Capital Accumulation, Innovation and Economic Growth: A Cross-Country Analysis

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DEDICATON

Dedicated to Allah the most merciful and my parents, my grandparents, specially my Father Sohail Akbar, my beloved mother Afshan Sharif, my Ant Shehla Sharif and my uncle Rauf ur Rehman and of course my all family, friends and teachers.

DECLARATION

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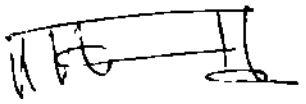

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Abstract

The main purpose of this study is to test the Howitt and Aghion (1998) theoretical model of innovation and capital accumulation using the 3 years averages of 76 developed and developing countries covering the time period 1997-2013 This study used an interaction model as used by Brambor et al (2006) and Bhatti et al (2013) for attainment of our results We estimate three models by using two proxies of innovation in each model The first model is the combination of 76 developed and developing countries The results show that innovation and capital accumulation are substitute to each other Furthermore, the results demonstrate that innovation has progressive and significant impact on economic growth On the other hand capital has progressive but insignificant impact on economic growth In second model (57 developed countries) the results are similar to our first model Lastly in our third model (19 developing countries), we found that there is a lot of variation in these results

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Chapter 1

Introduction

The investigation of the major sources of economic growth can be conducted in a number of ways and at different levels As discussed in Scott (1993), the early growth models focused on the effects of the basic inputs labor, capital and subsequently the impact of technology Then, the growth of inputs itself was examined Many studies propose different sources of economic growth including human capital, investment and technological innovation (Barro, 1991, Solow, 1956) If we talk about innovation, it is define as, any idea or introduction of any new component by an individual or firm in order to survive in market against their rivals is innovation Technological innovation is a process in which we invent new products/technologies on the basis of previous knowledge and experiments Likewise, according to a significant view, the key source to determine economic growth is innovation (Howitt and Aghion 1992, and Grossman and Helpman 1991) Similarly, when we talk about business R&D, firms do R&D by the view of monopoly rents which comes when there is a fruitful innovation In recent years, most of the social science publications are concentrating on innovation, so publication of innovation has increased much quicker than the whole number of such publication As an effect our understanding around innovation procedures, their social factors and economic influence is significantly improved Since innovation has affected almost all aspect of human life, it is concluded that innovation enhances economic growth (Romer 1990, Grossman and Helpman 1991) Giving credit to globalization and technological knowledge, an

economy is forced to accelerate its rhythm of innovation to expand its technological capabilities to foster competitiveness, productivity and most importantly to capture most of the global market share Romer (1986) has rightly marked Technological Development as one of the essential force for fueling economic growth However, economic growth is directly affected by the amount of innovation which is carried out domestically, how well the economy exploits external technological advancements by way of diffusion and finally how effectively an economy adopts such technological development (Martin and Ottaviano, 2001, Grossman and Helpman, 1994)

In 1970s, innovation had no such importance as it deserved and literature mostly focus on short run because of oil shocks and researchers took it as exogenous but in 1980s there emerged a huge body of literature and long run growth once again got space that take innovation as endogenous They focus on innovation and its relationship with living standards and economic development Furthermore, new age has been full of tremendous and mind boggling inventions that ushered eras of revolutions, from industrial revolution through information age, to the present Nano age No wonder, the human life has been radically changed and improved Today, innovation is a science fiction of the past and innovation of tomorrow is beyond reality of the future

Certain examples can be provided to authenticate the claims of this theory, for instance, the total value of Apple Inc has been $2 Billion back in 1997 prior to its technological leaps in innovation in terms of its flagship iPhone and other products like iPad and iPod Apple is now worth almost $600 billion that is mostly due to

innovation and economic growth Increase in the output of research, doesn't mean that this lead towards increase in the average growth rate because all the researches are not beneficial Innovation is one of the most important component of economic growth

Some studies up to some extent discourage innovation According to Grossman and Helpman (1991) in their hypothesis, efficient innovation in south discourage innovation in north Moreover, business stealing effect in which new innovation takes place of the old one, so the magnitude of innovation is going to decreases (Howitt and Aghion 1992) Furthermore, before 1992, Judd (1985) and Romer (1990) by using Dixit Stiglitz (1977) model of product variety conclude that "new products are no better than existing ones" On the other hand, Howitt and Aghion (1992) reject Judd (1985) and Romer (1990) point of view and comes up with the Schumpeter (1934) idea, a model of creative distraction in which new innovation continually destroying the old one

Many studies propose different sources of economic growth including human capital, investment, technological innovation and population growth (Barro, 1991, Solow, 1956) In the history many attempts have been made to capture the effect of capital accumulation on economic growth Likewise, (Lucas et al 1998) describe as the major player to determine long run economic growth world around In the support, some previous studies also discuss about the capital accumulation as a major contributor to economic growth (Colecchia and Schreyer, 2002, Rebelo, 1992, Tobin, 1965) Moreover, Bond et al, (2007) conclude that there is a large effect of investment, not just on the output per worker, but also on long run growth rate

Furthermore, Beaudry et al (2002) describe that there is a large effect of investment on growth Equally, according to neo classical growth theories, long term economic growth can be acquired through total factor of productivity (TFP) which on its part demands technological progress to contribute in economic growth (Howitt 2004)

It is widely acknowledged that capital takes a passive rather more of a supportive role when it comes to output, in other words capital effect output with no or very little improvement in growth (Aghion and Howitt 1998) In addition, a theory of Solow and Swan (1956) holds water to a certain extent that there is a point after which an economy would experience diminishing return on further investment in capital and technology

Some studies show that capital and innovation are important to each other For example, Kuwahara (2012) describe that when there is sufficient grant of capital (investment in R&D) with long run positive growth rate, the regime will change The reason behind is that when there is sufficient amount of capital endowment, it leads to falling R&D productivity Further, when there is enough capital stock for supporting R&D, economy will achieve long run economic growth According to Howitt and Aghion (1998), capital accumulation and technological progress need to play their own parts in complimentary manner to achieve continuous economic growth However, the theoretical predictions of their model are not tested empirically Therefore, this study attempts to fill-in this gap and investigates empirically, whether physical capital accumulation and innovation are complements or substitutes in generating economic growth

1.1 Objective of the study

There are two main purpose of our study

a. To test the theoretical model of Howitt and Aghion (Capital accumulation and technological innovation is complementary factor in long run growth process)

b To explore whether there exist any complementary/Substitutability between technological innovation and capital

1.2 Hypotheses

On the basis of our discussion in the above sub-section of objectives and reviewing the literature we formalized the following hypothesis

H1 The physical capital and innovation have a positive and significant impact on economic growth

H2 Innovation and capital are complementary to each other

1.3 Scheme of Study

The organization of the study is as follows Chapter 2 provides a review of growth literature related to innovation, literature on capital accumulation and literature on innovation and capital Chapter 3 discuss about the theoretical framework Chapter 4 describe the data and explain the empirical methodology used in our analysis We discuss our estimation results in Chapter 5 and we conclude our thesis in Chapter 6

Chapter 2

Literature Review

There is ample literature on innovation and capital accumulation We identify three themes of literature The first one is on innovation Second discuss capital accumulation and the last one is the combine literature on both (innovation and capital) Some studies are in the favor of innovation Some support capital and the last one combines both elements (innovation and capital) to determine economic growth

2.1. Growth Literature Related to Innovation

Our review shows various forms of innovation literature related to rapid growth While some studies suggested that formal R&D spending (Coad and Rao 2008) or more general R&D activities facilitate rapid growth (Stam and Wennberg 2009) According to Romer (1990), increase in the ideas lead to accumulated returns The accumulated ideas of an economy as a whole, rather than individual ideas, lead to increase in income per person The idea generation and its subsequent applicability leads to enhanced growth of the economy For example, the basic ways of farming are now replaced by mechanized farming, thus resulting in enhanced economic growth and increase in per capita income of a person Likewise, R&D based models support this view and suggest that technological progress results for maximizing individual profit (Marrewijk 1999) Similarly, in endogenous growth models, (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1998) conclude that the rate of technological progress results from incentives to innovate, as it determines

the long run economic growth without capital accumulation Romer (1990) supports the idea that research leads to technological progress, which eventually drives economic growth Furthermore, Roberts et al (1995), while describing plant productivity and survivability, highlighted the two main advantages of using advance manufacturing technologies firstly, it could directly rise the plant productivity and survivability, and secondly, a plant that has best managerial ability can fully utilize advance manufacturing technologies and implement new methods of production, is able to survive and grow because of their efficiency return This view is supported by Griliches and Siegel (1991) and Brynjolfson and Hitt (1993), use of advance manufacturing technologies and production are correlated to each other This ultimately creates a positive relationship between survival, technology adoption and growth (Roberts et al, 1995) Moreover, Blanchard (1997) concluded that technological progress drives growth Furthermore, Aghion and Howitt (1992) by using the growth model based on Schumpeter's method of creative destruction conclude that competition in technological development amongst research companies advances economic growth They also conclude in the favor of Schumpeter that innovation, if even by an individual, unusually benefits the whole economy Research is lifeline of innovation, without research innovation is dead and stagnant and technology would contribute to a certain point in economic growth, after that economic growth would become constant Aghion and Howitt (1998) observed that humans need is the mother of all inventions Empirical studies also support this notion and found that innovation has a positive impact on productivity of firms (Yih-Chyi and Chi-Mei 1999) According to Howitt (2000) point of view,

by using multi country model, indicated that diffusion and spillover of ideas could drive the convergence and growth

In this new era of innovation, technological levels have turned out to be the cardinal factors of competitive advantage It is also known that technological change impacts more on social returns to investment than private returns The most developed countries are now focusing on R&D and technological adoption (Mayer and Foster 2002) The innovation through R&D leads to greater saving in human capital and that raises the production per capita (Mayer and Foster 2002)

According to neoclassical framework investment is only important in short run, while technological progress is the key determinant in per capita growth in long run Boucekkine et al (2002) Mayer and Foster (2002) analyzed the variation in total manufacturing productivity in Mexican municipios from 1988 to 1993 in terms of human and physical capital inputs and variation in their outcomes They founded that rise in the outcomes of human capital proportionally raise productivity They also concluded that human capital are directly correlated with technological change Addition in human capital also increased technological change, resultantly increasing production Some studies focusing on the changing trend from capital accumulation based growth to R&D based growth (Zilibott 1995, Matsuyama 1999, Funke and Strulik 2000, Galor and Moav 2004, Irmen 2005)

Innovation is one of the key determinants of long term economic growth Olsen et al (2011) views, while discussing the key innovation indicators, innovation policy methods are conceptualized planned and executed based on theoretical thoughtful on market and general failure that are recognized in the national innovation system

According to this approach it is very important to rethink old policies on the way to new requirements, especially the requirements of identifying R&D based innovation as the main contributor in the present economies Private innovative entities are focused on portfolios of innovative developments, it plays a dominant role in all kind of companies in order to get long term economic advantages This interference basically focuses on innovative relationship, new business, long term and goal oriented Also, another point of view present market contains new product and services in turn increases R&D, fresh internal knowledge, project effect on R&D, rise in the exports and sales, collaboration (profitable and innovative followers), generally project is successful, contribution of knowledge growth, impact to planed effort on innovation, and the final contribution to the corporation's stand as an attractive and innovative business having a lot of possibilities Olsen et al (2011)

In recent decade, the trend of long run economic growth changed from capital accumulation to R&D because there is a strong connection between endogenous growth theory and long run economic growth Kuwahara (2012) He also found that when capital stock is sufficient for supporting R&D, long run economic growth will attain with R&D

Every economy has different or unique evaluation methods to control the economy If a country wants to achieve long run economic growth, it must have low cost of intermediate goods and there must be higher R&D efficiency When there will be higher R&D efficiency, it will lead towards increased long run economic growth and if an economy does not fulfill these terms and conditions, the economy is trapped in a vicious economic cycle Kuwahara (2012) When their will be sufficient grant of capital (particularly for

Investment in R&D) long run positive growth rate and a steady state point will be achieved The reason behind is that when their will be sufficient amount of capital endowment, it leads to falling investment in R&D productivity

Afonso et al (2013) discussing about the long run relationship between skill structure and technological structure, used extended model of endogenous direct technical change on cross country data, conclude that there is a positive relationship between the skill structure (ratio of high to low skilled industrial workers) and the technological structure (high vs low tech industrial sector) Combining both elements, economy will achieve long run economic growth He also observed that in the monopolistic economy that limits and revitalizes R&D for itself to prolong its market hegemony generating economic growth at a limited level. According to another point of view, Crescenzi and Pose (2013), using empirical analysis based on tailor made panel database from 1994 to 2007 of US, to forecast the innovation performance, observed that concentration of R&D activities is the key predictor at the local level They also found that the key predictor for regional innovative performance is local R&D investment In the same way, a huge literature describe that the important driver of innovative performance is local R&D investment at the local level in the U S (Feldman et al 1996, Acs et al 1997)

Armengot et al (2014) in his paper determine the factors of economic growth, using Romer (1990) model, analysis of three Southern European economies from 1960 to 2009, concluded that those economic policies which encourage technological progress, openness and innovation encourage economic growth and the economies that come to

an end or stop to convert themselves are meant to lost the path that leads to growth in economics

Besides, some studies describe, taking European economies as example, labor productivity is the factor of the growth in per capita income. More precisely, factors that fully utilized the available resources and involve technical progress and innovation in the production procedures (Caceres et al (2011) Matear et al (2012)), lead to increase in the total factor productivity (Howitt and Aghion 1992, Caballero and Jaffe 1993, Eaton and Kortum 1999, Mcgrattan and Schmitz 1999, Colino et al 2013)

Some recent studies contribute the new vision on the factor of economic growth Armengot et al (2014) sort out the contribution, the rate of growth increased by increasing in the stock of innovative ideas in the study state In this study it is also investigated that the Southern European economies for the last half century, apparent labor growth is generally due to development of total factor productivity owing to technological progress and innovation Another findings related to southern European economies, in 1960's shows that technological progress has increased 2 percent productivity per worker, hence, in economic growth

Further, one of the factor that effect economic growth is artificial intelligence When it used to substitute workers with machines, it will lead to increase in the future economic growth Fernald and Jones (2014)

Some studies do not support the above point of view If we talk about developing countries, technological change is not well accounted for, and are

more focused on complementary and substitute strategies to increase productivity Mayer and Foster (2002) Whereas, in developed countries the effect of innovation and technological progress is quiet slow as compared to developing countries Fernald and Jones (2014) discussing about the future of US growth, using Jones (2002) semi endogenous growth model and data from 1870 to 2012 concluded that the future of US is slower than its past

2.2. Literature on Capital Accumulation

Capital accumulation also plays an important role to boost economic growth Some studies support it while some reject it Studies that support capital accumulation towards economic growth are described below

Capital plays an independent role in the plant productivity and is directly relevant with plant growth and negatively related with plant failure Roberts et al (1995) A conference in Prague held in June 2000 represents "physical capital accumulation was found to be the dominant source of growth both within and across regions"

Additionally Todaro (2000) says that "a necessary condition" for economic growth is increase in investment Moreover, investment play a vital role for the economy of any country

People travel for education and working opportunities, in search of better standard of living Therefore, the investment in enterprises will attract skilled labor force Due to this, a large number of skilled labor and industrial attention will invite more specialized and innovative industry in the country This will increase the productivity of the country and it leads to economic growth Mayer and Foster (2002) In the same way Beaudry et al (2002) concludes that there is large effect of investment in more current periods Besides, the point that product demand is one of the key determinants for increase market size on technological change related In the favor of this view Howitt and Mayer (2000), using convergence club model, concluded that human and physical capital create higher incentives for innovation through the rising revenues in

a higher market According to significant view describe that investment in physical capital is not much important for economic growth Bond et al (2004)

Some of the macro based indicators sets take account of the strength of project, the key indicator of innovative ability in a country is capital investment The fact is that, countries have high private investment or great projects, shows great innovation action in the business sector Olsen et al (2011) Kuwahara (2012) evaluating the growth system shifting from factor accumulation to knowledge accumulation, using dynamic model that is based on Romer (1990) with endogenously accumulated R&D inputs According to his final results, long run growth rate is positively connected to physical capital accumulation Also, he showed that a country having low initial capital then its economic progress is based on capital accumulation

Some studies criticize the above mention view of capital accumulation According to Romer (1996) "the driving force of growth is accumulation of knowledge Capital accumulation is not central to growth"

Neo-classical framework states that in order to maintain economic growth rate in long run, there must be process of sustainable advancement in technological knowledge, like new products advance market or new process of production (Howitt and Aghion, 1998) Similarly, Jones (1995) and Blomstrom et al, (1996), finds no empirical evidence of capital accumulation and long run growth rates

Provided that recent empirical literature do not support any strong relationship between capital accumulation and growth (Easterly and Levine, 2001) Solow and

Swan (1956) the critical property of aggregate production function show the diminishing returns if there is capital accumulation

2.3. Literature on Innovation and Capital Accumulation

Innovation and capital's combine effect is also support by the existing literature on economic growth Innovation and capital's combined effect is also supported by the existing literature on economic growth According to Roberts et al (1995) while analyzing the plant performance developing three institution level U S Census Bureau data sets, found that the plants engaging or using advance technologies and capital intensive plants have less risk, whereas capital intensive plants have less risk of failing and are higher succeeding rate of growth They also found that rise in the advance manufacturing technologies (AMTs) and rises in the capital amount of input mix are positively correlated with plant growth and negatively correlated with plant failure Some other author's analyze plant performance and show evidence that plant have to adopt latest and more capital demanding technologies (Mansfield 1968, Romeo 1975, Kelley and Brooks 1991 and Dunne 1994)

Howitt and Aghion (1998) developed a simple endogenous growth model which combines the elements of Solow and Swan neoclassical model of capital accumulation and their model of creative destruction (1992) The theoretical combines effect of capital accumulation and innovation on economic growth and finds that if there will be subsidy to physical or human capital, it will have a permanent effect on economic growth rate Similarly Marrewijk (1999) suggests that capital and innovation are complementary to each other and neither of which takes

place without each other in long run According to economists, factors that are responsible for defining the progress rate in the economies and the factors that rises multifactor efficiency are organizational factors, capital expanding and investment in research and training (Kaldor 1961, Shell 1966, Jones and Williams 1998)

Literature concludes that in the history of development and growth, especially in earlier 1980s, innovation takes as exogenous and had no such value At that time capital is determine as a key factor in long run growth But after 1980s and in earlier 1990s, one of the greatest main debates supported innovation and took it as an endogenous

Armengol et al (2014) Howitt and Aghion play a vital role to determine innovation as a key to long run economic growth Now a days a lot of countries are trying to achieve long run economic growth and prosperity due to technological progress Similarly capital plays crucial role, it is the one of the most significant factor for economic growth When we combine both innovation and capital, they act like a substitutes of each other According to our analysis, we also found that innovation and capital both are substitute to each other

Chapter 3

Theoretical Framework

The top elementary share of growth theory in the long run is that in order to encourage a progressive growth rate of productivity per capita, the requirement is to be repeated developments in technological knowledge through innovative procedures

For the last two decades, economic history has practiced an excessive development of fresh growth theories This developed literature is divided into two parts The first type of models highlight on the endogenous accumulation of factors of production like human and physical capital (Bond et al 1996, Lucas 1998, Barro and Sala-i-Martin 2003) The second type of models are (Romer 1990, Grossman and Helpman 1991, Howitt and Aghion 1992, Howitt and Aghion 1998) In these models they share a collective feature that purposive research actions cause the technical progress which is the major contributor in long run growth In early 1980's, innovation have not much importance and not considered as a main component for determining long run economic growth but in late 1980's the whole scenario was changed and it became one of the main and key components for long run economic growth Equally, Howitt (2000), using Schumpeterian model describes that when their will be improvement in innovation in a country it will increase the productivity of the other countries It means that the countries who carry out R&D have to converge to similar long run growth tracks Likewise, in Phillip Lebel (2008), doing empirical study, he concluded that there is a positive effect

of innovation on economic growth Furthermore, Galindo and Mendez (2013) describe that economic action encourage innovation and entrepreneurship activities and that's lead towards economic growth Moreover, Jones (1995), the initial AK model established by (Romer 1986, Lucas 1988, Rebelo 1991) and successive growth models made by (Romer 1990, Grossman and Helpman 1991, Howitt and Aghion 1992), recommended that investment has long lasting effect on economic growth rate of the economy By technological spillovers and with learning by doing it can also expand the long run pathways of growth Herrerias and Orts (2010) Additionally, they also concluded that vastly skilled workforces make bigger values of fresh improved quality changes of commodities and could rise the production of physical capital over specialization and by educating the learning by doing process and that's result increasing the efficiency and production

Capital is one of the most important factor for generating long run economic growth Some authors like Howitt and Aghion (1998) suggest that, giving subsidy on capital is very reasonable for EG In fact, physical capital stock is truly used by R&D, like used in offices, computers, additional technical tools, space vehicles, laboratories, tools required for testing and making experimental models, plants, and so on Rise in the rate of capital subsidy will increase the encouragement, not just to accumulate capital but as well as to innovate This procedure will complete in two ways The first one, rise in the capital stock must encourage greater R&D over and done with a scale effect Due to this, it will increase the nationwide income and from this time the demand for the products made by successful innovators increases which is an incentive to innovate

The second way, rise in the capital in the long run will decrease the cost of capital, and hence decrease the capital factor for the R&D cost (Howitt and Aghion 1998)

Literature shows that Howitt and Aghion (1998) article, they presented a Schumpeterian growth theory, which treats innovation and capital accumulation as equivalent contributor for long run growth Their model includes the important features of Solow model (1956) of capital accumulation and Howitt and Aghion (1992) model of creative destruction is a simple framework On the other hand, the interpretation of neoclassical growth idea and further endogenous growth ideas, when their will be a subsidy to capital accumulation, any human or physical that will effect permanent to the growth rate of the economy According to this outcome, the acknowledgement of capital which is used as an input to R&D suggest that government have been faced by apparently unsolvable incentive difficulties when trying to support R&D straightly They argue that a wide support to capital accumulation is a mean of encouraging technological progress and growth in the long run as a direct subsidy to R&D Such a support might work not by encouraging a greater rate of technological progress through learning by doing through increasing the rate at which new technologies are embodied in new capital goods but relatively by increasing the incentive to innovations, there need capital for the production and implementation

Chapter 4

Data and Empirical Methodology

4.1. Data

Our estimation technique examines three year averages of growth in 76 countries (developed and developing) There are 57 developed and 19 developing countries and the time period is from 1997-2013 Our dependent variable is economic growth of real GDP per capita (EG) Our independent variables are initial value of (log) real per capita GDP (Y0) include to control for convergence, average years of schooling (SCHOOL) to allow for human capital (Barro, 1991, Mankiw et al, 1992) Capital stock growth (CAP) and research and development expenditure percent of GDP (RND) are the core independent variables The capital stock growth (CAP) is use as a measure of physical capital accumulation For innovation we use two proxies The first one is research and development expenditure percent of GDP (RND) use as input measure of innovation The second is total number of patent applications per million of population (PATENT) as an output measure of innovation For further robustness, we also include the following control variables in our basic model openness (OPEN), government size (GOV), and inflation (INF)

4.1.1. Dependent Variable

Our dependent variable is growth rate of real per capita GDP This data is taken from World Development Indicators WDI (2013) database This data is in constant 2005 U S dollars GDP per capita is the sum of gross value by all resident makers added

in the economy plus product taxes minus subsidies not counted in in the value of the products This value is calculated without creating depletion of natural resources or generating deduction for depreciation of developed assets GDP per capita basically is the gross domestic product divided by the midyear population For creation of growth rate, first of all we take natural log of current value of real per capita GDP and after that we subtract it from the natural log of previous value of real per capita GDP and in the last we multiply it with 100 This method is repeated for each single country for the new variable of growth rate for every country

4.1.2. Independent Variables

Capital stock growth (CAP) is used as a measure of physical capital accumulation Its data is taken from Penn World Tables, version 8 0 We take data of capital stock at constant 2005 national prices (in million 2005/US$) Research and Development expenditure percent of GDP (RND) data source is United Nation Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistic The definition of R&D expenditure percentage of GDP is the expenditure for research and development are recent and investment expenditure (both private and public) on inventive work carry out systematically to increase knowledge, society, culture and the use of information for new applicants CAP*RND is the interaction term of capital stock growth and research and development expenditure percent of GDP

Total number of patent applications per million of population (PATENT) is used as an output measure of innovation The data is taken from World Intellectual Property Organization (WIPO) For the construction of this variable, we take resident patent application, non-resident patent application and total population per million First we

add resident and non-resident patent applications and then we divided by total population per million After doing this we have total number of patent applications per million of population CAP*PATENT is the interaction term of capital stock growth and total number of patent applications per million of population

4.1.3. Control Variables

Y0 is the initial value of (log) real per capita GDP that is taken from WDI (2013) database Y0 is found to be significant in a wide range of specifications in the empirical growth literature (Levine and Renelt, 1992)

Secondary school enrolment percent of gross (SCHOOL) data is taken from United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics which is secondary school enrolment percent of gross Gross enrolment ratio is the ratio of total enrolment, unrelatedly to age, to the age group of population that formally match as the level of education made known

Openness (OPEN) is the sum of exports of goods and services percentage of GDP and the imports of goods and services percentage of GDP Openness data is taken from World Bank national accounts data and OECD National Accounts data files The exports of goods and services represent the value of market services and all goods given to the world The imports of goods and services represent the value of market services and all goods received from the world

General government final consumption expenditure percentage of GDP (GOV) data is also taken from World Bank national accounts data and OECD National Accounts data files GOV is general government final consumption expenditures also known

as formerly general government consumption It contains the current expenditures of the government for the buying of goods and services, expenditures on national security and defence but excluding government military expenditures that are part of government capital formation

Inflation (INF) data is taken from International Monetary Fund, International Financial Statistic and data files INF is measured by the consumer price index and reflects the annual percentage change in the cost of the average consumer of obtaining the basket of goods and services that may be fixed or changed at specified intervals

4.2. Summary Statistics

Table 4.1: Summary of Data for 76 Countries (Developed and Developing)

Variable	N	Mean	P50	SD	Min	Max
EG	456	2 597	2 500	2 941	-6 271	12 87
CAP	380	12 73	12 91	1 588	9 567	15 99
RND	375	-0 46	-0 387	1 062	-3 352	1 478
PATENT	412	4 48	4 529	1 579	-2 506	7 629
CAPRND	341	-6 156	-5 598	13 39	-44 58	19 30
CAPPATENT	352	58 39	57 22	23 24	-29 29	106 8
LY0	455	8 643	8 583	1 494	4 893	11 35
SCHOOL	420	4 454	4 537	0 351	2 283	5 047
OPEN	446	4 439	4 424	0 481	3 390	6 118
GOV	445	2 765	2 867	0 329	1 734	3 368
INF	452	2 031	1 907	0 657	-1 620	5 894

Note: EG is growth rate of real per capita GDP, CAP is log of physical capital stock, RND is log of R&D expenditures % of GDP, PATENT is log of total number of patent application per million of population, CAPRND is the log of CAP and RND (interaction term), CAPPATENT is the log of CAP and PATENT (interaction term), LY0 is log of initial value of real per capita GDP, SCHOOL is log of secondary school enrolment percent of gross, OPEN is log trade openness, GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

Table 4.2: Summary of Data for 57 Developed Countries

Variable	N	Mean	P50	SD	Min	Max
EG	342	2 382	2 259	2 862	-6 270	12 87
CAP	285	13 03	13 22	1 537	9 567	15 98
RND	299	- 1957	- 1605	9522	-3 087	1 477
PATENT	312	4 991	4 965	1 195	2 016	7 628
CAPRND	265	-2 918	-2 517	12 53	-44 57	19 30
CAPPATENT	265	4042 0	1893 5	5464 2	102 5	27293 3
LY0	341	9 291	9 255	1 051	7 357	11 35
SCHOOL	324	4 559	4 561	1680	4 063	5 046
OPEN	332	4 497	4 472	4921	3 489	6 118
GOV	332	2 845	2 926	2952	1 855	3 368
INF	339	1 933	1 760	6721	-1 620	5 894

Note: EG is growth rate of real per capita GDP, CAP is log of physical capital stock, RND is log of R&D expenditures % of GDP, PATENT is log of total number of patent application per million of population, CAPRND is the log of CAP and RND (interaction term), CAPPATENT is the log of CAP and PATENT (interaction term), LY0 is log of initial value of real per capita GDP, SCHOOL is log of secondary school enrolment percent of gross, OPEN is log trade openness, GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

Table 4.3: Summary of Data for 19 Developing Countries

Variable	N	Mean	P50	SD	Min	Max
EG	114	3 243	3 079	3 089	-4 360	12 37
CAP	95	11 83	11 21	1 389	9 956	14 93
RND	76	-1 501	-1 533	8023	-3 352	1140
PATENT	100	2 887	3 259	1 570	-2 506	4 901
CAPRND	76	-17 44	-16 58	9 678	-41 18	1 623
CAPPATENT	87	34 72	38 23	19 40	-29 28	70 06
LY0	114	6 702	6 904	7523	4 893	7 796
SCHOOL	96	4 096	4 352	5286	2 283	4 639
OPEN	114	4 268	4 258	4034	3 390	5 090
GOV	113	2 528	2 491	3105	1 734	3 175
INF	113	2 178	2 290	7634	-3 645	3 413

Note. EG is growth rate of real per capita GDP, CAP is log of physical capital stock, RND is log of R&D expenditures % of GDP, PATENT is log of total number of patent application per million of population, CAPRND is the log of CAP and RND (interaction term), CAPPATENT is the log of CAP and PATENT (interaction term), LY0 is log of initial value of real per capita GDP, SCHOOL is log of secondary school enrolment percent of gross, OPEN is log trade openness, GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

4.3. Estimation Methodology

In this section we discuss estimation methods and model specification that are used in our methodology We use an interaction model as used by Brambor et al (2006) and Bhatti et al (2013)

$$EG_{it} = \beta_1 Y0_{it} + \beta_2 SCHOOL_{it} + \beta_3 CAP_{it} + \beta_4 INO_{it} + \beta_5 CAP^{*} INO_{it} + \beta_6 X' + \eta_i + u_{it} \quad (4.1)$$

$i = 1,2,3, - - - -, 76$

$t = 1997, 1998, 1999, - - - -, 2013$

where, EG is economic growth, Y_0 is log of initial real per capita GDP, SCHOOL is human capital, CAP is capital stock growth, INO is innovation, we use two measures of innovation research and development (RND) and PATENT RND is used as input of innovation and PATENT is used as output of innovation X' is a vector of control variables such as OPEN, GOV and INF, u is stochastic error term The subscripts *(i)* and *(t)* represent countries and time respectively

For the estimation of our model, we used Hausman test to make a choice between random effect and fixed effect When we apply Hausman test on our model it gave us the results that fixed effect is feasible for our model We estimate the above equation two times by employing the method of fixed effects for panel data models as used by Islam (1995) First we estimate our model from RND (used as an input measure of innovation) and then we estimate our model from PATENT (used as an output measure of innovation) The first equation that we estimate with RND is,

$$EG_{it} = \beta_1 YO_{it} + \beta_2 SCHOOL_{it} + \beta_3 CAP_{it} + \beta_4 RND_{it} + \beta_5 CAP^{*}RND_{it} + \beta_6 X' + \eta_i + u_{it} \quad (4.2)$$

i = 1,2,3,- - - -, 76

t = 1997, 1998, 1999,- - - -, 2013

The second equation that we estimate with PATENT is

$$EG_{it} = \beta_1 YO_{it} + \beta_2 SCHOOL_{it} + \beta_3 CAP_{it} + \beta_4 PATENT_{it} + \beta_5 CAP^{*}PATENT_{it} + \beta_6 X' + \eta_i + u_{it} \quad (4.3)$$

i = 1,2,3,- - - -, 76

t = 1997, 1998, 1999,- - - -, 2013

Hausman test define whether the random effect model is more reliable or the fixed effect method This test examines the null hypothesis that random effect model is effective and reliable in contrast to the alternative hypothesis that random effect model is unreliable In our case it prefer fixed effect Further, we use robust option of STATA with all our regression equations

4.4.1. Fixed Effect Estimation

Panel data delivers us new information regarding "within variability" of matters and time periods, as a result regression methods used for panel data, allow us to advantage from these not the same types of information We analyze panel data by additional regression procedures as a substitute of specific regression procedures established for panel data but these other obtainable regression methods will not be ideal since of the problematic of absent variable bias The outcomes attained from common methods might be biased for the reason that it does not deliberate some

variables which cannot be detected but may affect the dependent variable There are two types of such unobserved effects First is fixed effect and the second one is random effect Hear we discuss the first type

Fixed effect which think through variations within subjects but keep on constant over time An amount of panel data methods are used in the growth literature to evaluate econometric models As Islam (1995), Arellano and Bover (1995) and Bond et al (2001), we also used Fixed Effect technique for panels This technique is mainly used to deal with the unobserved effects that differ within cases but stay constant over time It agrees us to developed the cross sectional facts for panel data to clarify the inconsistency of dependent variable with respect to independent variables and overlooked time invariant things The core advantage of fixed effect model is that it agree to unobserved specific effects to be connected with additional explanatory variables The indication is that, in gathering data, there might be probability of unconscious lack of knowledge of some variables which can be disturb the dependent variable Consequently, these unnoticed variables are covered by unnoticed effects

4.4.2. Random Effect Estimation

The second type of unobserved effect is random effect which measures the effect that keep on constant inside subjects but differ over time This estimation method studies the time series data of the panel data as additional significant This model assumes that unobserved effects are uncorrelated with explanatory variables in each time interval In detail, the assumption of fixed and random effect models is the same but in random effect, an adding unnoticed effects are uncorrelated with descriptive variables in collectively time period

4.4.3. Hausman Test

The fundamental difference among random and fixed effect method depend on the correlation among single specific effects and the descriptive variables of a regression Random effects method does not measure the connection among single specific effect and descriptive variables, whereas fixed effect agree to this correlation This change of expectation plays an essential role used for the investigators to pick out in the middle of random and fixed effects Many investigators discover fixed effect by means of an additional suitable tool to approximate the panel data for the reason that it measured constant effects Random effects technique is likewise used in convinced circumstances, precisely in models where fundamental independent variable is constant over time Even though these two panel data procedures have exclusive features, but it is problematic to choose between random and fixed effects used for a regression To overcome this trouble a detailed test for selecting in the middle of random effects and fixed effects model remained developed by Hausman (1978)

For a detailed data set and model, Hausman test observes whether the random effects technique is additionally effective or the fixed effects technique Hausman test examines the null hypothesis that random effects model is reliable and effective in contrast to the alternate hypothesis that random effects model is unreliable We accomplish Hausman test to pick out in the middle of random effects and fixed effects by means of a technique of estimation, and our examination result favor the technique of fixed effects In addition, we use robust selection of STATA by means of all our regression equation

Chapter 5

Estimation and Results

Before 1980,s most of the literature mostly focus on the capital Capital is the main component for long run economic growth (Mansfield 1968 and Romeo 1975). In mid-1980s most of the researchers focus on innovation that plays a leading role for the long run economic growth (Olsen et al 2011, Kuwahara 2012, Crescenzi and Pose 2013)

Our empirical analysis consists of 3 year averages on 76 countries (developed and developing) In our models we use two measures of innovation first is research and development (RND) as input and the second one is PATENT as output measure of innovation So our results of both RND and PATENT are in separate tables as mentioned below Our results are given in Table 5 1 with RND and Table 5 2 with PATENT For further robustness, we split our data into developed and developing countries There are 57 developed countries with three year averages and their results are shown in Table 5 3 with RND and Table 5 4 with PATENT and 19 developing countries and their results are shown in Table 5 5 with RND and Table 5 6 with PATENT

The dependent variable in our model is economic growth (EG) It further include two types (1) explain that all outliers are including in this model and (2), which describe that this model is not including outliers Model (2) is our general model in Table 5 1,

Table 5.1: 3 year averages for 76 countries (developed and developing)

3 Years Average	Model 1 Base line		Model 2 General	
Coefficient	All Obs (1)	Outliers Excluded (2)	All Obs (3)	Outliers Excluded (4)
CAP_{it}	1 239	1 883	- 2708	2338
	(0 552)	(0 191)	(0 898)	(0 864)
RND_{it}	8 223	11 74**	6 003	11 18***
	(0 272)	(0 034)	(0 387)	(0 010)
$CAP_{it} * RND_{it}$	- 7981	-1 038**	- 5901	- 9527***
	(0 171)	(0 017)	(0 291)	(0 007)
Control Variables				
$Y0_{it}$	-6 077***	-6 815***	-6 645***	-7 004***
	(0 000)	(0 000)	(0 001)	(0 000)
$SCHOOL_{it}$	4 844*	5 934***	4 487*	4 553***
	(0 088)	(0 002)	(0 064)	(0 001)
$OPEN_{it}$			6 613***	7 242***
			(0 000)	(0 000)
GOV_{it}			-7 529**	-9 981***
			(0 023)	(0 000)
INF_{it}			- 9873**	- 9767***
			(0 019)	(0 003)
Number of Observation	326	295	325	285

Notes The p-values are reported in brackets ***, ** and * indicate significance at 1%, 5% and 10 % respectively The dependent variable is real per capita GDP growth CAP is log of physical capital stock growth, RND is log of R&D expenditures % of GDP CAPRND is the log of CAP and RND (interaction term) LY0 is log of initial value of real per capita GDP SCHOOL is secondary school enrolment OPEN is log trade openness GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

5 2, 5 3, 5 4, 5 5 and 5 6 Model (3) is our Parsimonious model in Table 5 5 and 5 6 Model (1) is our baseline model which think through our main explanatory variables that is physical capital stock (CAP), R&D expenditures percent of GDP (RND), interaction of physical capital stock and R&D expenditures percent of GDP (CAP*RND), initial value of real per capita GDP (Y0) and human capital (SCHOOL) To get model (2), we take account of the control variables in model (1) such as OPEN, GOV and INF at the same time to evaluate the growth model in comprehensive view For the estimation of model (3), we eliminates some control variables step by step till our model gave us best possible results This practice is only in Table 5 5 and 5 6 In Table 5 1, model (1) and model (2) is divided in to two parts The first part is including outliers and the second part is without outliers

In Table 5 1, model (1) the coefficient of CAP shows that the impact of CAP on EG in first regression are positive and insignificant with and without outliers but in second model CAP has negative and insignificant effect including outliers but gave same results as model one without outliers, their amount on the other hand be different through the regression with not the same control variables The results of RND in models (1) and (2) are positively related to economic growth in all regression but insignificant in both models with outliers with economic growth and significant without outliers with EG The results indicate that RND plays a vital and key role for long term economic growth and it's very much important to improve the goods and its production process efficiently The interaction term CAP*RND has negative relationship with EG in all regression of model (1) and (2) Negative sign shows that

physical capital stock (CAP) and research and development expenditures percent of GDP (RND), they are substitute to each other This interaction term CAP*RND has insignificant effect on EG (including outliers) and highly significant effect on EG (without outliers) in both models Our baseline theoretical results also show that CAP and RND are substitute to each other (Howitt and Aghion, 1998)

The log of initial real per capita GDP (Y0) is involved to put up the merging effects in growth regression In these two models Y0 show negative and highly significant coefficient (with and without outliers) of initial value of real per capita GDP (Y0) Outcomes of growth regression used for combined data indicate that the variable of human capital which is average of schooling years (SCHOOL) has a positive and highly significant impact on EG (with and without outliers) in both model (1) and model (2) Some previous studies observe that quality of education is important for EG The literature and common hypothesis indicate the positive influence of human capital on EG, however some time results show negative sign, it may be due to the existence of outliers Studies that show negative effect of human

Capital on EG are Pritchett (2001) and Benhabib and Spiegel (1994)

The control variables that we use in our model are openness (OPEN), government size (GOV) and inflation (INF) The results of openness (OPEN) describe a positive and extremely significant (with and without outliers) relationship with EG The results of Government size (GOV) indicate negative and highly significant effect (with and without outliers) on economic growth Similarly, inflation results also show negative and highly significant effect (with and without outliers) on economic growth

Table 5.2: 3 year averages for 76 countries (developed and developing)

3 Years Average	Model 1 Base line		Model 2 General	
Coefficient	All Obs (1)	Outliers Excluded (2)	All Obs (3)	Outliers Excluded (4)
CAP_{it}	2 114	2 020	4639	7988
	(0 348)	(0 221)	(0 849)	(0 580)
$PATENT_{it}$	5 735*	5 452**	3 943	5 028**
	(0 061)	(0 031)	(0 126)	(0 014)
$CAP_{it} * PATENT_{it}$	- 4402*	- 3775*	- 2942	- 3753**
	(0 090)	(0 072)	(0 148)	(0 018)
Control Variables				
$Y0_{it}$	-5 274***	-4 464***	-6 158***	-4 837***
	(0 001)	(0 001)	(0 001)	(0 001)
$SCHOOL_{it}$	5 110**	5 097***	5 261***	5 422***
	(0 019)	(0 004)	(0 007)	(0 000)
$OPEN_{it}$			6 171***	5 613***
			(0 001)	(0 000)
GOV_{it}			-6 398**	-9 968***
			(0 021)	(0 000)
INF_{it}			-1 251***	-1 098***
			(0 001)	(0 001)
Number of Observation	335	306	334	303

Notes. The p-values are reported in brackets ***, ** and * indicate significance at 1%, 5% and 10 % respectively The dependent variable is real per capita GDP growth CAP is log of physical capital stock growth PATENT is log of total number of patent application per million of population CAPPATENT is the log of CAP and PATENT (interaction term) LY0 is log of initial value of real per capita GDP SCHOOL is secondary school enrolment OPEN is log trade openness GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

In Table 5 2, the core and main variables like physical capital stock (CAP) with PATENT show positive and insignificant effect on EG These results are very nearly to RND results in Table 5 1 and just only one sign is negative in Table 5 1 in general model (with outliers) This means that the effect of CAP is positively related to economic growth but not significant According to these results CAP is less important as compare to innovation PATENT results describe that there is positive and significant effect on EG but in model 2 (with outliers) the results are less insignificant but positive These innovation outcomes highly effect the long run economic growth Agreeing to our results, innovation is the key component for long run economic growth Through innovation economies can grow and become the leadings economies of the world The interaction term of CAP and PATENT (CAP*PATENT) shows that its effect on economic growth (with and without outliers) is negative and significant both baseline and general model Negative sign shows that CAP and PATENT are substitute to each other as Howitt and Aghion (1998) find in their theoretical model

In Table 5 2, Y0 results show negative and extremely significant connection with EG in both models (with and without outliers) These results are so much similar to the results of RND In the same way the results of secondary school enrollment (SCHOOL) of RND and PATENT are almost similar to each other SCHOOL results are positive and highly significant relation by EG (with and without outliers) The reason of their positive and highly significant results show that education is one of the most important variable to determine the long run economic growth When people get education and especially technical education, people start innovating new-

Table 5.3: 3 Year Averages for 57 Developed Countries

Developed Countries With (RND)	Model 1 Base line		Model 2 General	
Coefficient	All Obs (1)	Outliers Excluded (2)	All Obs (3)	Outliers Excluded (4)
CAP_{it}	2 384	2 085	3 311	2 323
	(0 455)	(0 356)	(0 265)	(0 174)
RND_{it}	10 03	10 81	9 833	10 89**
	(0 237)	(0 114)	(0 140)	(0 015)
$CAP_{it} * RND_{it}$	- 9760	- 9681*	- 8897	- 9100**
	(0 141)	(0 068)	(0 116)	(0 012)
Control Variables				
$Y0_{it}$	-7 184***	-7 266***	-11 46***	-10 21***
	(0 004)	(0 001)	(0 000)	(0 000)
$SCHOOL_{it}$	5 333*	6 017**	3 150	3 917***
	(0 090)	(0 011)	(0 248)	(0 006)
$OPEN_{it}$			8 754***	8 230***
			(0 000)	(0 000)
GOV_{it}			-11 36***	-11 81***
			(0 000)	(0 000)
INF_{it}			-1 003**	-1 014***
			(0 034)	(0 003)
Number of Observation	259	237	258	231

Notes: The p-values are reported in brackets ***, ** and * indicate significance at 1%, 5% and 10 % respectively The dependent variable is real per capita GDP growth CAP is log of physical capital stock growth, RND is log of R&D expenditures % of GDP CAPRND is the log of CAP and RND (interaction term) LY0 is log of initial value of real per capita GDP SCHOOL is secondary school enrolment OPEN is log trade openness GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

-invention and new production process that leads to increase in the efficiency of production, it leads to increase in economic growth The results of control variables OPEN, GOV and INF of Table 5 1 and 5 2 (with and without outliers) are same

In first 2 Tables, 5 1 and 5 2 we discuss about 76 developed and developing countries further we split our data in to two categories, 57 developed and 19 developing countries and check the results First we take 57 developed countries and run a regression and Table 5 3 shows these results In Table 5 3 results of CAP shows that the relationship of CAP and EG are positively and insignificantly associated with each other in both baseline and general model (with and without outliers) In developed countries the effect of investment is positive but insignificant because developed countries economic growth is already at high level So when we spend more, the effect of CAP is slowly effect the economic growth so that's why it's insignificant RND results are also positively related to economic growth (EG) in both models but in our baseline model it's insignificant with outliers and without outliers These results in developed countries may be due to highly competitive markets and high investment in innovation When there will be highly competitive markets, less possibility to earn huge profits, due to this almost every large firms will invest in innovation The possibility of new and effective innovations are going to decrease, people will discourage due to the failure in producing new products or inventions, may be that's the reason our results are insignificant In general model, including control variables (with outliers), RND results are insignificant with EG while excluding outliers results are significant These results are supported by our main regression models in Table 5 1 and 5 2 The interaction term of CAP and RND

shows negative impact on EG in both models The significance of interaction is different with and without outliers With outliers the interaction term is insignificant with EG in both models while excluding outliers the results are significantly related to EG These results are similar to the Tables 5 1 and 5 2

In Table 5 3 initial real per capita GDP (Y0) results determine the negative and extremely significant relationship with EG in both baseline and general model (with and without outliers) When we talk about secondary school enrollment (SCHOOL), it has a positive and significant impact on economic growth (EG) in both models, but in model 2 (with outliers) the results are insignificant This may be due to outliers The effect of secondary school enrollment (SCHOOL) on developed countries is positive, means education is very much important to achieve the long run growth

In our general model, Table 5 3, the control variable openness (OPEN) has positively and it is significantly connected to EG in developed countries The general government final consumption expenditures (GOV) has negatively related to economic growth (with and without outliers) and it's also very significant As always, inflation (INF) has negative but significant effect with EG

In Table 5 4 we run our regression on 57 developed countries with PATENT (output measure of innovation) The main findings of the central independent variable are CAP has positively affect our main dependent variable in baseline and general model Furthermore, in baseline model it is insignificant (with and without outliers) but in general including control variables, with outliers it is insignificant but while excluding outliers it becomes significant The results of PATENT shows that in both model its effect is positively related to EG but including outliers in both model it is

Table 5.4: 3 Year Averages for 57 Developed Countries

Developed Countries With (PATENT)	Model 1 Base line		Model 2 General	
Coefficient	All Obs (1)	Outliers Excluded (2)	All Obs (3)	Outliers Excluded (4)
CAP_{it}	3 261	4 188	2 256	4 712**
	(0 362)	(0 136)	(0 492)	(0 021)
$PATENT_{it}$	5 707	7 198**	2 964	6 517***
	(0 110)	(0 015)	(0 271)	(0 006)
$CAP_{it} * PATENT_{it}$	- 4491	- 5469**	- 2309	- 5130***
	(0 136)	(0 023)	(0 290)	(0 006)
Control Variables				
$Y0_{it}$	-6 951***	-6 571***	-10 39***	-9 971***
	(0 007)	(0 005)	(0 000)	(0 000)
$SCHOOL_{it}$	5 446**	6 212***	2 864	3 752***
	(0 019)	(0 000)	(0 221)	(0 005)
$OPEN_{it}$			8 548***	6 095***
			(0 000)	(0 000)
GOV_{it}			-11 21***	-13 96***
			(0 000)	(0 000)
INF_{it}			-1 427***	-1 302***
			(0 002)	(0 000)
Number of Observation	257	234	257	233

Notes: The p-values are reported in brackets ***, ** and * indicate significance at 1%, 5% and 10 % respectively The dependent variable is real per capita GDP growth CAP is log of physical capital stock growth PATENT is log of total number of patent application per million of population CAPPATENT is the log of CAP and PATENT (interaction term) LY0 is log of initial value of real per capita GDP SCHOOL is secondary school enrolment OPEN is log trade openness GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

insignificant but when we remove outliers in our regression the it shows significant to economic growth These results show the importance of innovation for attaining long run economic growth The interaction term results show that CAP and PATENT are substitute to each other because of the negative sign in both models (with and without outliers) The interaction term is insignificant with EG including outliers in both models and after excluding outliers it become significant

In Table 5 4, the results of Y0 conclude negatively related to EG and highly significant in both models SCHOOL has positive and significantly related to EG (with and without outliers) but in general model the results are insignificant with outliers and become significant without outliers Furthermore, the results of control variables are similar to the results in Table 5 3

In Table 5 5, we split our data in to two parts developed and developing countries and take 19 developing countries with 3 years averages In this Table we estimate three models First two models are the same as we estimate before but the third parsimonious model, we estimate to get good results The main independent variable CAP shows positive and highly insignificant connected to economic growth in all three models (with and without outliers) but it's not highly significant in model (1) without outliers. The positive sign of CAP shows that in developing, investment in RND expenditures like equipment's, infrastructure and salaries of highly qualified employees When there is investment in these sectors, it defiantly effect the EG positively According to our point of view, the reason why it's not significant in developing countries is due to lack facilities or it may be due to lack of investment

Table 5.5: 3 Year Averages for 19 Developing Countries

Poor Countries With RND	Model 1 Base line		Model 2 General		Model 3 Parsimonious	
Coefficient	All Obs (1)	Outliers Excluded (2)	All Obs (3)	Outliers Excluded (4)	All Obs (5)	Outliers Excluded (6)
CAP_{it}	7807	3 215	8300	5680	0517	9788
	(0 778)	(0 180)	(0 832)	(0 877)	(0 985)	(0 736)
RND_{it}	-8 874	5 859	-28 54	-11 76	-29 21	2 052
	(0 663)	(0 637)	(0 241)	(0 523)	(0 232)	(0 892)
$CAP_{it} * RND_{it}$	7633	- 4523	2 396	1 097	2 459	-0 417
	(0 638)	(0 672)	(0 226)	(0 475)	(0 223)	(0 975)
Control Variables						
$Y0_{it}$	-3 822*	-7 652***	-1 448	-3 249*	-1 300	-1 364
	(0 086)	(0 004)	(0 559)	(0 092)	(0 603)	(0 572)
$SCHOOL_{it}$	3 712	5 220	3 617	2 944	5 024	6955
	(0 464)	(0 176)	(0 362)	(0 339)	(0 251)	(0 864)
$OPEN_{it}$			4 654*	3 174		
			(0 082)	(0 250)		
GOV_{it}			-10 24	-11 53	-9 509*	-8 039*
			(0 158)	(0 128)	(0 106)	(0 102)
INF_{it}			-2 346	-1 793		
			(0 120)	(0 193)		
Number of Observation	67	61	67	66	67	65

Notes: The p-values are reported in brackets ***, ** and * indicate significance at 1%, 5% and 10 % respectively The dependent variable is real per capita GDP growth CAP is log of physical capital stock growth, RND is log of R&D expenditures % of GDP CAPRND is the log of CAP and RND (interaction term) LY0 is log of initial value of real per capita GDP SCHOOL is secondary school enrolment OPEN is log trade openness GOV is log of general government final consumption expenditures and INF is log of inflation (CPI)

RND results in model (1) (with outliers) shows negative and insignificant with economic growth While excluding outliers it becomes positive but still insignificant Model (3) results of RND are the same as model one In model (2), results indicates negative and insignificant with EG The interaction term CAP*RND in model (1) and model (3) indicates similar results It indicates positive and insignificant to EG In general model shows positive and insignificant effect on EG In general model positive sign shows that CAP and RND are substitute to each other

Initial real per capita GDP (Y0) shows that it is negatively related to economic growth and it is significant in baseline model and insignificant in model (2) and (3) with economic growth Secondary school enrollment (SCHOOL) represent positive but insignificant with economic growth in all models (with and without outliers)

In model (2), including control variable (OPEN) shows positive relation with EG but with outliers it shows significant to EG but without outliers it indicates insignificant effect with EG In developing countries trade shows positive but insignificant effect to EG In our point of view, these results are due to less exports and high imports because in developing countries there are low level investment, machinery, little assets and low level of skilled labor etc Due to all this, the production process is not efficient and the production of developing were very low, that's lead to decrease in exports so that's why OPEN is insignificant with EG (without outliers) The results of GOV shows negatively related to economic growth because when government spend high expenditures it negatively affect the EG In model (2) it is insignificant and in model (3) in becomes significant This significant shows that the expenditures made by government are productive, efficient and beneficial for the economy

In model (2), INF shows negative and insignificant with economic growth

In 19 developing countries, Table 5 6, we run our regression with PATENT as an output measure of innovation The central variables in our regression like CAP, in model (1) and (2) shows negative and insignificant relationship related to EG (with outliers) but when outliers are excluded, at that time it became positive but insignificant The positive sign shows that in developing countries, the effect of CAP is positively related to EG The reason is that when there is investment in under developed countries, the rate of EG grow faster as compare to developed countries In parsimonious model, the effect of CAP is totally negative with EG (with and without outliers) Table 5 6, model 1, results of PATENT shows that, in developing countries, PATENT are positively related to EG (with and without outliers) When there will be investment in innovation, production process becomes efficient because of new innovations, productivity and exports will increase and that will increase EG In model (2) and (3), the effect of PATENT is negative and insignificant with EG (including outliers) while without outliers the effect is positive but still insignificant to EG The interaction term results shows that in all models the effect of CAP and PATENT are positive and insignificant related to EG (with outliers), this means that they are complementary to each other and we used both CAP and PATENT to generate long run economic progress while without outliers the interaction concludes negative and insignificant relation to EG Here negative sign concludes that they are substitute to each other and that is our required results

In under developed countries the relationship between Y0 and EG in Table 5 6, model (1) shows that they are negative and significant (with outliers) but when we

exclude them the sign remain same but it turn into insignificant The remaining models (1) and (2) results describe that its results is negative and insignificant (with outliers) and when outliers are deleted then the effect is positive and insignificant in model (2) and significant in model (3) SCHOOL has positive effect on EG in all models but in model (1), it is totally insignificant (with and without outliers) and in model (2) and (3) it is significant with outliers and insignificant without outliers The positive sign shows that in developing countries education is basically required to generate economic growth because without education the economy will not work efficiently The reason is that when people have no knowledge and they don't know how to do efficient work, how to generate new innovations, how to generate new products etc This all depend on education

The findings of control variables in unindustrialized countries like OPEN shows positive effect on EG in model (2) and (3) but it shows insignificant results in model (2) (with and without outliers) In parsimonious model, the openness results are insignificant including outliers while it becomes significant excluding outliers The positive effect shows that in developing countries, the effect of openness (OPEN) is positive, means that when their will be an open economy, that's insolently grow the EG When we talk about government expenditures percent of GDP (GOV) in emerging countries the effect is negative due to the expenditures made by government The effect of GOV is insignificant in model (2) with outliers and it's significant without outliers In third model it is totally significant The effect of inflation (INF) on EG is negative and insignificant (with and without outliers)

Summary:

We use panel data which examines three year averages of growth on 76 developed and developing, 57 developed and 19 developing countries The results from 76 developed and developing countries and 57 developed countries show that innovation and capital accumulation are substitute to each other We cannot take them at the same time The remaining results from 19 developing countries has a lot of variability So the conclusion of our results is to choose one between innovation and capital accumulation

Chapter 6

Conclusion and Results

Capital and technological innovation plays a vital role in the economies for generating long run growth The main objectives of our study is to test the theoretical model of Howitt and Aghion (1998) and to examine whether capital and technological innovations are complementary/substitutes to each other In our study we divided our data in to three categories First we take a panel data of 76 countries (developed and developing) by using two different proxies for innovation First one is RND as an input and the second one is PATENT used as an output measure for innovation We run our first regression with RND and two models, baseline and general model for examining the combined relationship of innovation and capital with economic growth Similarly, in second regression we just replace RND with PATENT Secondly we take 57 developed countries from our data and run a regression It also has two regression, one is with RND and the second one is with PATENT Finally we run a regression on 19 developing countries with RND and PATENT separately

In our first model using RND, our results show that innovation and capital are substitute to each other in developed and developing countries Innovation shows positive and significant effect on EG while capital shows positive but insignificant effect on EG

In second model, using PATENT as an output measure for innovation shows the same result as we find from our first model

Similarly, when we run our third and fourth model with RND and PATENT in 57 developed countries, we find the same results as we obtain from our first model

On the contrary, the results of fifth and sixth model, using RND and PATENT in 19 developing countries are not much satisfying There is a lot of variation in these results

At the end we conclude that innovation and capital are substitutes Our first four models show that innovation plays a vital role to determine long run growth for developed and developing countries and especially for developed countries On the other hand our fifth and sixth models show that capital has positive effect in developing countries

Policy Recommendation

These results suggest that rather than focusing on these two factors, the policy makers may consider any of them, particularly innovation to enhance economic growth

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Appendix:

Table A1: Variable Definitions

Variable	Description	Source
Dependent Variable		
Growth rate of real per capita GDP **(EG)**	This variable is used as a measure of economic growth following Beck et al (2004) It is calculated as the log difference of real per capita GDP	World Development Indicators WDI (2013) database
Independent Variables		
Capital Stock Growth **(CAP)**	It is used as a measure of physical capital accumulation	Penn World Tables, Version 8 0
Research and Development Expenditures Percentage of GDP **(RND)**	Gross domestic expenditure on R&D as a percentage of GDP It is a standard expenditure measure which covers all types of R&D activities carried out on national territory in a given year It is used as a measure of innovation	United Nation Educational Scientific and Cultural Organization (UNESCO)
Interaction Term of CAP and RND **(CAP*RND)**		
Total number of Patent Applications Per Million of Population **(PATENT)**	It is used as an output measure of Innovation We take resident and non-resident patent application and total population per million First we add resident and non-resident patent applications and then we divided by total population per million After doing this we have total number of patent applications per million of population	World Intellectual Property Organization (WIPO)
Interaction Term of CAP and PATENT **(CAP*PATENT)**		
Control Variables		
Initial Value of (log) Real Per Capita GDP **(Y0)**		World Development Indicators WDI (2013) database
Secondary School Enrolment **(SCHOOL)**	Secondary school enrolment (% of gross)	United Nation Educational Scientific

		and Cultural Organization (UNESCO)
Openness (**OPEN**)	Trade openness ratio of exports to GDP ratio	World Bank National Accounts Data and OLCD National Accounts Data Files
Government size (**GOV**)	Government consumption government share of real per capita GDP	World Bank National Accounts Data and OLCD National Accounts Data Files
Inflation (**INF**)	Inflation annual percent change in CPI	International Monetary Fund and International Financial Statistic

Correlation Matrix

Table A2: Correlation Matrix of 76 Countries (Developed and Developing)

	EG	CAP	RND	PAT	CAP RND	CAP PAT	Ly0	SCH	OPEN	GOV	INF
EG	1										
CAP	-0 27	1									
RND	-0 23	0 41	1								
PAT	-0 08	0 32	0 59	1							
CAPRND	-0 22	0 36	0 99	0 59	1						
CAPPAT	-0 17	0 59	0 65	0 94	0 63	1					
Ly0	-0 26	0 45	0 68	0 68	0 66	0 72	1				
SCH	-0 03	0 26	0 52	0 67	0 51	0 63	0 68	1			
OPEN	0 17	-0 33	0 10	0 20	0 11	0 06	0 15	0 16	1		
GOV	-0 19	0 14	0 65	0 35	0 65	0 35	0 52	0 52	0 08	1	
INF	0 11	-0 18	-0 36	- 0 35	-0 36	-0 36	-0 51	- 0 30	-0 18	-0 30	1

Table A3: Correlation Matrix of 57 Developed Countries

	EG	CAP	RND	PAT	CAP RND	CAP PAT	Ly0	SCH	OPEN	GOV	INF
EG	1										
CAP	-0 28	1									
RND	-0 26	0 30	1								
PAT	-0 04	0 19	0 56	1							
CAPRND	-0 24	0 26	0 99	0 57	1						
CAPPAT	-0 15	0 55	0 60	0 91	0 60	1					
Ly0	-0 26	0 27	0 64	0 50	0 65	0 54	1				
SCH	-0 04	0 14	0 61	0 39	0 62	0 39	0 67	1			
OPEN	0 21	-0 43	0 06	0 08	0 07	-0 09	0 11	-0 06	1		
GOV	-0 17	0 01	0 57	0 20	0 57	0 18	0 45	0 57	-0 01	1	
INF	0 09	-0 09	-0 32	-0 29	-0 33	-0 29	-0 47	-0 30	-0 21	-0 27	1

Table A4: Correlation Matrix of 19 Developing Countries

	EG	CAP	RND	PAT	CAP RND	CAP PAT	Ly0	SCH	OPEN	GOV	INF
EG	1										
CAP	-0 12	1									
RND	0 09	0 28	1								
PAT	0 07	0 10	0 16	1							
CAPRND	0 11	0 10	0 97	0 16	1						
CAPPAT	0 03	0 35	0 24	0 96	0 19	1					
Ly0	-0 14	0 38	0 04	0 69	-0 01	0 74	1				
SCH	0 17	0 01	0 05	0 77	0 05	0 74	0 47	1			
OPEN	0 10	-0 28	-0 00	0 51	0 06	0 43	0 04	0 55	1		
GOV	-0 04	-0 03	0 65	0 18	0 70	0 19	0 01	0 27	0 34	1	
INF	-0 02	-0 07	0 06	-0 13	0 10	-0 13	-0 46	-0 05	0 25	0 05	1