correlation.

Therefore, it can be said that great depression affected both the per capita output and projected output growth badly in 2009 since for most countries reported a negative growth in both projected output growth and real output growth. The degree of correlation between projected output growth and real output growth are high which shows a strong relationship between them.

4.4.4 The Goodwin model

Figure 4. Projected output growth of the Goodwin model results

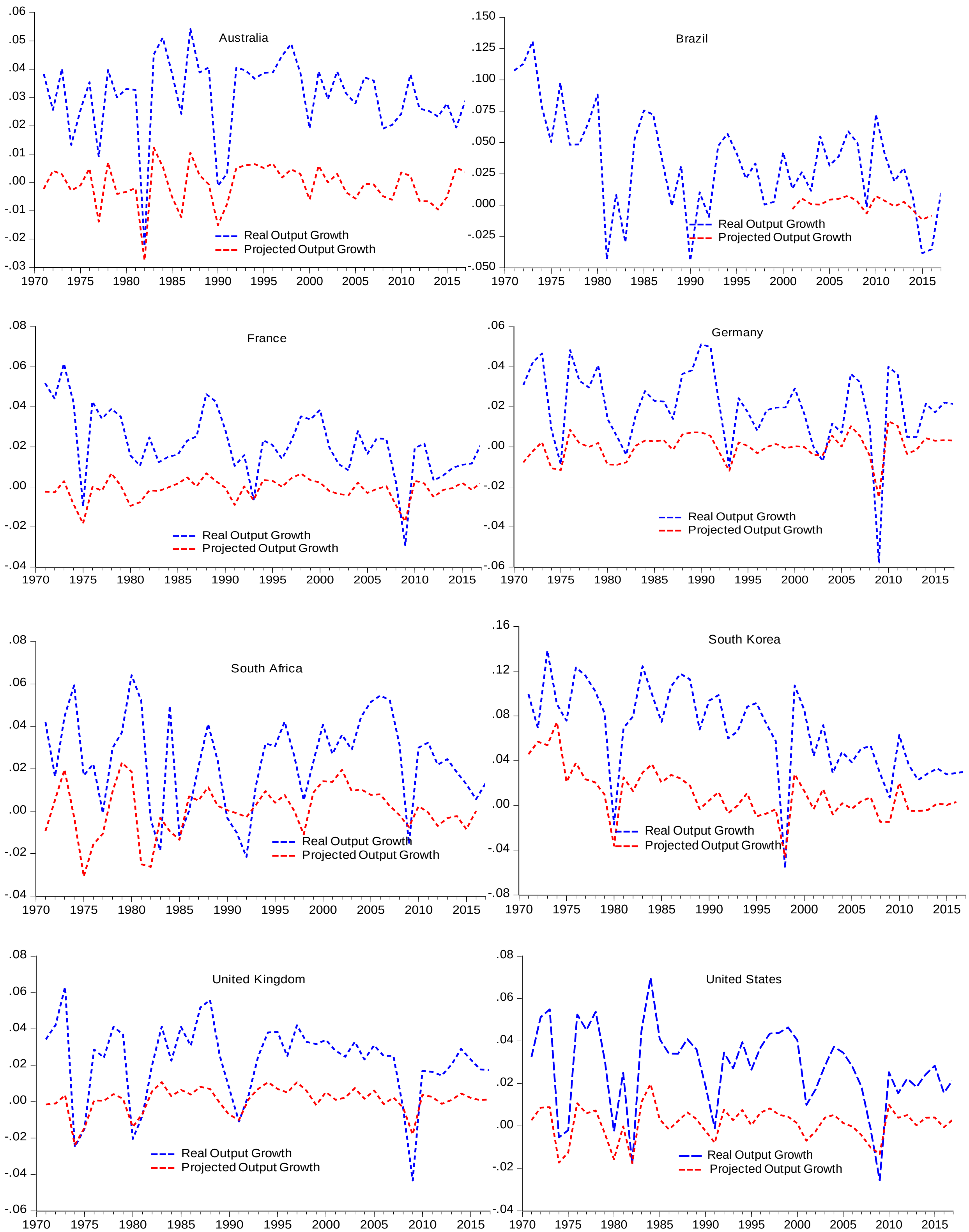


Figure 4 provide a graphic interpretation of real output growth rate against projected output growth rate using Goodwin model in 8 diverse countries. The results show that real output growth and projected output growth trails the same manner for the entire period of analysis. Furthermore, if projected output growth rises, real per capita GDP growth also takes impetus and conversely. However, the co-movement is weak in graphically explanation compared to the ones in Solow, extended Solow and Domar model.

In 1971, Australia reported -0.2 percent in projected output growth which resulted in higher 3.8 percent of real output growth. During 1982 estimated GDP projected output growth dipped to -2.8 percent which dragged real output growth down to -2.3 percent - found to be lowest growth for the successive period of analysis. Then great recession (2007 to 2009) affected projected output growth from -0.1 percent to -0.6 percent, which made real output growth from 3.6 percent to 2.0 percent. The relationship between projected output growth and real output growth pattern amounts to 27.93 percent, which implies a low degree of correlation.

For Brazil we reported a data limitation issue. The great recession (2007 to 2009) affected projected output growth from 7.5 percent to -0.67 percent, which made real output growth from 5.89 percent to -1.3 percent. The relationship between projected output growth and real output growth pattern amounts to 24.06 percent, which implies a low degree of correlation.

For France in 1971, they reported -0.2 percent in projected output growth, which resulted in relatively higher 5.2 percent of per capita, output growth. In the following year, they reported 0.3 percent growth of projected output growth followed by the relatively higher 6.2 percent real output growth- found to be highest growth for the successive period of analysis. Then great recession (2007 to 2009) affected projected output growth from 0 percent to -1.7 percent, which made real output growth from 2.4 percent to -2.9 percent. The relationship between projected output growth and real output growth pattern amounts to 69.74 percent, which implies a high degree of correlation.

Germany reported -0.8 percent in projected output growth in 1970, which resulted in relatively higher 3.1 percent of real output growth. During 2005, they reported 5.1 percent in projected output growth followed by the relatively higher 3.1 percent real output growth- found to be highest projected output growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 0.4 percent to -2.5 percent then followed by real output growth and from 3.2 percent to -5.8 percent. The relationship between projected output growth and real output growth pattern amounts to 53.57 percent, which implies a moderate degree of correlation.

During 1971, SA reported -0.8 percent in projected output growth, which resulted in relatively lower 0.5 percent of real output growth. During 1981, they reported -1.2 percent growth of projected output growth followed by the relatively 5.2 percent higher real output growth- found to be lowest growth for the successive period of analysis. Then in 2002 growth improved were projected output growth rose to -15.9 percent which dragged real output growth down to 3.6 percent - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 13.3 percent to 11.1 percent then followed by real output growth from 5.2 percent to -0.016 percent. The relationship between projected output growth and real output growth pattern amounts to 37.96 percent, which implies a low degree of correlation.

For South Korea, in 1971 they reported 4.6 percent of projected output growth which resulted in relatively higher 9.9 percent of real output growth. However, in 1998 they reported -4.6 percent growth of projected output growth followed by the relatively lower -5.6 percent growth of real output growth - found to be lowest growth for the successive period of analysis. Then the Great Recession (2007 to 2009) affected projected output growth from 0.7 percent to -1.5 percent then followed by real output growth from 5.3 percent to 0.7 percent. The relationship between projected output growth and real output growth pattern amounts to -30.56 percent, which implies a low and a negative degree of correlation.

For the UK, in 1971 they reported -0.2 percent in projected output growth, which resulted in relatively higher 3.4 percent of real output growth. During 1973, they reported 0.4 percent of projected output growth which resulted in relatively 6.3 percent higher real output growth- found to be highest growth for the successive period of analysis. However, in the following year projected output growth dipped to -2.4 percent which dragged real output growth down to -2.5 percent - found to be lowest growth for the successive period of analysis for projected output growth only. Then the great recession (2007 to 2009) affected projected output growth from 0.2 percent to -1.8

percent then followed by real output growth from 2.5 percent to -4.3 percent. The relationship between projected output growth and the actual growth pattern amounts to 10.04 percent, which implies the lowest degree of correlation.

For the US, in 1971 they reported 0.3 percent in projected output growth, which resulted in relatively higher 3.2 percent of real output growth. Then in 1984, they reported 7 percent of projected output growth followed by the relatively lower 2 percent growth actual output - found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from -0.4 percent to -1.3 percent then followed by real output growth and from 1.9 percent to -2.6 percent. The relationship between projected output growth and real output growth pattern amounts to 7.19 percent, which implies the lowest degree of correlation.

These conclude that the great recession affected real output growth badly in 2009, for all the countries since they which records the lowest growth ever. The relationship between projected output growth and real output growth display a high correlation for France, Germany, and South Korea. For South Korea, the results show a negative correlation, while for the remaining countries the results show the lowest degree of correlation.

4.4.5 The AK model

Figure 5. Projected output growth of the AK model results

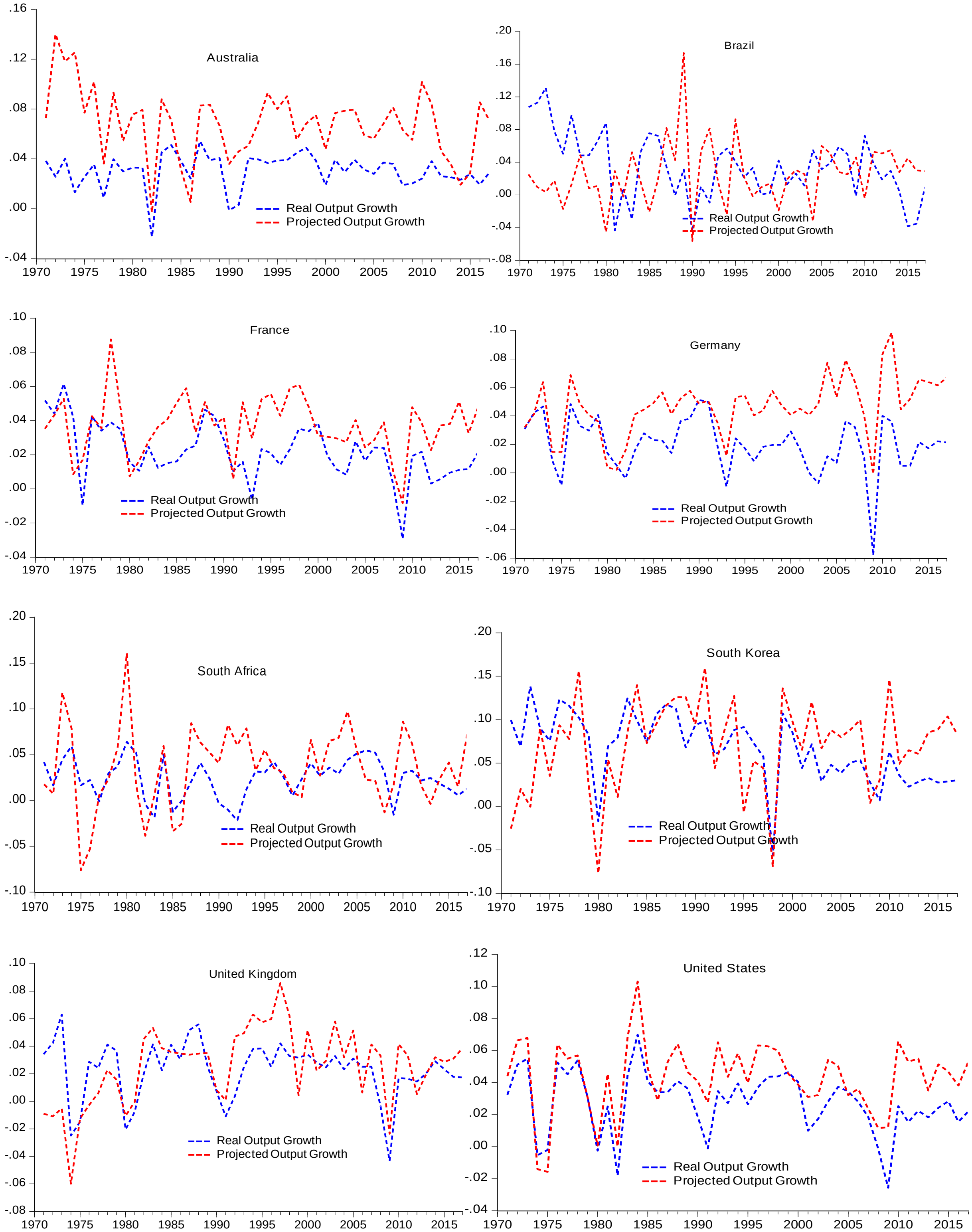


Figure 5 provide a graphic interpretation of real output growth rate against projected output growth rate using The AK model in 8 diverse countries. The results show that real output growth and projected output growth the trails same manner for the entire period of analysis. It Furthermore, if growth of estimated GDP rises, real per capita GDP growth also take impetus and conversely, but not exactly correlated.

For Australia, initially in 1971 they reported 7.3 percent in projected output growth, which resulted in lower 3.8 percent of real output growth. In 1974 projected output growth dipped to 0.3 percent which dragged real output growth down to -2.3 percent - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 8.1 percent to 5.5 percent, which made real output growth from 3.6 percent to 1.9 percent. The relationship between projected output growth and real output growth pattern amounts to 42.87 percent, which implies a low degree of correlation.

For Brazil, initially in 1971 they reported 2.5 percent in projected output growth, which resulted in relatively higher 10.7 percent of real output growth. During 1983 projected output growth rose to -5.3 percent which resulted in the same percentage of real output growth - found to be lowest for the subsequent period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 2.8 percent to -0.1 percent, which made real output growth from 5.9 percent to -0.1 percent. The relationship between projected output growth and real output growth pattern amounts to -0.22 percent, which implies a lowest and a negative degree of correlation.

For France, in 1970 they reported 3.5 percent in projected output growth, which resulted in relatively higher 5.2 percent of real output growth. In 1973, they reported 5.3 percent growth of projected output growth followed by the relatively higher 6.1 percent of real output growth -real output growth found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 3.9 percent to -0.8 percent, which made real output growth from 2.4 percent to -2.9 percent. The relationship between projected output growth and real output growth pattern amounts to 50.62 percent, which implies a moderate degree of correlation.

Germany, in 1971 they reported 3.2 percent in projected output growth, which resulted in the same percentage of real output growth. During 1973, they reported 5.1 percent growth of projected output growth which resulted in the same percentage of real output growth - found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 6.4 percent to -0.1 percent then followed by real output growth from 3.2 percent to -5.8 percent, which for 2009 - found to be highest during the subsequent period. The relationship between projected output growth and real output growth pattern amounts to 58.31 percent, which implies a moderate degree of correlation.

For SA, in 1971 they reported 1.8 percent in projected output growth, which resulted in relatively higher 4.2 percent of real output growth. During 1980, they reported 16.1 percent growth of projected output growth followed by the relatively lower 6.4 percent higher real output growth- found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 2.1 percent to 1.7 percent then followed by real output growth from 5.2 percent to -1.6 percent. The relationship between projected output growth and real output growth pattern amounts to 40.05 percent, which implies a low degree of correlation.

For South Korea, in 1971 reported -2.6 percent of projected output growth which resulted in relatively higher 9.9 percent of real output growth. During 1998, they reported -7 percent in projected output growth, which resulted in relatively higher - 5.6percent of real output growth - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 10 percent to 0.4 percent then followed by real output growth and from 5.3 percent to 0.7 percent. The relationship between projected output growth and real output growth pattern amounts to 44.05 percent, which implies a low degree of correlation.

For the UK, in 1970 they reported -0.9 percent in projected output growth, which resulted in relatively higher 3.4 percent of real output growth. During 1969, they reported -16.9 percent of projected output growth which resulted in relatively -0.9 percent higher real output growth- found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 4.1 percent to -2.4 percent then followed by real output growth from 2.6 percent to -4.3 percent - the real output growth - found to be highest growth for the successive period of analysis. The relationship between projected output growth and real output growth pattern amounts to 50.85 percent, which implies a moderate degree of correlation.

For the US, in 1971 they reported 4.4 percent in projected output growth, which resulted in relatively lower 3.2 percent of real output growth. Then in 1984, they reported 10.3 percent of projected output growth followed by the lower 7 percent growth actual output - found to be highest growth for the successive period of analysis. However, in 1974 projected output growth dipped to -2.7 percent which dragged real output growth down to -2.3 percent - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 2.4 percent to 1.2 percent then followed by real output growth and from 1.9 percent to -2.6 percent. The relationship between projected output growth and real output growth pattern amounts to 83.39 percent, which implies a high degree of correlation.

We therefore conclude that the Great recession affected real output growth badly in 2009, for Brazil, France Germany, SA, the UK, and US, which records with a negative growth. Projected output growth and real output growth - for the remaining countries not mentioned countries reported an enhancing growth rate. The relationship between projected output growth and real output growth pattern shows a high degree of correlation for France, Germany, U.K, and U.S.A and a negative degree of correlation for Brazil.

4.4.6 Lucas model

Figure 6. Projected output growth of the Lucas model results

Figure 6 provide a graphic interpretation of real output growth rate against projected output growth rate using Lucas model in 8 diverse countries. The results show that real output growth and projected output growth trails a similar manner for the entire period of analysis. Furthermore, if projected output growth rises, output growth a takes a rises impetus which shows a weakly relationship. However, the co-movement between the two variables is weakly in a graphically explanation compared to the one in Solow model, extended Solow and Domar model.

For Australia, in 1971 they reported -0.4 percent in projected output growth, which resulted in higher 3.8 percent of real output growth. During 1974 and 1982, they reported the same -1.2 percent growth of projected output growth followed by the relatively higher 1.3 percent and a relatively lower -2.3 percent of actual output, respectively. This is found to be lowest growth for the successive period of analysis, except for 1.3 percent of real output growth. Then the great recession (2007 to 2009) affected projected output growth from 0.3 percent to -0.3 percent, which made real output growth to decrease from 3.6 percent to 2 percent. The relationship between projected output growth and real output growth pattern amount to 69.33 percent, this implies a high degree of correlation.

For Brazil, in 1972 they reported 0.27 percent in projected output growth, which resulted in higher 10.74 percent of real output growth. Then the great recession (2007 to 2009) affected projected output growth from 0.21 percent to -0.48 percent which resulted in real output growth to fall from 5.9 percent to -0.13 percent. The relationship between projected output growth and real output growth pattern amount to 64.49 percent, this implies a high degree of correlation.

For France, in 1971 they reported -0.3 percent in projected output growth, which resulted in higher 5.2 percent of real output growth. During 1975 the growth dragged further down, they reported -0.9 percent growth of projected output growth which resulted in the same percent real output growth- projected output growth found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 0.3 percent to -0.6, which made real output growth to dramatically drop from 2.4 percent to -2.9 percent. The relationship between projected output growth and the per capita growth pattern amounts to 27.66 percent, which implies a low degree of correlation.

For Germany, in 1970 they reported -0.7 percent in projected output growth, which resulted in relatively higher 3.1 percent of real output growth. During 1991, they reported 1.8 percent of projected output growth followed by the relatively higher 5 percent real output growth- found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 0.4 percent to -0.5 percent, which made per real output growth to fall from 3.2 percent to -5.8 percent. The relationship between projected output growth and real output growth pattern amounts to 45.44 percent, which implies a low degree of correlation.

For SA, in 1971 they reported 0.6 percent in projected output growth, which resulted in higher 4.2 percent of real output growth. During 1991, they reported 0.9 percent of projected output growth followed by the higher 6.4 percent real output growth- found to be highest growth for the successive period of analysis. The great recession (2007 to 2009) affected projected output growth from -0.2 percent to -0.9 percent, which made per real output growth to fall from 5.2 percent to -1.6 percent. The relationship between projected output growth and real output growth pattern amounts to 50.32 percent, which is a moderate degree of correlation.

For South Korea, in 1971 they reported -0.2 percent of projected output growth which resulted in relatively higher 9.9 percent of real output growth. During 1998, they reported -4.6 percent of projected output growth followed by the relatively lower -5.6 percent higher real output growth- found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from -0.1 percent to -1.8 percent which resulted from 5.3 percent to 0.7 percent in real output growth. The relationship between real output growth and projected output growth pattern amounts to 51.25 percent, which implies a moderate degree of correlation.

For the UK, in 1971 they reported -0.1 percent in projected output growth, which resulted in higher 3.4 percent of real output growth. During 1973, they reported 0.6 percent of projected output growth followed by relatively higher 6.3 percent higher growth of real GDP - real output growth is found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 0 percent to -0.6 percent then followed by real output growth from 2.5 percent to -4.3 percent - real output growth is found to be highest growth for the successive period of analysis. The relationship between projected output growth and per capita growth pattern amounts to 55.44 percent, which implies a moderate degree of correlation.

For the US, in 1971 they reported 0.1 percent of projected output growth followed by the higher 3.2 percent growth of actual output. Furthermore, in 1984 projected output growth rose to 1.1 percent which dragged output growth up to 7 percent - found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from -0.5 percent to -1.1 percent then followed by real output growth from 1.9 percent to -2.6 percent. The relationship between the estimated growth and per capita growth pattern amounts to 82.04 percent, which implies the highest degree of correlation.

We concluded that the great depression affected both real output growth and projected output growth badly in 2009. However, real output growth for Australia changed from 3.6 percent to 2 percent - not extremely impacted relative to other countries. The relationship between projected output growth and per capita growth pattern shows a good degree of correlation and for US indicate the highest degree of correlation which amount to 82.04 percent.

4.4.7 Romer model

Figure 7. Projected output growth of the Romer model results

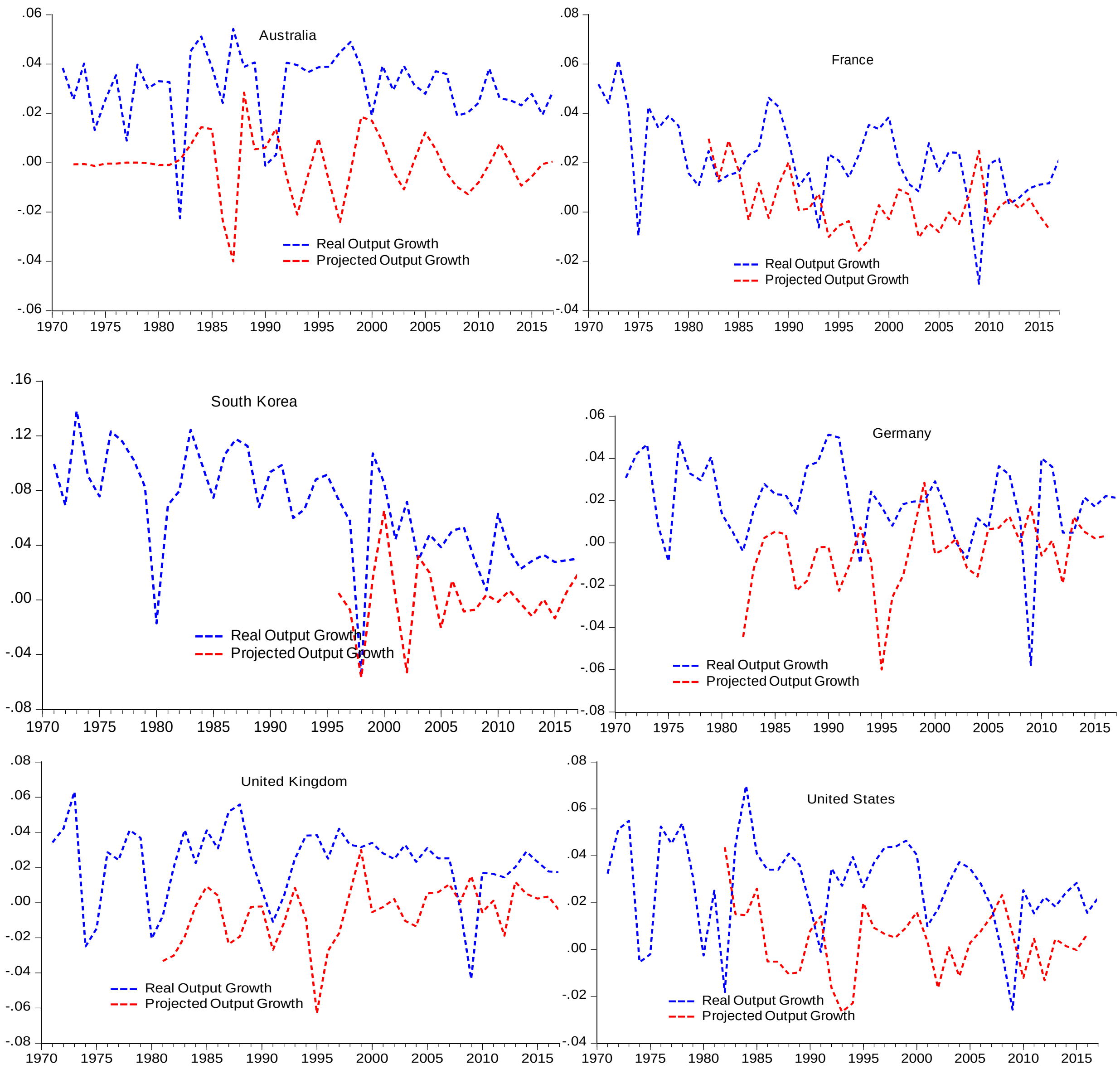


Figure 7 provide a graphic interpretation of real output growth rate against projected output growth rate using Romer model in 6 different countries. However, projected output growth for Brazil and SA could not be computed due to incomplete data. The results show that real output growth and projected output growth trails different manner for the entire period of analysis. Furthermore, if projected output growth raises, the real per capita GDP growth does not correspond and conversely, and they are weakly correlated.

For Australia, in 1984, they reported 1.4 percent in projected output growth, which resulted in relatively higher 5.1 percent of real output growth. Then the great recession (2007 to 2009) affected projected output growth from -0.4 percent to -1.3 percent, which made real output growth to drop from 3.6 percent to 2 percent. The relationship between projected output growth and real output growth is -10.02 percent, which implies a lowest and a negative degree of correlation.

For France, in 1982, they reported 3 percent in projected output growth, which resulted in relatively lower 2.5 percent of real output growth. Then the great recession (2007 to 2009) affected projected output growth from -0.5 percent to 2.5 percent, which made real output growth to fall from 2.4 percent to -2.9 percent - found to be lowest growth for the successive period of analysis only for real output growth. The relationship between projected output growth and real output growth is -26.01 percent, which implies a lowest and a negative degree of correlation.

For Germany, initially there were no values for projected output growth until 1982 were they reported -4.5 percent in projected output growth, which resulted in higher -0.4 percent of real output growth. During 1990, they reported -0.2 percent growth of projected output growth followed by higher 5 percent of real output growth - real output growth found to be highest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 1.2 percent to 1.7 percent, which made real output growth to fall from 3.2 percent to -5.8 percent. The coefficient of correlation between projected output growth and real output growth is -6.31 percent. This implies a lowest and a negative degree of correlation.

For South Korea, initially there were no values for projected output growth until 1990s. Then in 1998 they experience -5.2 percent of projected output growth which resulted in the same percentage for real output growth - found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from -0.8 percent to 0.4 percent which resulted dramatic fall from 5.3 percent to 0.7 percent of real output growth. The coefficient of correlation between real output growth and projected output growth pattern is 26.08 percent, which implies a low degree of correlation.

For the UK, initially there were no values for projected output growth until 1980s. Then in 1981, they reported -3.3 percent in projected output growth, which resulted in relatively lower -0.8 percent of real output growth. During 1995, they reported -6.3 percent of projected output growth followed by higher 2.5 percent of real output growth - projected output growth found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from 1.1 percent to 1.5 percent then followed by the dramatic fall from 2.5 percent to -4.3 percent of real output growth. The relationship between real output growth and projected output growth amounts to -11.73 percent, which implies a lowest and a negative degree of correlation.

For the US, initially there were no values for projected output growth until 1980s. Then in 1982, they reported 4.4 percent in projected output growth, which resulted in lower -1.8 percent of real output growth - projected output growth found to be lowest growth for the successive period of analysis. Then the great recession (2007 to 2009) affected projected output growth from -1.4 percent to 0.7 percent then followed by a dramatic fall from 1.9 percent to -2.6 percent of real output growth. The relationship between real output growth and projected output growth pattern amounts to -83.91 percent, which implies a lowest and a negative degree of correlation.

From the above results, we can conclude that the Great Recession affected real output growth badly in 2009. However, projected output growth computed in these model shows no influence at all from the crises - no effect that can be noticed from other countries except for Australia were the growth moved as follows -0.4 percent (2007) to -1.3 percent (2009). The degree of correlation is negative and low for all the countries except for South Korea which amount to 26.08 percent. Therefore, it can be concluded that the Romer model does not best predict real output growth.

4.4.8 Summary of figures results

This present the graphic representation of real output growth versus estimated parameters for seven growth models. We observe a strong co-movement between real output growth and projected output growth for extended Solow, Solow and Domar model. Furthermore, the degree of correlation results shows that the extended Solow model generally outperforms the other models for Australia, France, Germany, and USA. While the Solow model outperforms for Brazil and SA and Domar model outperforms for South Korea and the UK. Then the Lucas model outperforms Goodwin, The AK and Romer models for Australia, Brazil, SA, South Korea, and the UK. The models that performs poorly out of all is Romer model which shows a negative correlation for all the estimated countries.

4.5 The RMSE results

Table 15.The RMSE error of the competing models

	Aus.	Bra.	Fra	Ger	S A	SK	UK	US
Solow	0.77	0.59	0.49	0.60	0.89	1.25	0.69	0.58
Ex.SM	0.69	0.82	0.46	0.53	0.99	1.56	0.73	0.59
Domar	4.45	2.39	2.35	6.07	6.80	2.87	2.15	4.32
Goodwin	3.14	3.00	2.34	2.15	2.64	5.74	2.31	2.69
The AK	3.89	5.02	1.91	2.78	3.29	4.04	2.02	1.73
Lucas	3.06	4.12	2.26	2.27	2.67	6.70	2.63	2.87
Romer	3.28	-	2.02	2.91	-	3.35	3.24	3.12

RMEs in 10^{-2}

Table 15 shows that the overall mean values for 8 countries using Solow model, extended Solow model, Domar model, Goodwin model, The AK model, Lucas model and Romer model using the deviation between real output growth and projected output growth. The low RMSE value indicates superior estimate ability. The Solow model generally outperforms the other models for Brazil, SA, South Korea, the UK, and USA. While the extended Solow model also provides a superior estimate that outperforms the other models for Australia, France, and Germany.

4.6 Empirical forecasting of GDP growth

Macroeconomic variable (GDP, inflation, and unemployment) plays a key role for politicians, central banks, and companies to forecast the future. (Pilström & Pohl, 2009). The study by Andersson (2007) “Forecasting Swedish GDP Growth”, GDP plays a significant indication of the country performance effect within the economy which impact almost the whole nation. In this dissertation, the out of sample and in sample and forecasting are considered. Kraay and Monokroussos (1999) examines real output growth forecast using the neoclassical growth model and time series in large sample for developing and developed countries. His findings suggest that combining the growth models and growth models when forecasting real per capita output growth as the difference between the is small.

In this section, we forecast the Actual output for all eight different countries using Eq. (59), for Domar, Solow, the extended Solow, Goodwin, The AK, Lucas and Romer models. To see which one best predict real output growth in the period $t+1$, $t+2$ and $t+3$ when forecasted. The evaluation method in this dissertation uses the square difference of the actual output and estimated - standard deviation mean errors. Figures 8 to 10 provides a graphic representation of real output growth and one year, two year, and three year ahead output growth forecast from the seven competing models considered in this section. Table 16 and 17 presents standard deviation which summaries the RMSE, one yearly, two years and three years presented.

4.6.1 In Sample forecasting

Figure 8. Real output growth and one year ahead in sample forecasts.

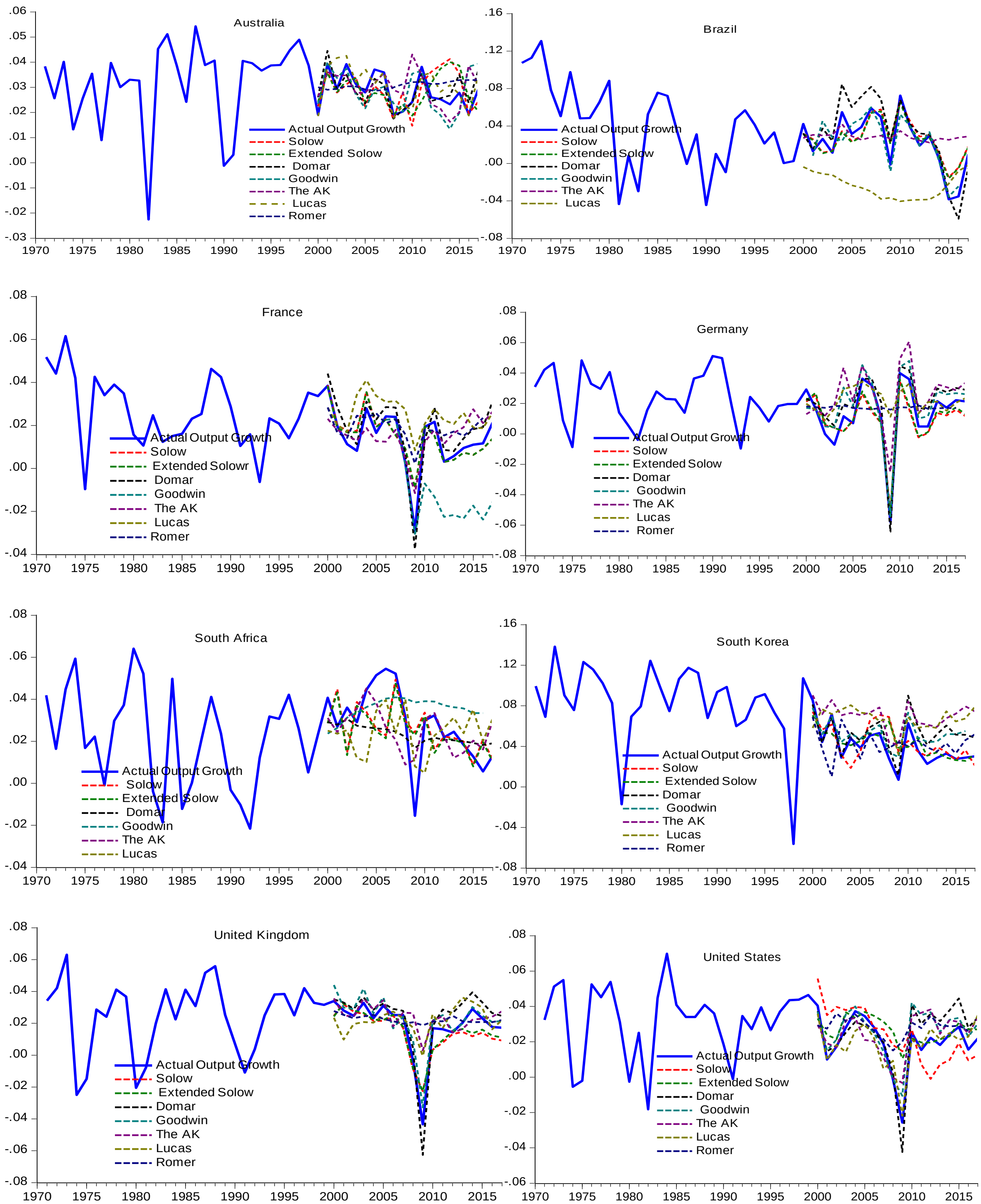


Figure 9. Real output growth and two year ahead in sample forecasts

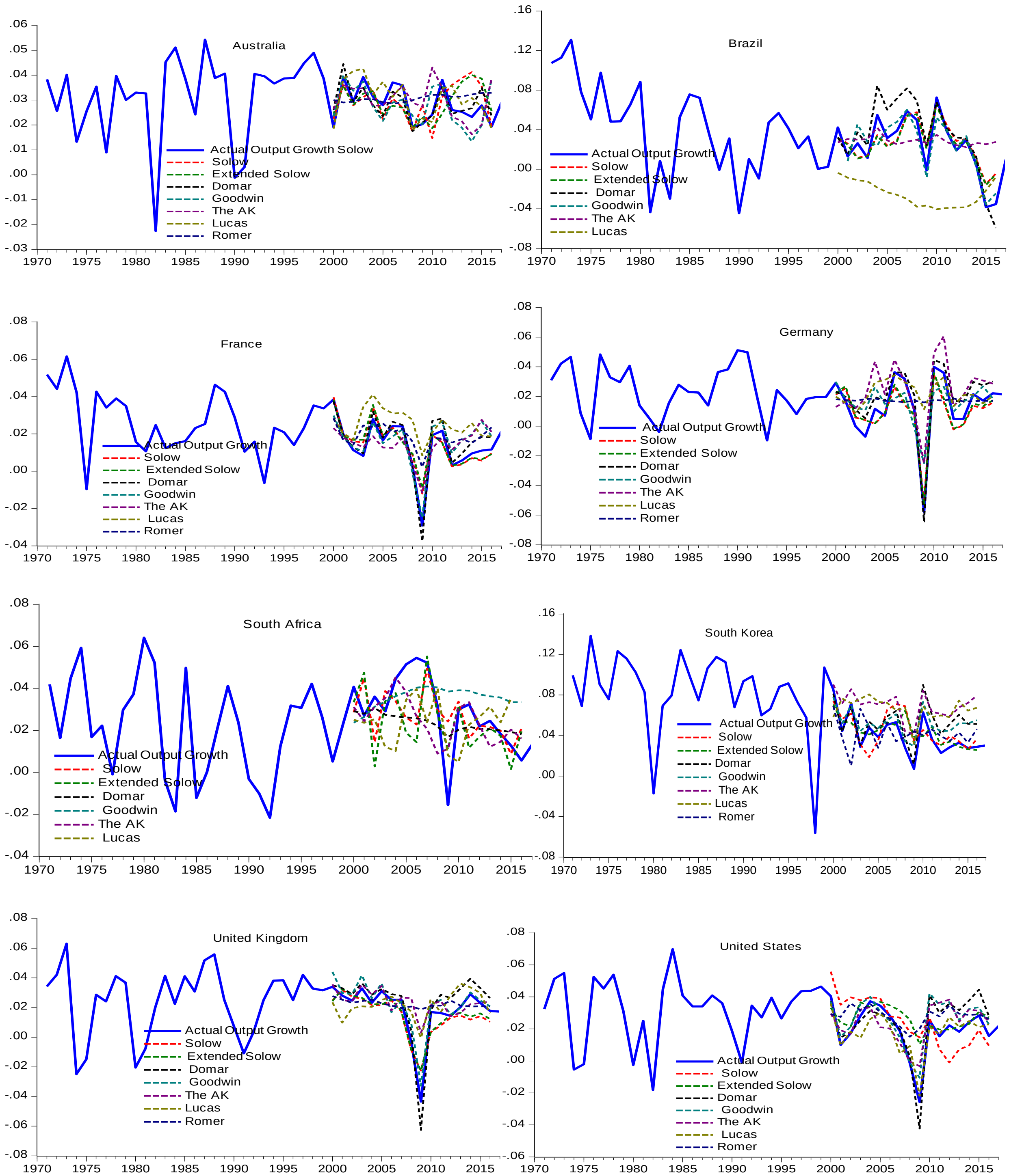
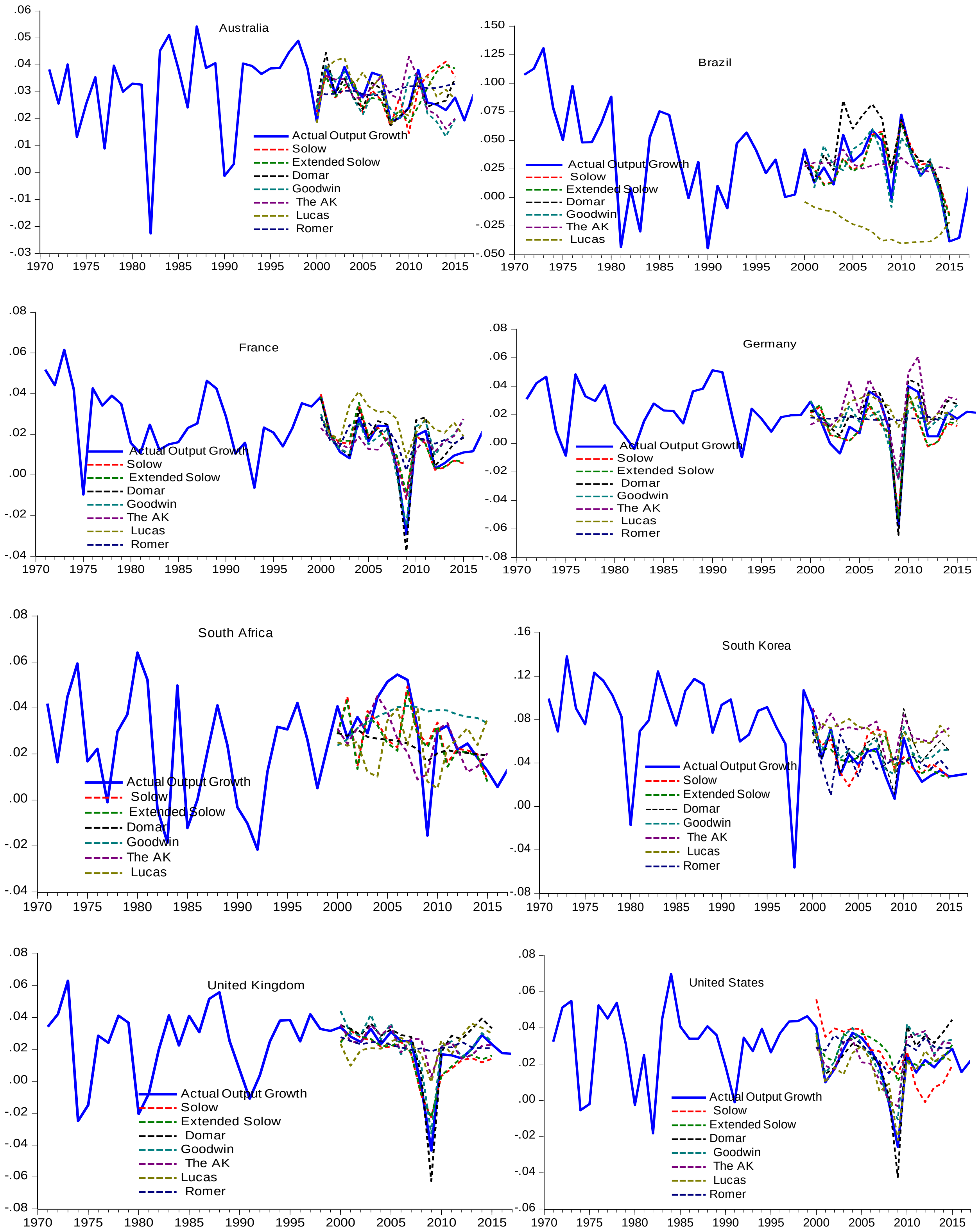


Figure 10. Real output growth and three year ahead in sample forecasts



4.6.2 Out of Sample forecasting

Figure 11. Real output growth and one year ahead out of sample forecasts

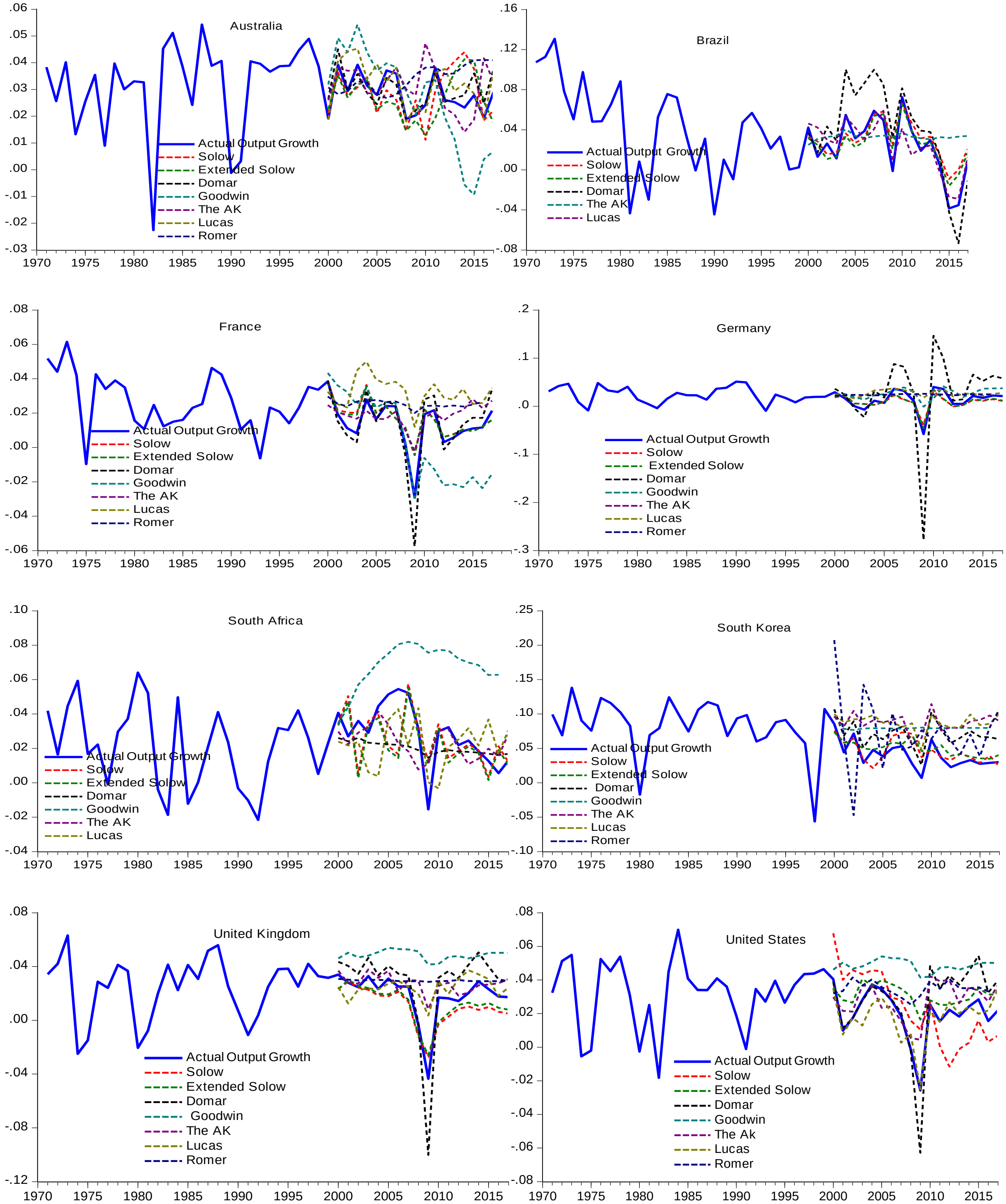


Figure 12. Real output growth and two year ahead out of sample forecasts

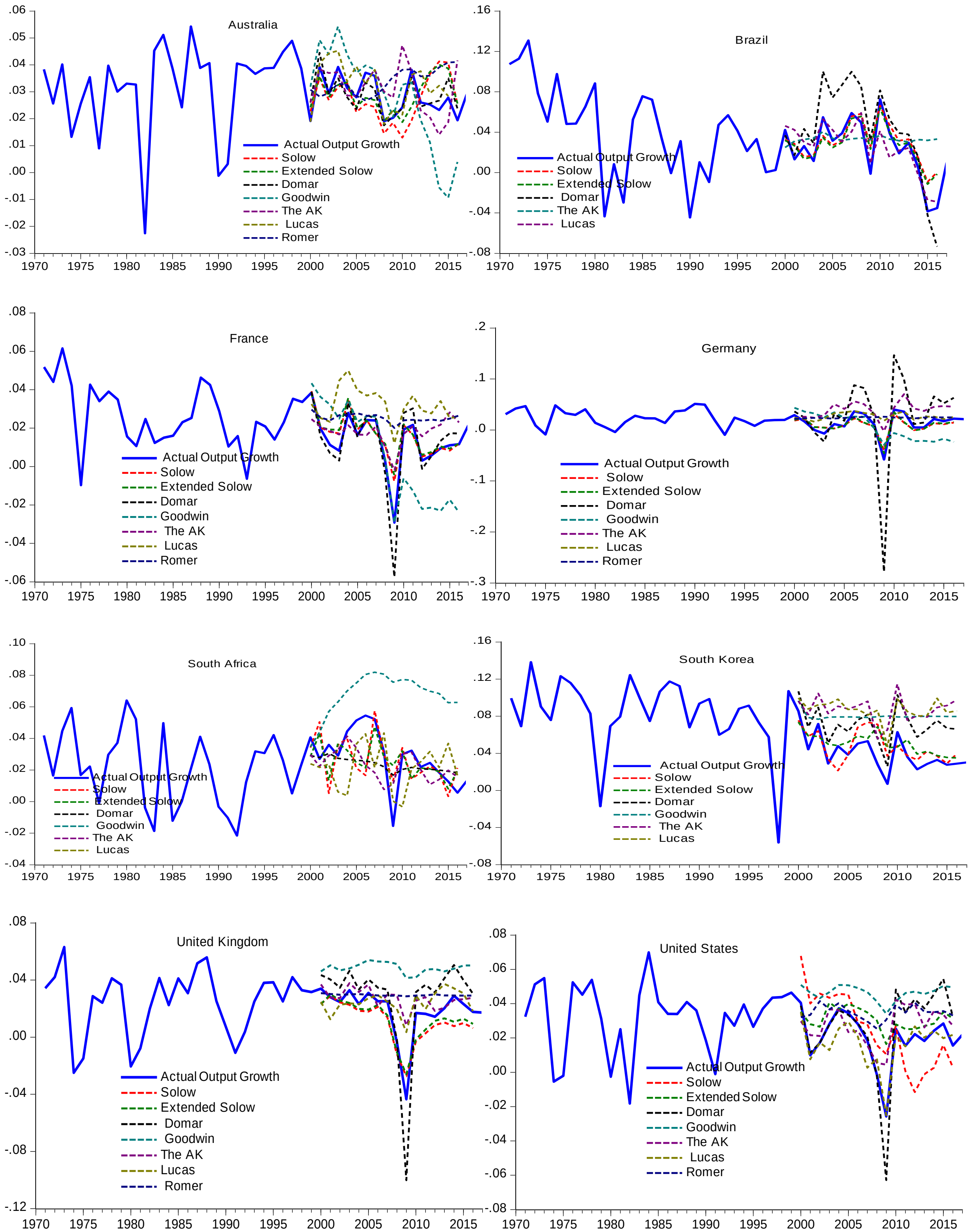
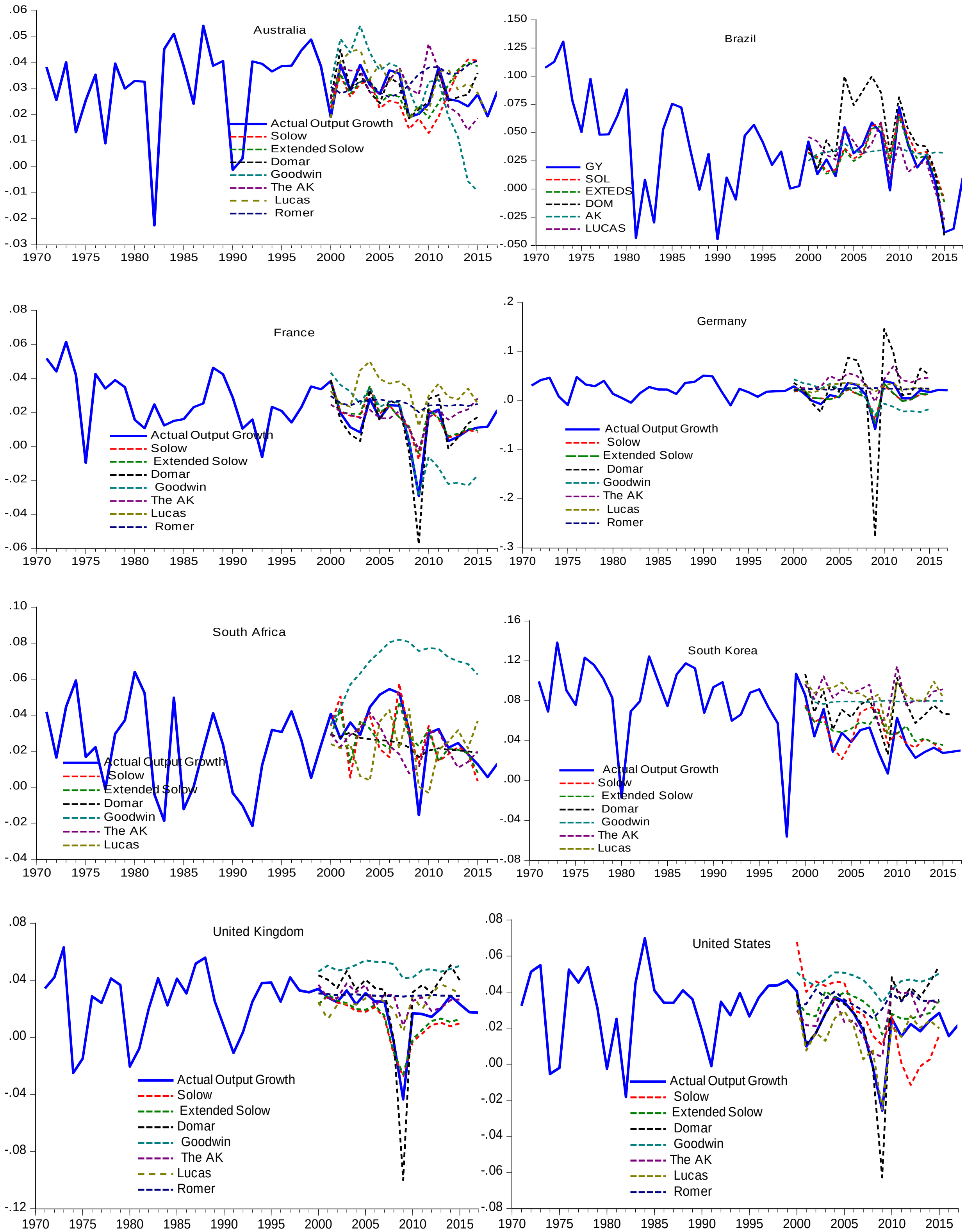


Figure 13. Real output growth and three year ahead out of sample forecasts



4.6.3 The RMSE of in sample and out of sample results

4.6.3.1 The in-sample results

Table 16.The RMSE error of the competing models in sample forecasts

	Model	Real output growth		
Horizon		**1**	**2**	**3**
Australia	Solow	0.67	0.68	0.72
	Extended Solow	0.68	0.67	0.68
	Domar	0.35	0.33	0.32
	Goodwin	0.61	0.59	0.51
	The AK	0.62	0.64	0.56
	Lucas	0.39	0.38	0.40
	Romer	0.70	0.72	0.68
Brazil	Solow	1.13	1.16	1.04
	Extended Solow	1.07	1.09	0.96
	Domar	1.48	1.48	1.42
	Goodwin	0.95	0.95	0.94
	The AK	2.18	2.19	1.94
	Lucas	5.25	5.49	5.66
	Romer	-	-	-
France	Solow	0.44	0.43	0.44
	Extended Solow	0.49	0.47	0.48
	Domar	0.58	0.35	0.34
	Goodwin	2.10	0.54	0.53
	The AK	0.81	0.83	0.82
	Lucas	1.26	1.31	1.35
	Romer	0.88	0.88	0.86

Germany	Solow	0.83	0.82	0.83
	Extended Solow	0.74	0.74	0.75
	Domar	0.78	0.78	0.78
	Goodwin	0.76	0.96	0.98
	The AK	1.36	1.37	1.41
	Lucas	1.22	1.28	1.35
	Romer	1.55	1.55	1.61
SA	Solow	1.21	1.27	1.27
	Extended Solow	1.24	1.38	1.38
	Domar	1.18	1.22	1.22
	Goodwin	1.44	1.44	1.36
	The AK	1.10	1.07	1.07
	Lucas	1.55	1.54	1.54
	Romer	1.73	1.71	1.71
South Korea	Solow	1.26	1.28	1.31
	Extended Solow	1.14	1.19	1.24
	Domar	1.34	1.31	1.25
	Goodwin	1.28	1.28	1.19
	The AK	2.98	2.89	2.75
	Lucas	2.96	2.85	2.79
	Romer	1.73	1.71	1.71
UK	Solow	0.77	0.77	0.77
	Extended Solow	0.70	0.71	0.71

	Domar	0.72	0.72	0.71
	Goodwin	0.51	0.51	0.53
	The AK	0.79	0.78	0.79
	Lucas	1.00	1.02	1.08
	Romer	0.91	0.93	0.98
USA	Solow	1.29	1.31	1.35
	Extended Solow	0.87	0.89	0.87
	Domar	0.88	0.87	0.84
	Goodwin	0.76	0.75	0.75
	The AK	0.91	0.90	0.90
	Lucas	0.62	0.58	0.57
	Romer	1.06	1.06	1.06

RMEs in 10^{-2}

The comparison started with one year, two year, and three year ahead time horizons. This forecast follows the same process done for first RMSE between real output growth and projected output growth for seven competing models using Eq. (60). The low RMSE value means superior forecast ability. The results for one year ahead forecast show that Goodwin and extended Solow model outperforms for the two countries each, the other models outperform for one country except for the Romer model. Then in two year ahead forecast the models that outperforms the others are Domar, extended Solow and Goodwin models for two countries each. Then in three year ahead forecast the Goodwin models outperforms the other models for three countries followed by Domar model which outperforms the other models for two countries.

Therefore, the Goodwin model generally outperforms the other models for Brazil and the UK, show superior forecast ability for the one year, two year, and three year time horizons. The following models outperforms for a specific country for the one year, two year, and three year time horizons: the extended Solow outperforms the other models for Germany and for South Korea only for one and two year time horizons, The AK model outperforms the other models for SA and the Lucas model outperforms the other models for the US show superior forecast ability for the one year, two year, and three year time horizons. The Domar model outperforms the other models for France in one year and three-year output ahead forecast. If we were to rank these growth models, the top two models that describe the superior forecast ability are the Goodwin model and the extended Solow model.

4.6.3.2 The out of Sample results

Table 17.The RMSE error of the competing models for out of sample forecasts

	Model	Real output growth		
Horizon		**1**	**2**	**3**
Australia	Solow	0.77	0.77	0.81
	Extended Solow	0.81	0.80	0.81
	Domar	0.35	0.32	0.31
	Goodwin	1.26	1.20	1.18
	The AK	0.67	0.69	0.59
	Lucas	0.47	0.48	0.45
	Romer	0.96	0.95	0.87
Brazil	Solow	1.26	1.27	1.12
	Extended Solow	1.15	1.16	1.02
	Domar	2.30	2.31	2.21
	Goodwin	-	-	-
	The AK	2.27	2.26	1.97
	Lucas	1.12	1.17	1.20
	Romer	-	-	-
France	Solow	0.45	0.45	0.48
	Extended Solow	0.51	0.51	0.54
	Domar	0.60	0.57	0.57
	Goodwin	1.79	1.68	1.57

	The AK	0.88	0.90	0.89
	Lucas	1.92	1.95	1.98
	Romer	1.32	1.32	1.31
Germany	Solow	0.94	0.93	0.94
	Extended Solow	0.84	0.83	0.84
	Domar	4.14	4.17	4.17
	Goodwin	1.63	1.73	1.63
	The AK	2.65	2.64	2.66
	Lucas	1.47	1.52	1.59
	Romer	1.70	1.70	1.79
SA	Solow	1.28	1.35	1.33
	Extended Solow	1.32	1.30	1.30
	Domar	1.37	1.22	1.22
	Goodwin	3.93	3.93	3.82
	The AK	1.20	1.18	1.19
	Lucas	1.64	1.63	1.66
	Romer	-	-	-
South Korea	Solow	1.32	1.36	1.38
	Extended Solow	1.44	1.47	1.52
	Domar	3.00	2.99	2.99
	Goodwin	3.93	3.93	3.86
	The AK	4.70	4.62	4.48
	Lucas	4.72	4.58	4.51
	Romer	-	-	-

UK	Solow	1.04	1.03	1.02
	Extended Solow	0.89	0.89	0.89
	Domar	1.54	1.56	1.58
	Goodwin	3.02	3.00	2.99
	The AK	0.96	0.93	0.93
	Lucas	1.02	1.04	1.10
	Romer	1.18	1.18	1.19
USA	Solow	1.75	1.77	1.80
	Extended Solow	1.17	1.18	1.16
	Domar	1.17	1.13	1.10
	Goodwin	2.66	2.65	2.60
	The AK	1.11	1.09	1.08
	Lucas	0.62	0.58	0.58
	Romer	1.59	1.60	1.59

RMEs in 10^{-2}

The comparisons for the one year, two year, and three year ahead output growth forecast among the models show that the extended Solow model outperforms for three countries and Solow model outperforms for two countries in each time horizons. Therefore, the extended Solow model generally outperforms the other models for Brazil, Germany and the UK show superior forecast ability for the one year, two year, and three year time horizons. While the Solow model outperforms the other models for France and South Korea for all the time horizons. For the remaining models we see Domar model out-performs for Australia, the AK model outperforms for SA and Lucas models outperforms for US, for all the time horizons. If we were to rank these growth models, the top two models that describe the superior forecast ability are the extended Solow model and Solow model.

4.7 Robustness checks on Empirical forecasting of GDP growth

In this section we examine if the standard errors discrepancy between the models are significant or not, this is follows from the RMSE Eq. (59) results. This is done through the standard error discrepancy between the two models at a time as follows:

$$\vartheta_{discre} = \vartheta_{mo1} - \vartheta_{mo2} \tag{61}$$

Where ϑ_{mo1} and ϑ_{mo2} denote the standard deviation of the forecast for model one and model two, respectively. The results provide the discrepancy of the standard deviation (ϑ_{discre}).

We then run the OLS regression of the discrepancy of the standard error against a constant as follows:

$$\vartheta_{discre} = \alpha_1 + \lambda_t \tag{62}$$

Where α_1 denote a constant term and λ_t is the error term.

If $\alpha_1 < 0$ the results implies that the model one (ϑ_{mo2}) produces forecasts that are better than the forecast from the model two (ϑ_{mo2}). This is to distinguish if the model one is statistically significant from model two - which is crucial in forecasting the growth model.

4.7.1 Robustness of in Sample forecast

Table 18.Standard deviation of the competing models in sample forecasts

	Model	Real output growth		
Horizon		**1**	**2**	**3**
Australia	Goodwin - Domar	0.26^{**}	0.26^{**}	0.19
	Goodwin - Ext. Solow	-0.07	-0.09	-0.17
	Goodwin - Solow	-0.05	-0.09	-0.21^{**}
	Goodwin - The AK	-0.004	-0.05	-0.05
	Goodwin - Lucas	0.22	0.22	0.11
	Goodwin - Romer	-0.09	-0.13	-0.17
	Ext. Solow - Solow	0.02	-0.003	-0.04
	Ext. Solow - The AK	0.07	0.03	0.12

	Solow - The AK	0.05	0.04	0.16
Brazil	Goodwin - Domar	-0.56	-0.56	-0.51
	Goodwin - Ext. Solow	-0.14	-0.14	-0.02
	Goodwin - Solow	-0.22	-0.22	-0.09
	Goodwin - The AK	-1.29^{**}	-1.29^{**}	-1.03^{***}
	Goodwin - Lucas	-4.60^{*}	-4.60^{*}	-4.80^{*}
	Goodwin - Romer	$-$	$-$	$-$
	Ext. Solow - Solow	-0.07	-0.07	-0.07
	Ext. Solow - The AK	-1.11^{*}	-1.11^{*}	-0.97^{*}
	Solow - The AK	-1.04^{*}	-1.04^{*}	-0.9^{*}
France	Goodwin - Domar	1.50^{*}	0.19^{**}	0.19
	Goodwin - Ext. Solow	1.58^{*}	0.07	0.04
	Goodwin - Solow	1.62^{*}	0.12	0.08
	Goodwin - The AK	1.20^{*}	-0.29^{*}	-0.30^{*}
	Goodwin - Lucas	0.82	-0.77^{*}	-0.82^{*}
	Goodwin - Romer	1.02	-034	-0.33
	Ext. Solow - Solow	0.07	0.08	0.09
	Ext. Solow - The AK	-0.30	-0.30	-0.28
	Solow - The AK	-0.37^{*}	-0.40^{*}	-0.38^{*}
Germany	Goodwin - Domar	-0.02	0.22	-0.04
	Goodwin - Ext. Solow	0.01	0.24	0.49^{**}
	Goodwin - Solow	-0.07^{***}	0.09^{***}	0.39^{***}
	Goodwin - The AK	-0.60^{*}	-0.24	-0.21
	Goodwin - Lucas	-0.47	-0.25	0.33
	Goodwin - Romer	-0.78	-0.79	0.24
	Ext. Solow - Solow	-0.09^{*}	-0.08^{*}	-0.08^{*}
	Ext. Solow - The AK	-0.62^{**}	-0.63^{**}	-0.66^{**}

	Solow - The AK	-0.53^{**}	-0.55^{**}	-0.58^{**}
SA	Goodwin - Domar	0.22	0.22	0.14
	Goodwin - Ext. Solow	0.14	0.06	-0.03
	Goodwin - Solow	0.16	0.16	0.09
	Goodwin - The AK	0.37	0.37	0.28
	Goodwin - Lucas	-0.09	-0.19	-0.19
	Goodwin - Romer	–	–	–
	Ext. Solow - Solow	0.02	0.11	0.12
	Ext. Solow - The AK	0.14	0.31	0.31
	Solow - The AK	0.11^{**}	0.21^{**}	0.19^{**}
South Korea	Goodwin - Domar	-0.04	-0.04	-0.06
	Goodwin - Ext. Solow	0.09	0.09	-0.05
	Goodwin - Solow	-0.004	-0.004	-0.12
	Goodwin - The AK	-1.61^{*}	-1.61^{*}	-1.56^{*}
	Goodwin - Lucas	-1.57^{*}	-1.57^{*}	-1.59^{*}
	Goodwin - Romer	-0.43	-0.43	-0.51
	Ext. Solow - Solow	-0.12	-0.09	-0.07
	Ext. Solow - The AK	-1.84^{*}	-1.70^{*}	-1.51^{*}
	Solow - The AK	-1.71^{*}	-1.61^{*}	-1.44^{*}
UK	Goodwin - Domar	-0.21	-0.20	-0.18
	Goodwin - Ext. Solow	-0.19	-0.19	-0.19
	Goodwin - Solow	-0.26	-0.25	-0.24
	Goodwin - The AK	-0.28	-0.26	-0.26
	Goodwin - Lucas	-0.48^{**}	-0.51^{**}	-0.55^{**}
	Goodwin - Romer	-0.40	-0.42	-0.45
	Ext. Solow - Solow	-0.06^{*}	-0.06^{*}	-0.05^{*}
	Ext. Solow - The AK	-0.09	-0.07	-0.07

	Solow - The AK	-0.03	-0.01	-0.02
USA	Goodwin - Domar	-0.13	-0.11	-0.09
	Goodwin - Ext. Solow	-0.11	-0.14	-0.12
	Goodwin - Solow	-0.53^{**}	-0.55^{**}	-0.60^{**}
	Goodwin - The AK	-0.16	-0.15	-0.14
	Goodwin - Lucas	0.14	0.17	0.18
	Goodwin - Romer	-0.31	-0.31	-0.31
	Ext. Solow - Solow	-0.42^{**}	-0.42^{**}	-0.48^{**}
	Ext. Solow - The AK	-0.04	-0.01	-0.02
	Solow - The AK	0.37	0.41	0.45

RMEs in 10^{-2}

The in-sample forecasting models are presented in the table above. In one year ahead forecast the Goodwin models significantly outperforms all other models for two countries (Brazil and Goodwin). These results show that the RMSE forecast which outperforms for the same two countries which confirms the accuracy of the forecast. Similar results are found in the two year ahead output growth forecast. Therefore, the extended Solow model outperforms other models but is not significant. The Results for Australia and France significantly show that the Domar model outperforms the Goodwin model. This validate the accuracy of the forecast as the model RMSE forecast outperforms the other models. The results support that for one year, two year, and three year output growth forecast the Goodwin model general significantly outperforms the other models for all eight countries considered.

Then in the remaining comparisons extended Solow against Solow and the AK models, the results show that the model generally significantly outperforms for Brazil, Germany, South Korea, USA and France except for Solow model in one year, two year, and three years ahead time horizon forecast. For the Solow model versus the AK models, the Solow model significantly outperforms for four countries (Brazil, France, South Korea, the UK) and insignificantly outperformed by (Australia, Germany, SA and USA) in one year, two year, and three years ahead time horizon forecast.

4.7.2 Robustness check of out of sample forecast

Table 19.Standard deviation of the competing models out of sample forecasts

Horizon	Model	Real output growth 1	2	3
Australia	Ext. Solow - Domar	0.46^{*}	0.47^{*}	0.50^{*}
	Ext. Solow - Solow	0.05	0.02	-0.01
	Ext. Solow - Goodwin	-0.44^{***}	-0.41	-0.37
	Ext. Solow - The AK	0.14	0.11	0.21
	Ext. Solow - Lucas	0.35	0.33	0.33
	Ext. Solow - Romer	-0.15	-0.15	-0.07
	Solow - Domar	0.41^{*}	0.45^{*}	0.50^{*}
	Solow - The AK	0.09	0.08	0.22
	Solow - Lucas	0.30^{**}	0.33^{**}	0.33^{**}
	Domar - The AK	-0.32	-0.37^{**}	-0.28
	Domar - Lucas	-0.12	-0.17	-0.17
	The AK - Lucas	0.20	0.11	0.11
Brazil	Ext. Solow - Domar	-1.15^{*}	-1.15^{*}	-1.20^{*}
	Ext. Solow - Solow	-0.11	-0.10	-0.10
	Ext. Solow - Goodwin	$-$	$-$	$-$
	Ext. Solow - The AK	-1.11^{*}	-1.10^{*}	-0.95^{*}
	Ext. Solow - Lucas	0.03	-0.006	-0.18
	Ext. Solow - Romer	$-$	$-$	$-$
	Solow - Domar	-1.04^{**}	-1.05^{**}	-1.10^{**}
	Solow - The AK	-1.00^{*}	-0.99^{*}	-0.85^{*}
	Solow - Lucas	0.14	0.10	-0.08
	Domar - The AK	0.03	0.06	0.25
	Domar - Lucas	1.18^{**}	1.15^{**}	1.02

	The AK - Lucas	1.15*	1.09**	0.77
France	Ext. Solow - Domar	−0.09	−0.05	−0.03
	Ext. Solow - Solow	0.06*	0.06*	0.07*
	Ext. Solow - Goodwin	−1.28*	−1.17*	−1.02*
	Ext. Solow - The AK	−0.37*	−0.39*	−0.34
	Ext. Solow - Lucas	−1.4*	−1.4*	−1.4*
	Ext. Solow - Romer	−0.81*	−0.81*	−0.77*
	Solow - Domar	−0.15	−0.12	−0.09
	Solow - The AK	−0.43*	−0.45*	−0.41*
	Solow - Lucas	−1.46*	−1.50*	−1.51*
	Domar - The AK	−0.28	−0.33**	−0.32
	Domar - Lucas	−1.31*	−1.38*	−1.41*
	The AK - Lucas	1.03*	−1.05*	−1.10*
Germany	Ext. Solow - Domar	−3.30*	−3.33*	−3.33*
	Ext. Solow - Solow	−0.10**	−0.10**	−0.10**
	Ext. Solow - Goodwin	−0.80*	−0.90*	−0.78*
	Ext. Solow -The AK	−1.81*	−1.81*	−1.82*
	Ext. Solow - Lucas	−0.63	−0.69	−0.75
	Ext. Solow - Romer	−0.87	−0.87	−0.94
	Solow - Domar	−3.20*	−3.23*	−3.23*
	Solow - The AK	−1.71*	−1.71*	−1.71*
	Solow - Lucas	−0.53	−0.58	−0.65
	Domar - The AK	1.49	1.53	1.51
	Domar - Lucas	2.67*	2.65*	2.58*
	The AK - Lucas	1.18*	1.12*	1.07*
SA	Ext. Solow - Domar	−0.04	0.08	0.08

	Ext. Solow - Solow	0.04	-0.05	-0.05
	Ext. Solow - Goodwin	-2.54^{*}	-2.63^{*}	-2.52^{*}
	Ext. Solow - The AK	0.13	0.12	0.10
	Ext. Solow - Lucas	-0.31	-0.33	0.37
	Ext. Solow - Romer	–	–	–
	Solow - Domar	-0.08	0.13	0.12
	Solow - The AK	0.09	0.17	0.15
	Solow - Lucas	-0.36	-0.28	-0.33
	Domar - The AK	0.16	0.04	0.03
	Domar - Lucas	-0.28	-0.41	-0.45
	The AK - Lucas	-0.44	-0.45	-0.47
South Korea	Ext. Solow - Domar	-1.56^{*}	-1.52^{*}	-1.42^{*}
	Ext. Solow - Solow	0.12	0.11	0.14
	Ext. Solow - Goodwin	-2.47^{*}	-2.47^{*}	-2.34^{*}
	Ext. Solow - The AK	-3.25^{*}	-3.16^{*}	-2.96^{*}
	Ext. Solow - Lucas	-3.28^{*}	-3.12^{*}	-2.99^{*}
	Ext. Solow - Romer	–	–	–
	Solow - Domar	-1.68^{*}	-1.63^{*}	-1.56^{*}
	Solow - The AK	-3.38^{*}	-3.27^{*}	-3.10^{*}
	Solow - Lucas	-3.40^{*}	-3.32^{*}	-3.14^{*}
	Domar - The AK	-1.69^{*}	-1.64^{*}	-1.54^{*}
	Domar - Lucas	-1.72^{*}	-1.60^{*}	-1.57^{*}
	The AK - Lucas	-0.02	0.04	-0.03
UK	Ext. Solow - Domar	-0.64^{*}	-0.67^{*}	-0.68^{*}
	Ext. Solow - Solow	-0.15^{*}	-0.14^{*}	-0.13^{*}

	Ext. Solow - Goodwin	-2.12^{*}	-2.11^{*}	-2.09^{*}
	Ext. Solow - The AK	-0.06	-0.04	-0.04
	Ext. Solow - Lucas	-0.12	-0.14	-0.20
	Ext. Solow - Romer	-0.29	-0.29	-0.29
	Solow - Domar	-0.49	-0.53^{**}	-0.55
	Solow - The AK	0.09	0.10	0.10
	Solow - Lucas	0.02	-0.004	-0.07
	Domar - The AK	-0.24	-2.16	-2.23
	Domar - Lucas	-0.30	-0.32	-0.39
	The AK - Lucas	-0.06	-0.10	-0.17
USA	Ext. Solow - Domar	-0.00007	0.05	0.06
	Ext. Solow - Solow	-0.59^{**}	-0.59^{**}	-0.64^{**}
	Ext. Solow - Goodwin	-1.49^{*}	-1.47^{*}	-1.45^{*}
	Ext. Solow - The AK	0.06	0.09	0.07
	Ext. Solow - Lucas	0.55	0.60^{**}	0.58
	Ext. Solow - Romer	-0.42^{**}	-0.42^{**}	-0.43^{**}
	Solow - Domar	0.59	0.64	0.70
	Solow - The AK	0.64^{*}	0.68^{*}	0.72^{*}
	Solow - Lucas	1.13^{*}	1.19^{*}	1.22^{*}
	Domar - The AK	0.06	0.04	0.01
	Domar - Lucas	0.55	0.55	0.52
	The AK - Lucas	0.49	0.51	0.51

RMEs in 10^{-2}

The out of sample forecasting models are presented in the table above. In one year, two year and three year forecast the RMSE forecast results show that the extended Solow model generally outperforms all other models for three countries (Brazil, Germany, and the UK), each. Furthermore, the results show that the extended Solow model significantly outperforms other models for the three countries mentioned. For France and Germany one year, two year and three year output growth ahead forecast, the Solow model significantly outperforms the extended Solow model this results validate the significance of the RMSE forecast.

Then the Solow model significantly outperforms Domar, the AK and Lucas models for France, Germany, South Korea, and Brazil (except for Lucas model in all time horizon ahead forecast). However, for Australia and USA the Solow model is insignificant in all the time horizons. While Domar model compared against AK model and Lucas model significantly outperforms for Australia, South Korea, the UK, and France, and insignificantly outperformed for the USA, Germany, and Brazil and for all the time horizons. The Domar model significantly outperforms the AK and Lucas models for Australia, SA, the UK, France - except for Lucas model forecast one year ahead and South Korea - except for Lucas model in two year ahead forecast. Lastly, he AK model significantly outperforms the Lucas model for Australia, Brazil, SA, the UK, France except for one year ahead forecast and South Korea - except for two year ahead forecast.

4.8 Reinforcement of findings

The OLS regression results show that the Solow model, the extended Solow model, Goodwin's model, and Lucas model all predict positive and significant impact of estimated growth rate of output on real output growth rate. Furthermore, for Domar model, the parameter term is significant, and the model predict a positive impact on projected output growth, except for SA. On the other hand, the robustness of the study emphasizes on the sensitivity of the parameters in relation to the unforeseen events that resulted in global financial crisis that hugely impacted all the countries considered. This shows that the data used is consistent throughout and support the unit root and stationarity test implemented before the regression.

This dissertation emphasizes on learning more about the relationship between the projected output growth and the actual output growth, we found it crucial to learn more about the co-movement of the mentioned variables as well as their degree of correlation. The stronger the co-movement and the higher the degree of correlation implies the more accurate the prediction is which in this study is found to be for extended Solow, Solow model and Domar model. However, the results for Goodwin model shows a weaker co-movement and correlation of the projected output growth and the actual output growth which implies the less accurate the prediction is. Furthermore, for our OLS regression results we use RMSE to examine how close is projected output growth to the actual output growth using the square root of the mean. The results support Solow model and the extended Solow model which shows a good accuracy of the prediction errors for the models considered. This has important implications on long run growth rate to alleviates poverty and inequality through enhancing employment opportunities and labour productivity. As the model that produces the best estimate of the actual output growth can be used by the policy makers, then align the effect to poverty and inequality issues that a country experience. The projected output growth and the actual output growth provided the outlook of how the country economic growth expanded in the long run.

This dissertation also considered the countries in which the price stability is the primary mandate when conducting the monetary policy. Therefore, this influenced the study to conduct the in sample and out of sample forecasting to see which model best predict the actual output growth and to assess if the results differs from the OLS results, co-movements, degree correlation and RMSE conducted. The results show that for in sample, the Goodwin model generally outperforms all other models followed by the extended Solow model in one year, two year, and three year time horizons. For out of sample the results show that the extended Solow model generally outperforms all other model in one year, two year, and three year time horizons followed by Solow model. In addition, the robustness of in sample and out of sample, validates that indeed model one produces better forecast than model two. Therefore, the results generally support the extended Solow model throughout the study even though for in sample results fails to generally outperforms all other models. However, we cannot rule out the Solow model results that have produced a consistent result except for in sample forecasting. The results for other models like Goodwin, Lucas and Domar also shows superior estimate and forecast of actual output growth. However, this is lacks consistency and only holds under certain exceptions.

5. Conclusion

In relation to the OLS regression, this study finds that the Solow model, the extended Solow model, Goodwin's model, and Lucas model all predict positive and significant econometrically linear relation of projected output growth on real output growth. The stationarity test and unit root test for Solow model, the extended Solow model and Domar model for projected output growth and real output growth were both found to be stationary at level I (0). Therefore, the regression analysis for the Solow model and the extended Solow model has been found to be dependent on consistent outputs in the long run.

Furthermore, the robustness checks which uses a smaller sample size of pre - global financial crisis 1970-2017 yield the same results as the full sample size. In addition, the co-movement and correlation between the projected output growth and the actual output growth outperforms for Solow, extended Solow and Domar models and the degree of correlation results shows that the extended Solow model generally outperforms the other models. We find that the Solow model outperforms the extended Solow model from the standpoint RMSE. While the extended Solow model also provides a superior estimate that outperforms the other models. This finding highlights on the importance of endogenous growth models that there is no need of moving away from Solow model, the extended Solow model and Domar model them when projecting the actual output growth. This result yields a useful information for long run economic growth for decision making and long-term planning for national priorities such as infrastructure investment and pension funds etc.

Lastly, examine which model have a superior forecast ability for the observed period t+1, t+2 and t+3. For in sample forecasting, the Goodwin model generally outperforms the other models for Brazil and the UK, show superior forecast ability for the one year, two year, and three year time horizons. The following models outperforms for a specific country for the one year, two year, and three year time horizons: the Goodwin model outperforms the other models for Germany and for South Korea only for one and two year time horizons, The AK model outperforms the other models for SA and the Lucas model outperforms the other models for the US show superior forecast ability for the one year, two year, and three year time horizons.

If we were to rank these growth models, the top two models that describe the superior forecast ability are the Goodwin model and the extended Solow model. For out of sample forecasting the results are as follows: the extended Solow outperforms the other models for Germany and for UK only for one and two-three year time horizons, Solow outperforms the other models for France and for South Korea only for one and two-three year time horizons. The AK model outperforms the other models for SA and the Lucas model outperforms the other models for the US show superior forecast ability for the one year, two year, and three year time horizons. Therefore, the Solow model and the extended Solow model generally outperforms the other models in out of sample forecasting.

If we were to rank these growth models, the top three models that describe the superior forecast ability are Solow model, extended Solow model and Goodwin model. The robustness of the RMSE forecast for the standard deviation models support both out of sample and in sample and forecasting. The results illustrate that for all the models that generally outperforms the others are also statistically significant from one model to another.

Therefore, it can be said that considering all the cases the models that economist can best use when estimating real output growth are the extended Solow model then followed by the Solow model which only performs poorly on sample forecasting. The extended Solow model outperforms the other models except for RMSE between projected output growth and real output growth - where Solow model outperforms for five countries and the extended Solow outperforms on the remaining three countries.

5.1 Policy Implications and Recommendations

The study by Rao and Cooray (2012), outlines on the common belief that the exogenous growth of Solow Model provides no use for policy makers and their irrelevance on developing countries. This implies that the Solow model lacks significance policy implications for growth. The endogenous growth model offers the same common belief for developing countries - with optimising agents it results in a sustainable actual output growth in the long run. With these critics outlined this study focused on observing if the projected output growth plays a crucial role for a long run economic growth determination. The Study results generally shows that the Solow and the extended Solow models outperforms the other models when estimating and forecasting the projected output growth against the actual output growth. And that the projected output growth for developing countries offers a useful result in most of the models besides the endogenous growth models due to lack of data, that can be useful for the policy makers.

Therefore, the recommended policy implication will be to ensure that the budget deficits and tax system is under control as this would results in more savings. The higher savings rate will result in higher level of output in the long run, which is good for the economy even though is not a sustained GDP per capita. In addition, this study studied the policy implications of monetary policy on economic growth. Therefore, it would be of interest to study about the fiscal policy implications through examining the relationship between the projected output growth and the demand side variables. This have been done only for Solow model by Kim and Lim (2004) and found the demand side variables to predict the Solow residual. To address the issue of Solow model and the extended Solow model not explaining where the growth comes from as it takes productivity as exogeneous. We recommend a further study that "endogenize" Solow model with the following factors such as Patent protection, free trade, education, subsidize research and development and infrastructure to see the impact of them on actual output growth.

6. Appendix A

The production function method used to project potential output uses the same components as of Solow model that is presented in chapter 3 below.

Firstly, calculate the TFP as:

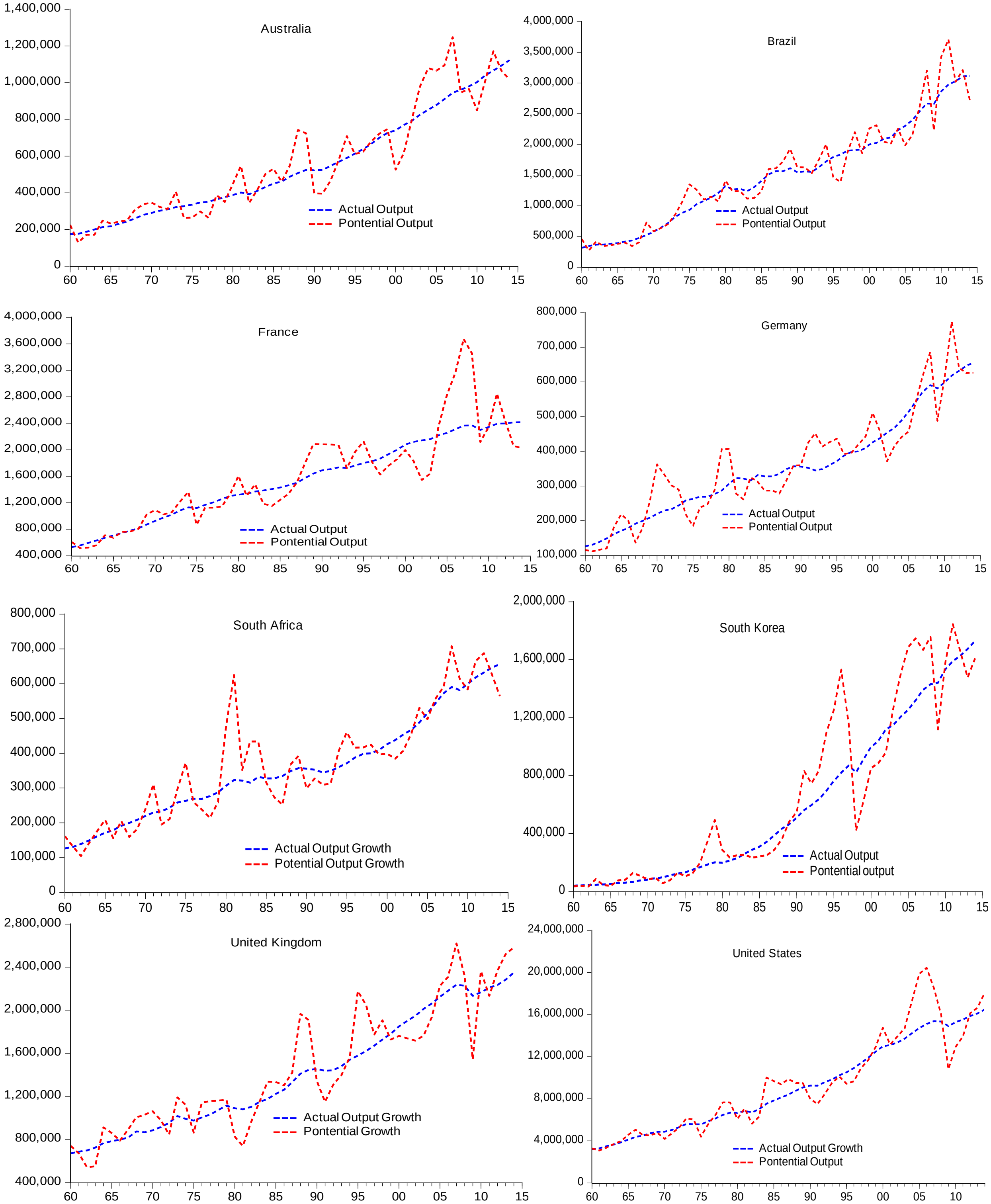
$$A_t = \frac{Y_t}{K_t^{\alpha} * L_t^{(1-\alpha)}} \qquad (A1)$$

Then derive labour and TFP's trends by applying the HP Filter. Therefore, the potential output becomes:

$$Y_t^* = A_t^* K_t^{\alpha} (L_t^{1-\alpha})^* \qquad (A2)$$

Where Y_t^* denote pontential output, $(L_t^{1-\alpha})^*$ denote labour trend and A_t^* denote TFP trend. Following Lienert and Gillmore (2015), there are two stages that central bank uses to project potential output: Firstly, they use the past years/quarterly data to project potential output.

A.1 The potential output versus real output growth

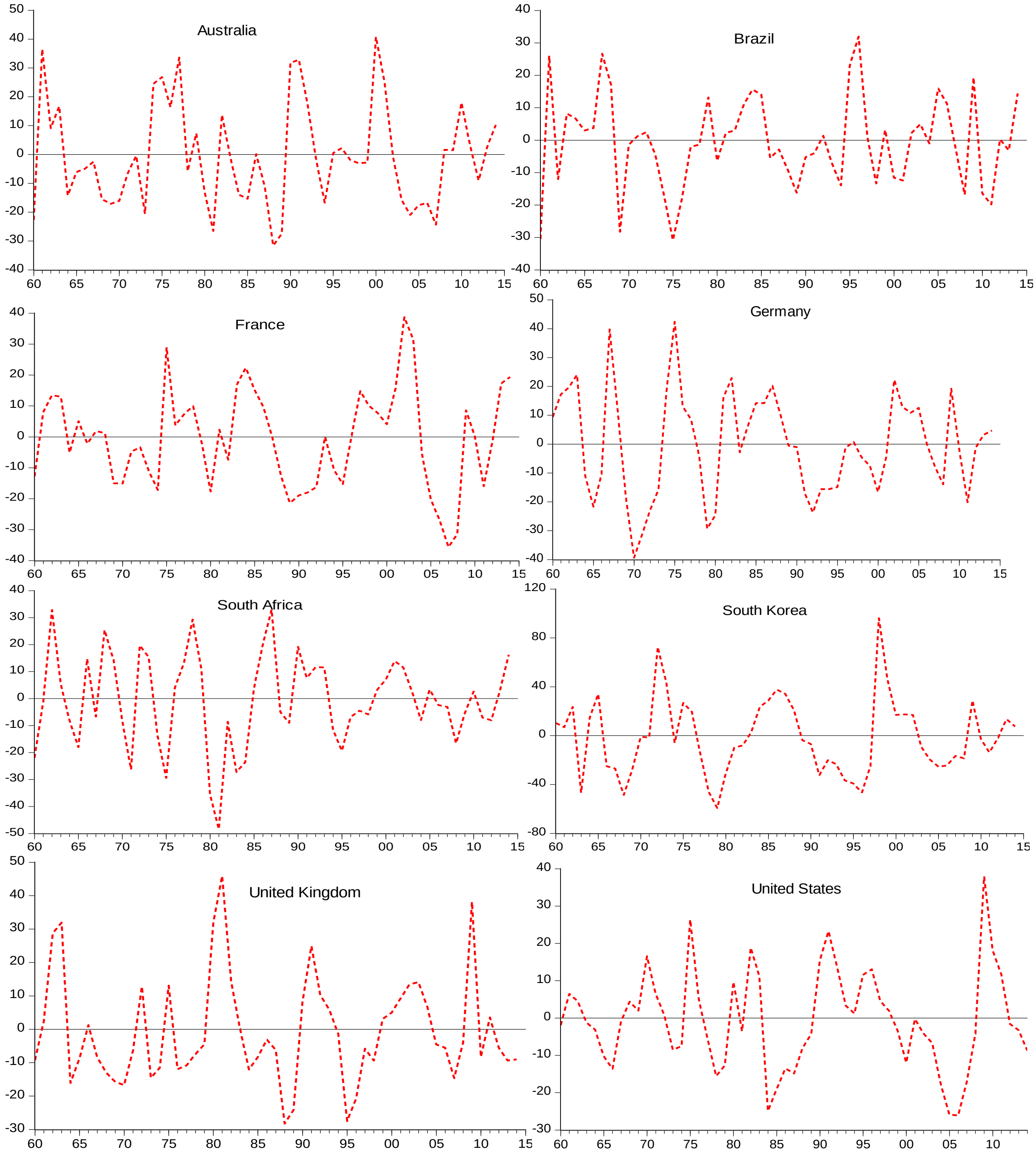


Lastly, isolate forecast of the future paths of the output gaps and potential output. Therefore, the output gap (z) becomes the difference between the real GDP and potential output ($\bar{y}$).

$$z_t = (y_t - \bar{y}_t) \qquad (A3)$$

We have computed the growth of real GDP and potential outputs which are presented in the following in figure 1 Appendix A. In most of the countries, we observe that, the potential output growth fluctuates around the real GDP growth.

A.2 The output gap



A.3. Unit root test and stationarity test

We conduct Augmented Dickey Fuller test statistic with Schwartz info Criteria, using the trend and intercept. For all the countries considered the actual output growth, Solow model, Extended Solow model, and Domar model test were found to be stationary at level I (0). Therefore, the regression analysis shows that the output is consistent in the long run. The AK model results were consistent except for South Korea were stationarity found at level I (1).

A.3.1 Australia

A.3.1.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.431610	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.1.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.431610	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.1.3 Stationarity test for estimated output growth for Extended Solow Model

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.431610	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.1.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-6.284240	0.0000

Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.1.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.895442	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.1.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.390445	0.0003
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.1.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.752033	0.0001
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

A.3.1.8 Stationarity test for estimated output growth for Romer Model

Null Hypothesis: EY has a unit root

Exogenous: Constant

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.748914	0.0064
Test critical values:	1% level	-3.584743	
	5% level	-2.928142	
	10% level	-2.602225	

A.3.2 Brazil

A.3.2.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.664699	0.0026
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.2.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.595429	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.2.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.502364	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.2.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.884938	0.0014
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.2.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY,2) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=3)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.275347	0.0057
Test critical values:	1% level	-4.886426	
	5% level	-3.828975	

	10% level	-3.362984	

A.3.2.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.077357	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.2.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.669463	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3 France

A.3.3.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.294563	0.0004
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.580081	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.580081	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.108926	0.0007
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic		-5.165717	0.0006
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.442341	0.0003
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.668940	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.3.8 Stationarity test for estimated output growth for Romer Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.550580	0.0048
Test critical values:	1% level	-4.252879	
	5% level	-3.548490	
	10% level	-3.207094	

A.3.4 Germany

A.3.4.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.813195	0.0001
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.4.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.575136	0.0033
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.4.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.617761	0.0030
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.4.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

	t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic		-6.932274	0.0000
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

A.3.4.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.235917	0.0000
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

A.3.4.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.142880	0.0000
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

A.3.4.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.475154	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.4.8 Stationarity test for estimated output growth for Romer Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.832881	0.0023
Test critical values:	1% level	-4.252879	
	5% level	-3.548490	
	10% level	-3.207094	

A.3.5 South Africa

A.3.5.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.708332	0.0023
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.5.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.654723	0.0027
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.5.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.773385	0.0019
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.5.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.563288	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.5.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY,2) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.179482	0.0000

Test critical values:	1% level	-4.186481
	5% level	-3.518090
	10% level	-3.189732

A.3.5.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.916632	0.0001
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

A.3.5.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-7.174555	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.6 South Korea

A.3.6.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.546215	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.6.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.430749	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.6.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.385901	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.6.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.637708	0.0000
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.6.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.312642	0.0004
Test critical values:	1% level	-4.175640	
	5% level	-3.513075	
	10% level	-3.186854	

A.3.6.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-8.635241	0.0000
Test critical values:	1% level	-4.180911	
	5% level	-3.515523	
	10% level	-3.188259	

A.3.6.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.838256	0.0016
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	

	10% level	-3.185512	

A.3.6.8 Stationarity test for estimated output growth for Romer Model

Null Hypothesis: D(EY,2) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 4 (Automatic - based on SIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.512243	0.0004
Test critical values:	1% level	-4.667883	
	5% level	-3.733200	
	10% level	-3.310349	

A.3.7 United Kingdom

A.3.7.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.557116	0.0035
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.416682	0.0003
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.412133	0.0003
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.876855	0.0014
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.590870	0.0032
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic		-4.175811	0.0099
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.182503	0.0006
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.7.8 Stationarity test for estimated output growth for Romer Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.454148	0.0058
Test critical values:	1% level	-4.234972	
	5% level	-3.540328	
	10% level	-3.202445	

A.3.8 United States

A.3.8.1 Stationarity test result for actual output growth

Null Hypothesis: GY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.107208	0.0007
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.2 Stationarity test for estimated output growth for Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.061639	0.0008
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.3 Stationarity test for estimated output growth for extended Solow Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.769766	0.0019
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.4 Stationarity test for estimated output growth for Domar Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.940081	0.0001
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.5 Stationarity test for estimated output growth for Goodwin Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.505452	0.0002
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.6 Stationarity test for estimated output growth for The AK Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.422492	0.0003
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.7 Stationarity test for estimated output growth for Lucas Model

Null Hypothesis: D(EY) has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.703147	0.0001
Test critical values:	1% level	-4.170583	
	5% level	-3.510740	
	10% level	-3.185512	

A.3.8.8 Stationarity test for estimated output growth for Romer Model

Null Hypothesis: EY has a unit root

Exogenous: Constant, Linear Trend

Lag Length: 0 (Automatic - based on SIC, maxlag=8)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.560643	0.0047
Test critical values:	1% level	-4.252879	
	5% level	-3.548490	
	10% level	-3.207094	

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