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TECHNOLOGICAL ADVANCEMENT AND TOTAL FACTOR PRODUCTIVITY GROWTH: A PANEL DATA ANALYSIS OF ASIAN GROWING ECONOMIES

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Abstract. The paper empirically examines the potential determinants of total factor productivity (TFP) growth in order to assess the role of technological advancement in promoting productivity. The particular emphasis is placed on intangible sources such as research and development and information and communication technology in defining the TFP growth. Fixed effect with robust standard errors panel data approach is applied for estimation in the case of nine Asian growing and emerging economies over the period 1996 to 2015. The results indicate that information & communication technology, Governance and gross domestic investment as a percentage of GDP yield positive and statistically significant impact on TFP growth of selected countries. The research and development expenditure although yield positive impact but not statistically significant. Policy attention must be committed to provide universal information & communication technology coupled with broadband connectivity to facilitate the ICT use, make substantial investments to improve R&D capability and quality of capital stock and necessary steps should also be taken to improve Governance and education system to enhance TFP growth.

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I. INTRODUCTION

The developing countries are suffering from a number of economic problems like low output growth, poverty, inflation, unemployment, high trade and budget deficit and low saving and investment rate. Therefore, the living standard of people in developing countries is poor as compared to developed countries. The only way to improve the living standard is the sustainable output growth. The sustained economic growth can be achieved either by increasing the growth of factors of production or by improving the total factor productivity (TFP). Total factor productivity growth is the part of overall growth which is not because of increase in inputs but is due to better technology, innovation, specialization and better organization (World Bank, 1993). It is a change in overall growth at given quantity of inputs. The enhancement of TFP means the enhancement of a country's capability of producing more output with the same level of inputs. Through the enhancement of TFP, the long run output growth is possible even with scarcity of real factors of production. The TFP growth leads to the better and efficient use of available resources. The developing countries having limited factors of production can achieve sustainable growth through advancement of total factor productivity and its advancement is dependent on technological advancement. It is the most important indicator of long-run economic prospects. Increasing the total factor productivity can raise living standard because it increases real income of people which enhances their ability to purchase goods and services, improve housing and education, enjoy leisure and contribute to social and environmental programs. This study is aimed to investigate the ways of enhancing TFP growth.

It is a bitter reality that almost all developing countries face the scarcity of technology crucial to boost the productivity of factors of production. On the other hand, high-tech developed countries seriously invest on R & D that is why most of technology is clustered in developed counties. The role of improved technology has been a central part of the growth strategies of technologically advanced countries. The import of

high-tech products, Technology embodied machinery and intermediate goods and foreign direct investment (FDI) are channels of external technology exposures. The MNCs import modern machinery along with the ideas and knowledge generated through cumulated domestic R & D capital stock of parent country. Knowledge and technology were treated as significant endogenous determinants of economic development and as drivers of TFP growth by the endogenous growth theory originated and advocated by Romer (1990), Lucas (1988), Grossman and Helpman (1991) and Aghion and Howitt, 1998.

In this era of digitization, more than 3.2 billion people of the World are users of the internet and digital communication between citizens, companies and countries that is considered as a critical driver of productivity growth. It is referred to as post-industrial revolution and also referred to comprehensive changes brought by digital computing and ICT[1] revolution which includes computer, mobile phones, smart phones, tablets, digital cellular phones and internet connectivity. Digital revolution and ICT have affected the productivity by changing the working conditions and workplaces altogether[2]. The advances in transportation, communication, financial services, Governance, energy system and variety of other technological advances have affected the productivity. Therefore, revisiting the potential determinants of TFP growth is very important and crucial in this present era.

Over the last few decades, Asia has been the major contributor to the World economy which is driven by its cheap labor. The high GDP growth of Asian economies during the last few decades has transformed Asia from low to middle income region but the real challenge for Asian growing economies is to sustain growth which mainly depends on improvement in total factor productivity. According to the ADB report 2016 "The Asia 2050" if the Asia continues with the same growth trajectory, it could achieve 52% share of World GDP by 2050. The report concludes that this achievement is only possible if Asian economies transform their economies into knowledge based economies as the knowledge is significant promoter of TFP. The poverty level in the

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[1] The index of information and communication technology

[2] ICT usage enhances the innovation which induces higher total factor productivity growth.

region remains high and resources are insufficient to tackle the challenges. Therefore, it is essential for Asia to seek a different strategy not only for sustainability of economic growth but also to accelerate it. The enhancement of TFP growth through innovation and technological advancement is the only option to meet region's challenges. Human capital, R&D, ICT and Governance are the four main pillars of TFP growth.

Rapidly advancing technology has brought big changes in the whole structures of the economies and has affected the total factor productivity. Information and communication technology has a number of measurements and interpretations but the past studies on ICT and productivity concentrated only on a single dimension like hardware side which just includes computers and computing related equipments. Therefore, productivity paradox remained unresolved and the impact of ICT on productivity growth needs to be examined by taking usage side of ICT and this study aims to do that. In this era of knowledge based economies having rapidly changing technology, innovation and digitization it is very important to re-visit the sources of total factor productivity growth. This study aims to contribute to the growth literature by empirically investigating the determinants of TFP growth.

In order to assess the role of technological advancement and innovation in promoting TFP growth, the objective of this study is to investigate the potential determinants of TFP growth by empirically examining the impact of increased use of ICT[3], Human capital, R&D, Governance, exposure to external technology, Financial deepening and other control variables on TFP growth of nine Asian growing economies and recommend the suitable policies for its enhancement. For this purpose, the study constructed the indices of TFP, information & communication technology (ICT), exposure to external technology (EET) and financial deepening (FD) by using the appropriate statistical and mathematical procedure. The specific emphasis of present study is to examine the knowledge based determinants of TFP growth which is unique contribution to the growth literature. Therefore, this study has

[3]The use of information communication technology is measured by the Mobile cellular subscriptions, number of internet users, number of PCs, fixed broad band subscription and fixed telephone subscription.

very important implication for the achievement of long-term sustainable output growth and better living standard of developing countries.

II. LITERATURE REVIEW

A lot of literature has shown that the countries which have low growth performance are those which are unable to develop appropriate technological capacities. There are also debates in literature regarding measurements of total factor productivity, its potential determinants and specification issues or methodology to be used. In this section a comprehensive review of the theoretical and empirical literature is provided.

The technology and knowledge has been considered as a significant determinant of growth since the endogenous growth theory by Lucas (1988), Romer (1986, 1990) and Grossman and Helpman (1991). Advancement in technology is crucial for developing economies to catch up with high-tech economies. Since the 1960s, technological differences have gained support to be the main determinant of growth and development differentials (Abramovitz, 1986). The technology as a driver of TFP growth was also advocated by Aghion and Howitt (1998.)

Previous studies examined the impact of ICT investment on productivity and they found productivity paradox of ICT. In other words, it was expected that ICT investment has the key role in boosting productivity but they found unexpected results and no major contribution from ICT investment in productivity growth was found. The studies on productivity paradox include Zachary (1991), Brynjolfsson (1993, 1994) and Greenwood and Yorukoglu. (1996). According to Sichel (1997) there is no clear finding and consensus among the researchers regarding the contribution of ICT investment to the productivity.

Ulku (2004) suggests that innovations measured by the proxy of patent application are important determinant of GDP per capita and TFP. Only large OECD countries are found to be able to stimulate their innovation by investing in R&D and small OECD countries are found to be in the learning stage to promote their own innovation. It is also found that innovation affects the growth rate only for short period of time which is opposite to the findings of many studies, such as, Romer (1990). Potterie and Guellec (2001) investigated the impact of R&D on TFP

growth of 16 OECD economies over the period 1980 to 1998. The results show that R&D has important role for TFP growth.

Drucker (2007) analyzed the difference between the traditional economies and today's evolving knowledge based economy in 21st century; mega projects of investment will be in knowledge management, scientific and technological advances and innovations in which human capital will be the sole factor and knowledge will be a transferable source on different prices at different places. Thus effective application and efficacious use of knowledge, skills and attitudes will be a pre-requisite condition to meet with national and international competition in order to achieve economic development.

Krammer (2008) examined the role of knowledge spillover via FDI and international trade on growth in the case of European and transition countries from 1990 to 2006 by using panel co-integration test. The result of study showed that FDI and trade both were main source of foreign technology transformation. The impact of technology through trade is significant as compare to FDI. The absorption capacity of host countries measured with domestic R&D and human capital found to be crucial for productivity. The study concluded that technology transfer via liberalization was very beneficial for developing countries but effective utilization of this technology depends on absorption capacity of these countries. However, the role of some important sources of external technology, like imports of high tech machinery and capital good and licensing have not been examined by this study.

Saba (2016) estimated the total factor productivity of Indian economy by using growth accounting approach for the period 1961 to 2008. The study found that the average growth of TFP was 1.5% over the period 1961-2008. The TFP growth from 1961 to 1970 was although positive but very low and zero. The study also observed that TFP growth of manufacturing sector remained negative during 1971 to 1980 suggesting technological regress during this period. The reactions of low productivity were due to external shocks like oil price, war, drought along with stick and rigid regulations.

Alves, R.P (2017) analyzed the main reasons of showdown in productivity of Portugal since 1990s by examining its major determinations. Because of economic integration of the Portugal into

growing markets its productivity was expected to converge to the developed economics but it did not happen paradoxically. The study identified that the main reasons for this slowdown in productivity were the misallocation of resource and market inefficiencies. The policy focus remained in job creation without sustainable improvement in resource allocation. The study proposed stable and effective economic policies with continuous evaluation both the public and private sectors. It was also found that there were too small, dependent and too indebted firms in Portugal and heavily dependent on domestic demand. Therefore, these firms need to be integrated into global value chains to catch up with the global prettier of productivity.

Bergeaud, A et al. (2017) analyzed the long terms trends in GDP growth and TFP growth over the period 1890-2015 in the case of four most developed areas of the world: The US, the Europe, the British and Japan, The GDP growth was decomposed into its components which were working time employment, capital intensity. TFP growth and population found to be the main determinant of changes in GDP growth. The study also attempted to investigate the factors affecting the TFP growth therefore the impact of quality of factors and technology diffusion on TFP growth was examined. The quality of factors was measured by average age of capital machinery and average level of education. The shocks of technology were measured by ICT and electricity. The result showed that both ICT and electricity waves had positive and significant association with TFP growth but the impact of ICT wave was smaller than the impact of electricity. However, this study accepted that the large part of productivity still remained unexplained and further future research is required to explain the drivers of TFP growth. It concluded that the accurate fore-casting of growth was difficult because of lack of understanding and knowledge about the drivers of GDP and TFP growth. The study recommended that innovations should be promoted and opportunities of new technology shocks like ICT revolution should not be missed in order to enhance TFP growth.

Exposure to the foreign technology through various channels of technology transformation is a widely explored topic in economic literature. Bulk of studies agrees on the key findings that the major channels of technology diffusion are foreign direct investment, trade in products, transmission of techniques, knowledge and people movement

of human resource from one country to other. Foreign R&D capital stock is an effective channel of technology transmission via capital and technology imports. The impact of foreign technology depends on absorption capacity of the host country which is measured by level of human capital and R&D. The work on foreign technology transformation includes the studies by Coe and Helpman (1995), Eaton and Kortum (1996), XU and Wang (2000), Melitz (2003), Hoekman, et al. (2005), and Boermans (2010). However, the impact of exposure to external technology on TFP growth has not been examined empirically.

The studies review above suffered some serious shortcomings. The mostly previous studies used total labor force or employed labour force as an input in TFP measurement which is inappropriate. The employed labour force after adjusting with number of hours worked is appropriate measure. The adjustment of labour force matters for accurate measurement of TFP. Secondly, most of previous studies used gross capital stock as an input in TFP calculation. This measure of input is also not appropriate. The real capital stock which represents actual number of machinery in physical form instead of nominal term is accurate measure of capital input for TFP estimation. Thirdly most of studies used nominal GDP for measuring TFP which is also not appropriate because real GDP reflects the actual performance of economy by excluding the inflationary factor. Therefore, real GDP should be used in TFP measurement. All mentioned shortcomings have been addressed in present study.

All past studies vary in their definition of ICT and in their method of measuring ICT. Due to rapidly developing technology, higher productivity is expected but previous studies have mixed finding and have no clear cut evidence regarding the impact of this enormous improvement in ICT on productivity. Information and communication technology has a number of measurements and interpretations but the past studies on ICT and productivity concentrated only on a single dimension like hardware side which just includes computers and computing related equipment. Therefore, productivity paradox remained unresolved and the impact of ICT on productivity growth needs to be examined by taking usage side of ICT and this study aims to do that.

III. THEORETICAL FOUNDATION

The theoretical foundation is a structure which supports exiting theories and concepts related to particular research topic. It describes the existing and previous theories which enlightens why research problem of specific topic of interest exists. The existing theories are framed to predict, explain and understand phenomenon in order to extend the knowledge within particular assumptions.

PRODUCTIVITY INDEX

Generally, the index of productivity can be represented as a ratio of output index to input index which measures the ability of inputs to produce output that is:

$$A_t = \frac{Q_t}{X_t} \qquad \text{For t} \quad = 0, \ldots. \text{T}$$

Where A_t is productivity index, Q_t and X_t are output and inputs quantity indices, respectively. If the input index X_t contains single input then the productivity index A_t will be partial productivity index, for example, labor productivity or capital productivity index. However, there are limitations of partial productivity index like omitted inputs bias. For example, increase in productivity of labor may be because of increase in the quantity of capital per worker which is an omitted input in the labor productivity measurement rather than the actual increase in labor productivity. If input index X_t contains two or more inputs, then productivity index A_t becomes the total factor productivity (TFP) index. Mostly it is constructed using two inputs labor and capital. Total factor productivity index is constructed by using disaggregated quantities of inputs. The inputs quantities are needed to be weighted by their respective shares in output while developing the inputs indices. Most commonly used concept of TFP growth in literature is as under[4].

TFP growth = Output growth – input(s) growth

[4]Kathuria et al., (2013).

This measure of TFP growth includes all the residuals after accounting for the growth of inputs that is why it is also known as "the index of ignorance"[5].

GROWTH ACCOUNTING APPROACH

The growth accounting approach is based on Cobb-Douglas aggregate production function which assumes constant returns to scale and Hicks neutral technical progress[6]. The production function for aggregate output can be written as under.

$$Q_t = A(t)F(K, L) \qquad 1$$

The above equation reveals that aggregate output (Q_t) is the function of capital (K), labor (L) and TFP (A_t). Total Factor Productivity A(t) accounts for the shift of production function over time and capture the effect of long term technological advancement or technical change in total output. Taking the logarithmic differential of equation (1) both side.

$$\frac{dQ}{dt} = \hat{A}F(K, L) + A\frac{\partial F}{\partial K}\frac{\partial K}{\partial t} + A\frac{\partial F}{\partial L}\frac{\partial L}{\partial t} \qquad 2$$

Replacing $\frac{dQ}{dt} = \hat{Q}, \frac{\partial K}{\partial t} = \hat{K}$ *and* $\frac{\partial L}{\partial t} = \hat{L}$

$$\hat{Q} = \hat{A}F(K, L) + A\frac{\partial F}{\partial K}\hat{K} + A\frac{\partial F}{\partial L}\hat{L} \qquad 3$$

Dividing the both side of equation 3 by Q

$$\frac{\hat{Q}}{Q} = \frac{\hat{A}}{A} + A\frac{\partial F}{\partial K}\frac{K}{K}\frac{\hat{K}}{Q} + A\frac{\partial F}{\partial L}\frac{L}{L}\frac{\hat{L}}{Q} \qquad 4$$

By putting $\frac{\partial Q}{\partial K} = A\frac{\partial F}{\partial K}$ *and* $\frac{\partial Q}{\partial L} = A\frac{\partial F}{\partial L}$ then equation 4 become

[5]Abramovitz (1956).

[6] See Solow (1957).

$$\frac{\hat{Q}}{Q} = \frac{\hat{A}}{A} + \frac{\partial Q}{\partial K}\frac{K}{Q}\frac{\hat{K}}{K} + \frac{\partial Q}{\partial L}\frac{L}{Q}\frac{\hat{L}}{L} \qquad 5$$

Denoting $\frac{\partial Q}{\partial K}\frac{K}{Q}$ by F_K and $\frac{\partial Q}{\partial L}\frac{L}{Q}$ by F_L

$$\frac{\hat{Q}}{Q} = \frac{\hat{A}}{A} + F_K\frac{\hat{K}}{K} + F_L\frac{\hat{L}}{L}$$

Where F_K and F_L are the relative output factor shares of capital and labor respectively

Now denoting $\frac{\hat{Q}}{Q} = q_t, \frac{\hat{K}}{K} = l \text{ and } \frac{\hat{A}}{A} = TFPG$

$$q = TFPG + F_K k + F_L l$$

or

$$TFPG = q - F_K k - F_L l \qquad 6$$

In equation 6 *TFPG* is the growth of total factor productivity, *q* represents the growth of real GDP, *k* is growth rate of capital stock and growth rate of labor input. If the data on real GDP growth, growth rate of capital stock and labor and their factor shares is available then TFP growth can be measured by equation 6.

The TFP index can be written as a ratio of output index and inputs index as under:

$$TFP_t = \frac{Q_t}{X_t} \qquad 7$$

Where Q_t is output index which is based on growth of real GDP relative to base year and X_t is combined index of labor and capital based growth rates of both factors of production relative to base year and weighted with their respective shares in gross output.

Equation 7 can be written as:

$$TFP_t = \frac{Q_t}{F_K K_t + F_L L_t} \qquad 8$$

Taking the natural logarithm on both side of equation 8

$$\ln TFP_t = \ln Q_t - F_K \ln K_t - F_L \ln L_t \qquad 9$$

Taking lag on both sides of equation 9

$$\ln TFP_{t-1} = \ln Q_{t-1} - F_K \ln K_{t-1} - F_L \ln L_{t-1} \qquad 10$$

Subtracting equation 10 from equation 9

$$\ln TFP_t - \ln TFP_{t-1} = \ln Q_t - \ln Q_{t-1} - \{F_K(\ln K_t - \ln K_{t-1}) + F_L(\ln L_t - \ln L_{t-1})\} \qquad 11$$

where

$\ln TFP_t - \ln TFP_{t-1} = TFPG$, $\ln Q_t - \ln Q_{t-1} = q$, $\ln K_t - \ln K_{t-1} = k$ and $\ln L_t - \ln L_{t-1} = 1$

TFPG is the growth of total factor productivity, *q* represents the growth of real GDP, *k* is growth rate of capital stock and *l* growth rate of labor input replacing in equation 11.

$$TFPG = q - F_K k - F_L l \qquad 12$$

The equation 12 shows that the index number approach derives the same results as drawn through the growth accounting approach in equation 6. Therefore, the index number approach of TFP measurement is an extension and complement of the growth accounting approach.

Growth accounting approach to measure the TFP has the following merits. First, growth accounting or Solow residual approach has been extensively used in the productivity growth literature as it is easy and simple to apply. Second, it can also be applied even in the case of missing data for some time periods. Thirdly, when data is available only for small number of years then the growth accounting and index number approach are the only methods which can be applied for TFP estimation. Last, it gives TFP estimates in detail for each period in order to monitor the growth performance of the economy regularly.

IV. DATA AND METHODOLOGY

The study includes panel of nine Asian growing and emerging economies (China, Hong Kong, India, Korea, Malaysia, Singapore, Pakistan,

Thailand and Turkey) over the period: 1996 to 2015. The growing and emerging countries having data available on all the variables used in the analysis have been selected from Asian region. Turkey is one of the top emerging economies of Western Asia in terms of annual growth rate of GDP (7.4%) ahead of Korea, Rep. (3.1%) Malaysia (5.9%), Singapore (3.6%), China (6.9%), India (6.6%), Pakistan (5.7%), Thailand (3.9%) and Hong Kong (3.8%) according to World bank data 2017, despite slowdown of Gross Domestic Product by 4.7% in 2009 due to financial scarcity, Turkey achieved 8.5% growth rate in 2010 very next year to the crisis and 11.11% in 2011. The GDP of Turkey increased by 105%, from 2004 to 2014 i.e. it doubled according to the International Monetary Fund's report (2015). That is the reason for including Turkey in the productivity analysis of emerging markets of Asia. The purpose of study is to analyze the productivity growth and therefore difference in economies does not matter in this regard. A balanced panel data on yearly basis is used. The data on different variable is collected from Penn World Tables, OECD's Main Science and Technology Indicators and World Development Indicators (WDI). The other sources of data are given in Table 1. All data is expressed as percentage of GDP, percentage of population or as percentage of imports/exports in order to maximize the cross-country comparability of panel data. In this way the influence of data outliers can also be minimized. All the variables are used in logarithm form except Governance. Data on All the indicators used in the construction of indices are normalized and converted into a uniform scale ranging from 0 to 100 through mini-max method of normalization. The weights used for calculating the indices are determined by the method of Principal Components Analysis (PCA). The detail of indices is given in the Table 1.

The index number approach as an extension of growth accounting approach has been used to estimate TFP index. An alternative measure of two factors of production (labour and capital has been used) instead of traditional measures of these input factors. In traditional method which was mostly used in previous studies the labour is measured as total number of employed workers and capital is measured as gross capital stock in monetary terms such as dollars or rupees. In this study the employed workers after adjusting for hours of worked is used as an alternative input measure to estimate TFP index. Similarly, real capital

stock which is adjusted for inflation is used as an alternative measure of this input. The TFP index is measured at based year of 1990. The Shares of respective compensation in GDP of labour and capital has been used as weights to measure the TFP index[7]. However, in the case of Pakistan the weights of labour and capital measured by Ahmad, H.K. (2011) have been used.

The data of real GDP, capital stock, employed labour force, average annual hours worked and share of labour compensation in gross domestic product taken from 9.0 version of Penn World Table (PWT) is based on latest World Bank International Comparison Program (ICP), 2011 also known as benchmark year[8]. The data of capital stock is built up on the basis of investment assets having major four categories: structures, machinery, transport and other assets. Structures include residential and non-residential, machinery includes computer, printer, communication equipment and other assets contain software, intellectual property and other intangible assets. The data of real GDP has been revised and improved because of incorporation of latest ICP 2011 as a benchmark. This revision of real GDP data is very important for cross country comparison and analysis. The data of Gross R&D expenditure is taken from the database of OECD: Science, technology and innovation. It expresses the total expenditure on R&D including R&D within a country and funding from abroad but it excludes payments made by country for R&D to abroad. It consists of R&D expenditure in government sector, business sector, non-profit firms and higher education. The missing values in data are interpolated by the method of averaging the observations of preceding and succeeding years. However, in construction of an index if more observations are missing then zero weight is assigned to missing entries.[9]The variables are used in logarithm form in estimation.

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[7] For detail see *Robert C. Feenstra, Robert Inklaar and Marcel Timmer (2013)*

[8] For detail see Feenstra et al. (2015) also visit: "http://www.rug.nl/research/ggdc/data/pwt/v81/the_next_generation_of_the_penn_world_table.pdf" and "(http://www.rug.nl/research/ggdc/data/pwt/pwt-8.0)".

[9]Dreher, (2006)

TABLE 1

The Detail of Indicators Used in Indexes

Indicator	Sources of data	Variable weights (%)
Information & Communication Technology		
Internet users (per 100 people)	World Development Indicators	23
Mobile cellular subscriptions (per 100 people)	World Development Indicators	20
Personal Computer (per 100 people)	ECONSTATS™ and www.nakono.com	23
Fixed telephone subscriptions (per 100 people)	World Development Indicators and ITU	13
Fixed broadband subscriptions (per 100 people)	World Development Indicators	21
Exposure to external technology		
Imports of high-tech Manufactures (% of total Imports)	UNCTAD	30
Technology imports intensity (% of total imports)	UNCTAD	30
Foreign direct investment, net inflows (% of GDP)	World Development Indicators	25
Royalties and license fee payments (% of total services Imports)	UNCTAD and WDI	15
Financial deepening		
Domestic Credit by the Financial sector (% of GDP)	World Development Indicators	35
Financial system deposits (% of GDP)	World Development Indicators	35
Liquid liabilities (% of GDP)	World Development Indicators	30
Governance		
Government effectiveness	World Governance Indicators	16.7
Voice and accountability	World Governance Indicators	16.7
Regulatory quality	World Governance Indicators	16.6
Control of corruption	World Governance Indicators	16.6
Rule of law Kaufmann	World Governance Indicators	16.7
Political stability	World Governance Indicators	16.7

Source: Author's own calculation

In panel data analysis across autocorrelation of disturbances is likely to be present which leads to biased estimation of standard errors. To overcome this problem, the robust standard errors is used. Therefore, fixed effects with robust standard errors estimation technique is used in this study for estimation of model. The estimates obtained through this method are robust and arbitrary accommodate to contemporaneously (cross sectional) correlation, within cross-section serial correlation and

heteroskedasticity[10]. It indicates that estimated model has panel corrected standard errors robust to contemporaneous correlation, heteroskedasticity and serial correlation[11]. Redundant fixed effects test, Lagrange Multiplier Tests for Random Effects and Correlated Random Effects - Hausman Test are used for selection of the best and appropriate model and estimation technique.

V. MODEL SPECIFICATION

A lot of literature has shown that the countries which have low growth performance are those which are unable in developing appropriate technological capacities. The technology as a driver of TFP growth is advocated by Lucas (1988); Romer (1990); Aghion and Howitt (1998). Education and human capital are very important for productivity growth (Nelson and Phelps, 1966; Benhabib and Spiegel, 1994, 2005). Training, higher education and R&D help to enhance the productivity.

The financial deepening index indicates maturity of financial and banking sector which helps to improve the productivity by promoting the investment in all sectors of the economy. Olson et al. (1998), Kaufmann & Kraay (2002), Maurice and Wang (2004), Williams & Siddique (2008) and Everhart et al. (2009) conclude that there is positive and significant role of Governance in raising the level of productivity growth. Similarly, gross domestic investment-to-GDP ratio represents not only addition to the capital stock of the economy but also captures the improvement in the quality of capital stock. It is measured by the gross domestic investment as percentage of GDP. Ahmad, H.K. (2011) finds positive and significant relationship between investment to GDP ratio and TFP growth. The most of literature examining the impact of electricity on TFP finds that the overall effect varies across countries[12].

Foreign technology imported through trade openness is assumed to have positive impact on TFP because it has potential to acquire knowledge of production in the form of machinery and capital goods (Madsen and Philip, 2006). Similarly, FDI which is also one of the

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[10]Wooldridge 2002, p.148-153, Arellano, 1987 and E-views user Guide Ix.

[11]NihatTas, EmarahOnder and Ali Hepsen (2013)

[12]Fedderke and Bogetic, 2006 and Noumba Um, Vellutini and Straub (2009).

indicators of technological diffusion is also positively related to TFP because FDI brings new technology, know-how, knowledge and its positive externalities (Savvides and Zachariadis, 2005; Keller, 2001). For assessing the impact of all sources of external technology on TFP growth jointly, the index of "exposure to external technology" is developed[13].

Information and communication technology revolution which includes computer, mobile phones, smart phones, tablets, digital cellular phones and internet connectivity positively affects the productivity by changing the working conditions and workplaces. The positive contribution of ICT has also been advocated in pervious literature[14]. For assessing its impact on TFP growth the index of ICT has been developed in present study. Research and development can affect TFP growth in two ways, firstly it directly stimulates innovation and secondly it improves the ability to learn and imitate external technology. The second role of R&D is captured through its interaction with exposure to external technology. The role of interaction between imported technology and domestic capacity building, such as, R&D in boosting productivity has been advocated by Mayer, (2001). On the basis of above discussion, the following model is specified for analysis:

$$TFP_{it} = \alpha_0 + \alpha_1(RD)_{it} + \alpha_2(ICT)_{it} + \alpha_3(I)_{it} + \alpha_4(G)_{it} + \alpha_5(FD)_{it} + \alpha_6(EET)_{it} + \alpha_7(HC)_{it} + \alpha_8(EC)_{it} + \alpha_9(RD)(EET)_{it} + \varphi_i + \varphi_t + \varepsilon_{it} \quad (13)$$

The country dummies φ_i are included in order to capture the country-specific fixed conditions which may affect the long-run growth. Countries specific fixed effects are, such as, institutional, geographical and ethnic heterogeneity that do not change during the selected period of time. Social characteristics such as language, religion, colonial legacy and ethnic division are time invariant and hardly change (Acemoglue et al., 2012; Alesina et al., 2003). The time dummies φ_t are for taking account of the exogenous shocks that are common to all countries like

[13]Global Economic prospects 2008.

[14]Stiroh (2002) found that in ICT using industries the productivity is higher as compare to non-ICT industries. Piatkowski (2004) also analyzed the contribution of ICT to productivity growth in the case of eight transition economies of Easter and central Europe. He found large contribution of ICT to productivity growth.

exchange rate changes or oil price changes and ε_{it} is stochastic error term. The description of variables is given in the Table 2.

TABLE 2

Variables Description

Variables	Description
TFP	Index of Total Factor Productivity
RD	R&D expenditure (in millions $)
ICT	Index of Information and Communication Technology
I	Gross domestic investment as percentage of GDP
G	index of Governance
FD	Index of Financial Deepening
EET	Index of exposure to external technology
HC	Human Capital measured by Secondary enrollment with 3 year lag
EC	Electric power consumption (kWh per capita)
φ_i	Country dummy
φ_t	Time dummy
ε_{it}	Stochastic Error term.

VI. EMPIRICAL RESULTS

Empirical analysis has great importance in the field of economics. The empirical work examines the economic issues and problems deeply and watchfully and on the basis of its findings existing theories can be falsified or validated. This section contains the empirical analysis of this study.

First, the Redundant Fixed Effects Tests is used to examine whether the fixed cross-section effects are redundant or necessary in the panel model regression. The null hypothesis of redundant fixed effects test is that the fixed effects are un-necessary and thus are redundant. The result of this test is given in Table 3.

TABLE 3

Redundant Fixed Effects Tests (Test Cross-Section Fixed Effects)

Effects Test	Statistic	Df.	Prob.
Cross-section F	7.54*	(8,162)	0.00
Cross-section Chi-square	57.00*	8	0.00

*Note: * indicates significance at 1% level*
Source: Author's estimates

According to the results of redundant fixed effects test the p-values of F-statistic (sum of squares) and likelihood ratio (chi squares statistic) reject the null hypothesis strongly. The results of test indicate that the fixed effects are statistically significant. It can be concluded that fixed effects estimation is appropriate. Results also indicate that pooled OLS estimates the model by hiding the heterogeneity of cross-sections which is not appropriate.

TABLE 4

Lagrange Multiplier Tests for Random Effects

Test Hypothesis	Cross-section	Time	Both
Breusch-Pagan	27.06	9.80	36.86
	(0.00)	(0.00)	(0.00)
Honda	5.20	3.13	5.89
	(0.00)	(0.00)	(0.00)
King-Wu	5.20	3.13	6.07
	(0.00)	(0.00)	(0.00)
Standardized Honda	12.43	3.39	4.01
	(0.00)	(0.00)	(0.00)
Standardized King-Wu	12.43	3.39	5.42
	(0.00)	(0.00)	(0.00)

Source: Author's estimates

Lagrange Multiplier (LM) helps to decide between regression through simple OLS and regression with some effects (random)[15]. The result of LM tests is reported in Table 4 which shows that there are uncounted for random effects in the residuals of pooled estimators. The value of p of all tests is well below the significance levels. Therefore, null hypothesis of pooled OLS model is adequately and strongly rejected.

[15]Oscar Torres-Reyna (2007)

TABLE 5

Correlated Random Effects-Hausman Test
(Test Cross-Section Random Effects)

Variables	Fixed effects (^{FE})	Random effects (^{RE})	Difference $\left[Var\left(\hat{\alpha}^{FE}\right) - Var\left(\hat{\alpha}^{RE}\right)\right]$
R&D Expenditure	0.0428358	0.029045	156813
Information and Communication Technology	0.0489163	0.0513346	0.0062979
Gross Domestic Investment (% of GDP)	0.0687915	0.0843477	0.0143962
Governance	0.045734	0.0548176	0.0286200
Financial Deepening	-0.0182978	0.049106	0.0159163
Exposure to external technology	-0.1227505	-0.1364684	0.0412488
Human capital	-0.0394796	-0.0597235	0.0378016
Electric power consumption (kWh per capita)	-0.1917364	-0.2248995	0.0351524
Interaction term	0.0112425	0.0131335	0.0045983

H_0: The RE estimator is consistent (Difference in coefficients is not systematic)

$$x^2 = \left(\hat{\alpha}^{FE} - \hat{\alpha}^{RE}\right)' \left[Var\left(\hat{\alpha}^{FE}\right) - Var\left(\hat{\alpha}^{RE}\right)\right]^{-1} \left(\hat{\alpha}^{FE} - \hat{\alpha}^{RE}\right) = 23.27^{*}$$

Prob.$> \chi^2 = 0.01$

*Note: * indicates rejection of null hypothesis at 1% level of significance*
Source: Author's estimates

In the above Table 5, the result of Hausman Test is given. The assumption of uncorrelated country specific effects is tested with help of this test. According to result the null hypothesis is strongly rejected which indicates that the estimation through fixed effects model is appropriate and must be preferred over random effects model. On the basis of results of varieties of diagnostic test performed in previously, it can be concluded that only the fixed effects (robust standard errors) estimation is appropriate.

TABLE 6

Fixed effects robust standard errors estimation results

Dependent variable Total Factor Productivity (TFP)			
Explanatory variables	Coefficient	t-statistic	p-value
R&D Expenditure	0.04	1.28	0.200
Information and Communication Technology	0.05*	3.07	0.000
Gross Domestic Investment (% of GDP)	0.07**	2.45	0.015
Governance	0.05***	1.93	0.055
Financial Deepening	-0.02	-1.21	0.230
Exposure to external technology	-0.12	-1.43	0.150
Human capital	-0.04	-0.95	0.342
Electric power consumption (kWh per capita)	-0.19*	-4.45	0.000
Interaction term	0.01	1.15	0.251
Intercept	5.93*	9.32	0.000
R-squared=0.78 Adjusted R-squared=0.75 F-statistic=33.42* Prob.(F-stat): 0.00			

*Note: * indicates significance at 1% level, ** at 5% level and *** at 10% level.*
Source: Author's estimates

The Table 6 reports the fixed effects robust standard errors estimation results with TFP as the dependent variable and its explanatory variables. The reported results show that the model as a whole is good fit and significant as the value of R^2 =0.78 and adjusted R^2 is 0.75 which means that 75% variation in TFP growth is explained by independent variables. According to results, the adoption and usages of information and communication technology (ICT) have positive and significant impact on TFP growth. The value of coefficient of ICT index is about 0.05 which indicates that 10% increase in the value of index leads to 0.5% growth of TFP. The result reflects the facts that presently, in knowledge based economies, the most effective tools for raising the productivity are ICT based. ICT has generated number of tools which work on information in digital form. Its impact is impressive as it is being used in every sector of the economy from agriculture to manufacturing and industries to services sector to Government. It is a key determinant of TFP because it represents a system of new technology that affects everything including "what to produce by economies, how economies produce and how this production is to organize and manage. It has important policy implication for economies especially for developing

countries to get benefit from ICT. Several steps can be taken to increase the penetration rate of ICT where it is low.

Research &Development expenditure which measures the national innovative capacity is another important determinant of TFP growth which is positively correlated with TFP growth but is not significant. The Asian economies need to build R&D capability in order to make it a significance contributor to TFP growth. Gross domestic investment as percentage of GDP has positive and significant effect on TFP growth. Gross domestic investment represents not only addition to the capital stock of the economy but also captures the improvement in the quality of capital stock. The coefficient has expected sign in accordance with theory as new machinery and equipment is more productive, therefore, it plays positive and significant role in enhancing the total factor productivity growth. The value of the coefficient is about 0.07 which indicates that 10% growth in gross domestic investment leads to 0.7% growth in TFP. This result is consistent with the findings of Ahmad (2011) and Farrokh and Martin (1995). Therefore, measures should be taken to promote both public and private investment which will be helpful in achieving sustainable economic growth by promoting TFP growth.

The impact of Governance on TFP also appears to be positive and significant. The value of coefficient of Governance index is about 0.05 which indicates that 10% increase in the value of index leads to 0.5% growth in TFP. The result is consistent with the previous findings. The result confirms that the economies with quality of governance and better institutions have higher productivity growth. Governance affects the productivity positively and significantly. Growth enhancing governance affects the productive by maintaining political stability rule of law, protection of property rights and control of corruption in the country. The impact of electric power consumption on TFP growth is negative which is consistent with the findings of Straub, Warlter and Vellutini (2008). The rapid population growth along with high economic growth has led to high domestic demand for electric power in most of the Asian economies. With fixed supply of electricity, the increasing domestic demand is causing shortage of electric power in production sector and therefore it appears to be negatively related with productivity growth.

The variable exposure to external technology and its interaction with R&D have no significant effect on TFP growth. This reflects the fact that these economies have not yet achieved a threshold level of internal capacity building like R&D and education attainment that is sufficient to learn and absorb external technology.

VII. CONCLUSION

The main objective of this study was to estimate total factor productivity and investigate its potential determinants in the sample countries. In this era of knowledge based economies having rapidly changing technology, innovation and digitization, it is very important to re-visit the sources of total factor productivity growth. For this purpose, the impact of increasing use of information & communication technology (ICT), human capital (HC), R&D, Governance (G), exposure to external technology (EET), financial deepening (FD) and other control variables on total factor productivity growth have been examined empirically by using Fixed Effect with Robust Standard errors estimation method. The indices of TFP, information & communication technology (ICT), exposure to external technology (EET), financial deepening (FD) and Governance (G) have been developed by using the appropriate statistical and mathematical procedure. This study analyzed a panel of 9 Asian emerging and growing economies for the period 1996 to 2015.

The results indicate that information & communication technology, Governance and capital augmentation as a result of gross domestic investment have positive and statistically significant impact on TFP growth of selected Asian economies. Research & development expenditure which measures the national innovative capacity is another important determinant of TFP growth which is positively correlated with TFP growth but not significant.

Policy attention must be committed to provide universal information & communication technology coupled with broadband connectivity to facilitate the ICT use, make substantial investments to improve R&D capability and quality of capital stock and improve Governance and education system to enhance TFP growth. Similarly, as good governance plays a very crucial role for enhancing productivity of country, therefore, policy making authorities should also focus on improving the overall quality of governance.

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