A STUDY ON THE EFFECT OF EDUCATION PARTICIPATION ON TOTAL FACTOR OF PRODUCTIVITY

By

Jung, Woo Jin

THESIS

Submitted to

KDI School of Public Policy and Management

in partial fulfillment of the requirements for the degree of

MASTER OF DEVELOPMENT POLICY

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ABSTRACT

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Endogenous growth model opens up a channel to linkage between education and economic growth. However, the effect of education is difficult to capture, as it influences economy through direct and indirect channels. Average years of schooling are commonly employed as a proxy for human capital. However, it may only show the partial effect of education on economy as it reflects aggregated education level without considering the cohort effect. In order to explore the cohort effect of education on economy, this study takes the measurement of the completion rate of primary and lower secondary education. The data captures increasing participation in basic education overtime, and increase of education completion rate among cohort may have a positive influence on Total Factor of Productivity (TFP) growth. The author analyzes the relationship between education completion rate of primary and lower secondary education, and TFP growth rate by using worldwide panels from 1970 to 2000 covering 60 to 71 countries. While only secondary education shows a positive impact on TFP growth, both primary and secondary education completion rates are positively associated with technical efficiency change (imitation). The result implies that basic education contributes to productivity growth through accelerating adaption of technology.

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I. Introduction

Expanding education accessibility is positively associated with several development outcomes. For instance, increase of enrollment rate in primary education reduced HIV incidents in Malawi and Uganda (Behraman, 2015). Low fertility rate is also highly associated with female primary education (Barro, 1996). Crime rates are also reduced by increasing high school graduation (Fella & Gallipoli, 2014). Increasing education accessibility has been promoted in many developing countries as it makes such numerous contributions to the society. The United Nations' Millennium Development Goals target to achieve universal primary education, and in line with the global initiatives policies, such as conditional cash transfer and government's subsidies to public schools, have been implemented to promote participation in basic education. In addition, endogenous growth model emphasizes education as one of the determinants for economic growth (Perkins, Radelet, Lindauer & Block, 2013). Therefore, education gains more importance in the society as a foundation for welfare as well as a source of sustainable economic growth.

Although endogenous growth model recognizes the role of education in economic growth by incorporating human capital into growth equation, the empirical evidences showing impact of human capital are inconsistent. While positive impact of human capital on economic growth was suggested (Mankiw, Romer, & Weil, 1992), Benhabib and Spiegel (1994) argued that human capital does not account for economic growth. Also, the conditional effect of human capital is suggested to explain this inconsistency (Krueger & Lindahl, 2001). Kruger and Lindahl found that the positive correlation between human capital and growth is limited to the countries where they initially have low level of education. In fact, these inconsistent results may be inevitable because education has impacted economy through direct and indirect channel. Thus,

exploring the role of human capital requires an understanding on complex channels that education has influenced.

In this regard, externality of education is an important topic for exploring indirect impact of education on economy. For example, spillover effect of education implies additional benefit from providing education in a society (Wantchekon, Klasnja, and Novta, 2015). Wantchekon et al. (2015) argued that education positively influences both students and their decedents. Village-level externality of education is also found in second generation. In addition, Kim & Lim (2012) investigated social return of college education in Korean economic development and they found a positive spillover effect of college education in Korea. In their research, the positive association between an increase of college graduate workers and Gross Domestic Production per non-college graduate worker is suggested. Thus, several researches imply that provision of education could have a positive influence not only on the beneficiaries but also on their surroundings.

Similarly, the macroeconomic effect of education with respect to the externality of human capital has been explored. Solow residual, also known as total factor of productivity (TFP), is a remaining portion in economic growth that capital and labor accumulation do not account for, and it captures the contribution to efficiency, innovation, and other factors on productivity (Perkins, Radelet, Lindauer & Block, 2013). The empirical evidence suggests that skilled labor and higher level of education have a TFP growth enhancing effect (Vandenbussche et al., 2005, Ang et al., 2011). However, as education impacts society through direct and indirect channels, the result may only reflect partial externality of education affecting human capital. In this regard, the study aims to suggest a different perspective in investigating education. As access

to education has been improved overtime, more people are being educated than the previous generation. There may be a positive cohort effect on economy from the increased education participation. Thus, the research focuses on the change in participation in education overtime with respect to its contribution on a country's productivity.

This paper contributes to the literature by applying a new perspective for assessing contribution of education in economy. As education attainment has been considered as a source of human capital accumulation that enhances productivity of labor, previous researches have been conducted focusing on average years of education. However, as education accessibility expands overtime and more people are educated within the generation, there may be a positive externality that increases productivity. Education provides homogeneous experience to students regardless of their socio-economic status (Sharpe, 1992), which may contribute to social cohesiveness. It also instills common norms and values, and creates social capital (Helliwell & Putnam, 2007). Considering possible additional channels for externality, exploring cohort effect according to increase of participation in basic education may enable us to uncover the impact of education and enhance our understanding of education and economic growth. In this study, education completion rate among relevant population is employed to analyze cohort effect of education on a country's Total Factor of Productivity (TFP) growth.

To summarize empirical results, a positive relationship between lower secondary education completion rate and TFP growth is found. According to the analysis employing composition of TFP growth, this positive relationship is caused by improving technical efficiency in the economy. Meanwhile, the primary education completion rate is also positively associated with TFP growth but the coefficients are insignificant. Despite of this weak

correlation, the significant positive relationship between completion of primary education and technical efficiency is found as well. Improvement in technical efficiency is also called as imitation, which means that a country adopts new technology from advanced countries. Thus, the result suggests that expanding basic education may have a positive impact on TFP growth by accelerating adaption of technology.

This paper is organized as follows. The next section briefly reviews the literature on relevant theories and empirical papers about productivity growth and education. Section 3 and 4 will give economic specification and the data employed in the analysis. Section 5 presents the result and its interpretations. Section 6 concludes and the insight from the analysis will be provided.

II. Literature Review

Under endogenous growth model, various empirical researches have been followed to provide the evidences showing importance of human capital in economic growth. Barro (1996) showed that higher initial education level, longer life expectancy, and lower fertility rate are positively associated with higher growth rate. Mankiw et al. (1992) found the faster rate of convergence in income per capita when human capital is considered as input of economic growth. The result implies that human capital is a critical factor for enhancing economic growth. In addition, education plays a significant role in regional economic prosperity (Bosworth & Collins, 2003, & Yamarik, 2011). Bosworth and Collins (2003) argued that rapid economic growth in East Asia is generated by physical and human capital accumulation. Yamarik (2011) also found a significant positive impact of education on economic growth in United States. In the research, education accounts for 20-25 percent of growth in income per worker. In general, the empirical

evidences suggest that human capital should be considered as a source of economic growth.

While human capital is considered as a determinant for economic growth, the consensus on its magnitude has not been drawn yet. Acemoglu et al. (2014) found that effect of human capital on growth is limited, when institution effect is controlled. The study implies that good institutions are a prerequisite condition for long-run economic growth while the contribution of human capital is not large. In conclusion, the relationship between human capital and economic growth is not conclusive. The contribution of education, especially, is difficult to pinpoint its magnitude because its influence on economic growth appears both through direct and indirect channels.

As researchers recognize complicated shapes of education, the effect of human capital is examined separately according to education attainment level. Papageorgiou (2003) analyzed the contribution of human capital on growth outcomes based on education level. According to the study, education is generally positive regardless of education level, but the effect appears differently with respect to education level. While primary education improves production of final output, post-primary education is positively correlated with innovation and imitation. Keller (2005) explored the relationship between the level of education and economic growth based on enrollment rate and government expenditure on education. The analysis emphasizes the importance of secondary education as growth enhancing factors, and the indirect impact of education on development goals, such as reducing fertility rate and promoting trade, is also highlighted. Therefore, as the impact of education has varied depending on level of attainment, its multi-dimensional aspects should be considered in the analysis.

In addition, the contributions of education on growth are also supported in regional

studies (Jalil & Idrees, 2012, Mcmahon, 1998). Jalil and Idrees (2012) showed the relationship between different level of education and economic growth in Pakistan. The positive effect of education is found in all levels of education from primary to tertiary education, while secondary education is identified as a more important determinant of economic growth than other levels of education. A similar trend is found in economic growth in East Asia (Mcmahon, 1998). According to the analysis of five countries in East Asia, enrollment rates of primary and secondary education show a significantly positive relationship with its economic growth in the region. In terms of public investment education, public investment in secondary education indicates a positive and highly significant association with growth, while investment in primary education seems to have a weak association with economic growth. One of the reasons for the insignificant or even negative association between primary education and growth is that the most of countries in analysis achieved universal primary education in 1965. In general, the positive relationship between economic growth and education is also found in regional studies, and a higher growth enhancing effect of secondary education is suggested.

Meanwhile, the indirect impact of human capital has been explored with respect to its contribution on TFP growth. Theoretically, the externality of the human capital enables the permanent economic growth without reaching a steady state (Perkins, Radelet, Lindauer & Block, 2013). Vandenbussche et al. (2004) found an increasing importance of high skilled labor as a country's technology level approaches a technology frontier. The findings of Vandenbussche et al. (2004) are tested by Ang et al. (2011) based on education attainment. The result supports the earlier findings, and some additional findings in the study are noteworthy. According to their analysis, primary and secondary education promotes imitation while the growth enhancing effect of higher education is significant only in high and middle income countries. In a low income

country, education is not an important factor for productivity growth. Similarly, Danquah and Ouattara (2014) estimated the contribution of human capital to productivity growth in sub-Saharan Africa. Although human capital does not have any significant impact on productivity growth in sub-Saharan Africa, it contributes to improvement of efficiency in the countries. In sum, conditional positive externality of human capital is found in the analysis. The contribution of human capital to TFP growths differs depending on education attainment and income level.

Indeed, the impact of education is not easy to capture (Acemoglu & Angrist, 2000, Park, 2006). Acemoglu & Angrist (2000) implied that the evidences showing human capital externalities from previous researches are overestimated. In their research, applying compulsory schooling law as an instrument variable, the externality of education is estimated to be around 1~3%, which is smaller than private return of education. Also, conflicting evidences are found with regard to distribution of education attainment. While some argued that the unequal distribution of education is expected to have a negative impact on growth (Lopez, Thomas & Wang, 1998), Park (2006) found a positive relationship between dispersion of human capital and economic growth. The study of Park suggests that the high variation of average schooling has a positive impact on growth. Although education shows a positive growth enhancing effect as an input in the economy, the consensus on its magnitude is not drawn yet. Also, the effect may vary according to its distribution. Thus, the impact of education should be analyzed with various perspectives in order to grasp the full dynamics.

With respect to investigating education externalities, considering different channels of education could help us to expand our understanding on its externalities. Agenor & Dinh (2015) argued social capital has a positive contribution on economic growth by promoting imitation. In

this regard, school provides a platform for generating social interactions and transferring social responsibilities (Dinda, 2008). Also, a climate of trust is influenced by the average level of education (Helliwell & Putnam, 2007). When people realize the association between higher level of education and trust, they are more likely to trust others. Thus, people will trust more regardless of their education level, when there is a higher average level of education. The empirical analysis of Helliwell and Putnam (2007) shows that average level of education increases social trust. In addition, Dina (2008) found that additional years of schooling increase social trust as well as income level. The empirical analysis suggests that one additional year of schooling increases growth rate by 0.13 to 0.22% through creating trust. In this regard, education is one of the important factors for development of social capital (Fukuyaman, 1995), and higher average level of schooling is an important indicator for social trust (Dina, 2008). Thus, increase of participation in education may have positive externalities on TFP through enhancing social capital because social capital can be accumulated through interactions among cohort

In conclusion, the provision of education has an influence on economic growth through multiple channels. Education provides additional human capital in the economy, and interaction of human capital generates the externalities as well. It also influences social capital by transferring general norms and conventions. In this regard, impacts of education should be investigated through various perspectives. In this research, the relationship between participation in the basic education and TFP growth will be investigated. As a country achieves universal primary education, it would increase the country's average level of education as well as ensure a common platform for interaction. Moreover, using completion rate as an independent variable is more accurate than enrollment rate, as it indicates the portion of students who completed basic education. Gross enrollment rate can be high even when there are many repeaters, while a

substantial number of children are alienated form basic education (Perkins, Radelet, Lindauer & Block, 2013). In short, the research will investigate the relationship between primary and secondary education completion rates and TFP growth to study the positive influence of education, focusing on the cohort effect of education.

III. Econometric Specification Model

Change of Total Factor of Productivity and education completion rate

The earlier discussion suggests that expanding participation in primary and lower secondary education would have a positive association with the country's TFP growth. The relationship between the changes of Total Factor of Productivity and education completion rate is studied, and for that a specification developed by Vandenbussche et al. (2004) is employed in this study.

$$\log(Y_{it}) = \beta_0 + \beta_1 \log(X_{it1\sim5/1\sim3}) + \beta_2 \log(\text{Proximity}._{it-1}) + \beta_3 Z_{it} + a_i + \delta_t + \varepsilon_i \quad (2)$$

Where Y_{it} is a change of Total Factor of Productivity, the technology proximity from technology frontier (USA) is applied in the model, as it is commonly employed in a similar previous analysis. X_{1it} represents the portion of primary education completion rate or lower secondary education completion rate. Lagged terms for both variables are employed in this equation considering a time lag affecting TFP after the graduation. For analysis with primary completion rate, 5-year-lagged terms are generated, and for lower secondary education, a 3-year of time lag is applied. To avoid multi-collinearity problem, the lagged variables are independently employed in the model.

The control variables are index of human capital per person, tertiary education

enrollment rate, openness (Trade/GDP), Foreign Direct Investment (FDI), education expenditure, inflation, democracy and property right (Polity-IV). a_i captures the time-invariant country fixed effect, and δ_t captures an unobservable individual invariant time effect. ε_{it} is an idiosyncratic error. i and t represent individual countries and time respectively.

While the model is interested in capturing the impact of participation in basic education on TFP change of a country, the findings of Vandenbussche et al. (2004) are incorporated in the specification. First of all, technology proximity indicates relative technology level in country i to the USA. As a catching-up effect diminishes over time, it is expected to have a negative relationship with TFP growth. Secondly, tertiary education enrollment rate is employed in the model as skilled labor is more likely to have a TFP growth enhancing effect. The variable will predict the effect of incremental portion of skilled labor on the TFP growth rather than total skilled labor in a country. Lastly, the previous literature (Vandenbussche et al. 2004, Danquah & Ouattara, 2014) applies interaction terms between technology proximity and human capital to capture an increasing role of human capital as a country develops toward technology frontier. The interaction term is not included in this analysis, as accumulated human capital is the variable of interest in this research. In the analysis, only human capital of a country is also controlled for simplifying the interpretation. Other variables that are expected to have an impact on the country's TFP growth, such as inflation, FDI, and openness, are also controlled.

Furthermore, an additional analysis is conducted by employing decompositions of TFP growth as a dependent variable to identify the dynamics in TFP growth. TFP growth can be decomposed into technical change (TC) and technical efficiency change (TEC). The technical change represents innovation which is generated by movement of frontier. The technical

efficiency change marks the change in a relative position to frontier (Isaksson, 2007). TEC is also known as imitation that translates into catching-up of frontier. The analysis focusing on components of TFP growth allows us to identify the source of TFP growth.

The empirical estimations are based on a fixed effects model for panel data of 71countries, covering period from 1970 to 2000 However, due to the availability of data set, 11 countries are dropped in the analysis of lower secondary education. As a result, 71 countries are analyzed for primary education, and 60 countries are analyzed for secondary education. There are few discrepancies in composition of countries. The countries that are employed in the analysis are listed in appendix. In primary education analysis, the dataset consists of 20 high income, 19 upper middle income, 20 lower middle income, and 12 low income countries. For lower secondary education analysis, the dataset consists of 14 high income, 18 upper-middle income 18 lower-middle income and 10 low income countries. It is identified following the World Bank's classification of income level. The number of observations is from 524 to 862, depending on the model specification.

The research explores the relationship between basic education completion rate (primary and lower secondary education) and TFP growth. If a positive relationship is found, expanding education participation would have a positive contribution to TFP growth. If it shows a negative relationship, the country's productivity growth may be enhanced when basic education is provided selectively.

IV. Data

Table 1. Descriptive statistics

Variables	Obs.	Mean	Std.	Dev.	Min
Total Factor of Productivity Change	1759	1.000032	0.058395	0.603	1.5
Technical Change	1759	0.9980222	0.0475111	0.814	1.203
Technical Efficiency Change	1759	1.003928	0.0711779	0.586	1.443
Primary Completion rate	1759	0.665814	0.28904	0.054248	1.253291
Lower Secondary Completion rate	1040	0.407836	0.299468	0.006137	1.143641
Log of Life Expectancy	1737	4.102528	0.188542	3.313591	4.395388
Log of Human Capital	1509	0.646018	0.292761	0.043249	1.212975
TFP Proximity to USA	1744	-1.07424	0.620009	-3.57555	0.065788
FDI	1493	1.583517	3.270812	-12.2084	39.80924
Education Expenditure	1688	3.752753	1.766449	0.5	32.36785
Trade	1661	0.680727	0.386209	0.075374	3.341331
Inflation	1474	0.347558	6.327403	-0.11449	237.7313
Enrollment Rate of Tertiary Education	1359	0.127791	0.140868	0	0.824391
Property Right (Constraint on executive)	1684	1.675772	14.50185	-88	7
Democratic	1684	0.355701	7.778191	-11	10

The world productivity database is developed by the United Nations Industrial Development Organization. The database offers various measures of total factor productivity (TFP) across 112 countries for 40 years (1960-2000). Among different methods employed in the database, TFP estimated by Data Envelopment Analysis (DEA) is selected as a dependent variable for this study. Basically, the TFP measured by DEA provides information regarding relative distance of technology from the United States. The estimation using DEA is commonly utilized in analysis on TFP growth. One of the benefits of DEA is that it allows more realistic implication about TFP growth (Isaksso, 2007). DEA measures not only technical change (innovation) but also technical efficiency change (imitation) which can be achieved by catching up. The dataset offers the relative proximity from USA with country i and the country's TFP change each year.

The completion rates of primary and lower secondary school are key independent variables. They capture the portion of the students in last grade with respect to the relative population in the country. It provides an idea about the portion that completed basic education and fully participated in country's basic education among relative population. Although it has its own limitation, it allows us to capture the cohort effect rather than aggregated contribution of human capital. In fact, enrollment rate only shows general inflow of schools in a country, and it does not necessarily mean that the students stay in school till the end. Thus, using completion rate as an independent variable will capture the effect of the portion that fully participated in basic education among the relevant population.

Lastly, various databases are utilized to construct control variables. Life expectancy is controlled as it is expected to have an influence on investment decision of education as well as a country's productivity. If people believe that they will live longer, they are more likely to spend more time on education. In addition, the Penn World Data provides information about human capital in a country. The index of human capital per person is estimated based on years of schooling (Barro & Lee, 2012) and returns to education (Psacharopoulos, 1994). Executive constraints (proxy for property right) and democracy are also controlled, and the data is gathered from POLITY™ IV PROJECT data base. To construct democracy dummy, the variable is constructed simply by deducting the institutionalized autocracy score from the institutionalized democracy score (democ-autoc). The calculation method is suggested by Danquah and Ouattara (2014), and it gives us data range from -11 to 10. Other control variables are gathered by using the World Bank database. The details on the sources and the definitions of data are indicated in appendix.

V. Results

Lagged positive effect of lower secondary education on TFP change

While primary education shows an insignificant relationship with TFP change, lower secondary education completion rate is positively associated with TFP change with a two-year time lag. According to the analysis, a 1 percent increase in lower secondary education completion rate positively affects TFP change by 0.07. The coefficient is statistically significant at 5 percent significance level. Although insignificant results are found in the analysis of primary education completion rate, the coefficients are consistently positive. This positive relationship becomes clear in the analysis of decompositions of TFP growth. The completion rate of primary education has a positive influence on technical efficiency. The details of the results are to be discussed in the following section. Therefore, basic education seems to have a positive relationship with TFP growth, and at least lower secondary education completion should be ensured in order to bring about a positive impact on country's productivity growth.

In addition, findings from control variables are consistent with previous study. The proximity to frontier is negatively associated with TFP change. It means that the catching-up effect in TFP growth diminishes as a country reaches technology frontier. On the other hand, human capital is found to have an insignificant relationship with TFP growth in both analysis for primary education and lower secondary education. The insignificant result could be led by a high correlation between human capital and education completion rate. However, although human capital shows a strong correlation with both completion rate and tertiary enrollment rate, the analysis using decompositions of TFP growth also shows that an insignificant relationship persists (Table 4-7). Thus, the result may imply that the externality of aggregated human capital does not have a significant impact on a country's productivity change.

Meanwhile, tertiary education shows a positive relationship with TFP growth in the model employing primary education completion rate as an independent variable (Table 2), but its significance level drops in the analysis employing lower secondary education completion rate (Table 3). One possible explanation for the insignificant result is a contradicting relationship with the component of TFP growth. Tertiary education is positively associated with TEC (imitation), while it shows a negative relationship with TC (innovation). The insignificant result may be caused by a contradicting relationship as the opposite impact seems to countervail each other (Table 6-7). The details of the analysis will be discussed in the following section. Furthermore, inflation and expenditure on education show a negative association with TFP growth. In general, the findings from the analysis of TFP growth are similar to previous analysis.

Imitation or Innovation?

Segregating TFP growth into technical efficiency change (TEC, imitation) and technical change (TC, innovation) allows us to understand the channels that induce TFP growth. Technical efficiency change implies improvement in imitation, while technical change means technological advances, also known as innovation. According to the analysis employing components of TFP growth, the primary completion rate shows a positive relationship with imitation with a four-year time lag. A 1 percent increase in primary education completion rate is positively associated with technical efficiency change by 0.08. On the other hand, primary education completion rate has an insignificant impact on TC. Thus, the positive association between primary education completion rate and TFP growth from previous analysis is likely to be generated through improvement in technical efficiency.

A similar result is found for secondary education completion rate but the result is not robust. While it shows an insignificant relationship with innovation, a positive relationship with

efficiency improvement in the 3rd year is suggested. The coefficient is significant at 10 percent significance level. Although the relationship is not robust for secondary education, the positive association with TFP growth, TC, and TEC is consistent in the 2nd year. Based on the analysis, the positive lagged impact of lower secondary education can be suggested while its channel is unclear.

In addition, some findings from control variables are also noteworthy. Proximity to USA's technology level is significantly negative for efficiency change, while it becomes insignificant with technical change. It means that the effect of catching-up diminishes overtime, and innovation does not get affected by technology difference. Life expectancy is positively associated with innovation, while it shows a negative relationship with imitation. Moreover, tertiary education shows a contradicting result as well. While it is negatively associated with innovation, it shows a positive relationship with imitation. Based on comparison between the results from the analysis of TC and TEC, most of the coefficients show the opposite impact. The contradicting result could imply that determinants of innovation and imitation may differ. To explain such contradicting results, further investigation considering quality of education or relationship between other variables is required.

Table 2. TFP change and primary education

	Total Factor of Productivity Change				
Primary Completion Rate	0.011				
(% of relevant age group, t-1)	(0.032)				
Primary Completion Rate		0.011			
(% of relevant age group, t-2)		(0.039)			
Primary Completion Rate			0.036		
(% of relevant age group, t-3)			(0.033)		
Primary Completion Rate				0.049	
(% of relevant age group, t-4)				(0.033)	
Primary Completion Rate					0.029
(% of relevant age group, t-5)					(0.035)
Log of Technology	-0.141	-0.127	-0.109	-0.126	-0.122
Proximity to USA $_{(T-1)}$	(0.031)***	(0.030)***	(0.028)***	(0.029)***	(0.021)***
Log of Human Capital $_{(t-1)}$	0.070	0.056	0.023	0.075	0.043
	(0.075)	(0.079)	(0.061)	(0.064)	(0.060)
Log of Life Expectancy at Birth	-0.054	-0.032	-0.022	-0.046	-0.038
	(0.054)	(0.054)	(0.046)	(0.053)	(0.044)
Tertiary Education	0.119	0.129	0.092	0.138	0.110
Enrollment Rate $_{(T-1)}$	(0.048)**	(0.049)**	(0.055)	(0.053)**	(0.044)**
FDI	-0.000	-0.000	-0.001	-0.000	-0.000
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Education Expenditure	-0.009	-0.007	-0.009	-0.009	-0.007
	(0.004)**	(0.004)*	(0.004)**	(0.004)**	(0.004)**
Trade	0.005	-0.002	-0.014	-0.003	-0.032
	(0.023)	(0.026)	(0.027)	(0.027)	(0.026)
Inflation	-0.055	-0.033	-0.020	-0.005	-0.001
	(0.014)***	(0.012)***	(0.005)***	(0.001)***	(0.000)***
Institutions	Yes	Yes	Yes	Yes	Yes
Country	FE	FE	FE	FE	FE
Time	Yes	Yes	Yes	Yes	Yes
	(0.027)	(0.035)	(0.020)	(0.020)	(0.021)
_cons	1.126	1.040	1.023	1.033	1.016
	(0.240)***	(0.230)***	(0.200)***	(0.229)***	(0.181)***
R^2	0.16	0.14	0.16	0.16	0.14
N	862	835	820	818	799
Number of Countries	71	71	69	70	67

* $p<0.1$; ** $p<0.05$; *** $p<0.01$ Robust standard errors are in parenthesis.

Table 3. TFP growth and lower secondary education

	Total Factor of Productivity Change		
Lower Secondary Completion rate	-0.020		
(% of relevant age group, t-1)	(0.041)		
Lower Secondary Completion rate		0.070	
(% of relevant age group, t-2)		(0.034)**	
Lower Secondary Completion rate			0.047
(% of relevant age group, t-3)			(0.030)
Log of Technology	-0.185	-0.177	-0.157
Proximity to USA $_{(T-1)}$	(0.055)***	(0.051)***	(0.047)***
Log of Human Capital $_{(t-1)}$	-0.061	-0.038	-0.028
	(0.110)	(0.112)	(0.120)
Log of Life Expectancy at Birth	0.011	-0.021	0.008
	(0.062)	(0.060)	(0.066)
Tertiary Education	0.108	0.118	0.081
Enrollment Rate $_{(T-1)}$	(0.082)	(0.070)*	(0.064)
FDI	-0.001	-0.001	0.001
	(0.003)	(0.004)	(0.004)
Education Expenditure	-0.009	-0.011	-0.010
	(0.005)*	(0.005)**	(0.006)
Trade	0.019	0.019	0.008
	(0.028)	(0.028)	(0.027)
Inflation	-0.039	-0.049	-0.026
	(0.034)	(0.015)***	(0.009)***
Institutions	Yes	Yes	Yes
Country	FE	FE	FE
Time	Yes	Yes	Yes
_cons	0.896	1.026	0.909
	(0.288)***	(0.274)***	(0.269)***
R^2	0.19	0.17	0.19
N	544	538	524
Number of Countries	59	61	58

* $p<0.1$; ** $p<0.05$; *** $p<0.01$ Robust standard errors are in parenthesis.

Table 4. Technical change and primary education

	The Component of TFP Change: Technical Change (Innovation)				
Primary Completion Rate	0.017				
(% of relevant age group, t-1)	(0.016)				
Primary Completion Rate		-0.024			
(% of relevant age group, t-2)		(0.025)			
Primary Completion Rate			-0.013		
(% of relevant age group, t-3)			(0.022)		
Primary Completion Rate				-0.033	
(% of relevant age group, t-4)				(0.021)	
Primary Completion Rate					-0.005
(% of relevant age group, t-5)					(0.019)
Log of Technology	0.015	0.022	0.022	0.029	0.015
Proximity to USA $_{(T-1)}$	(0.018)	(0.021)	(0.018)	(0.015)*	(0.017)
Log of Human Capital $_{(t-1)}$	0.039	0.063	0.038	0.066	0.100
	(0.047)	(0.049)	(0.048)	(0.044)	(0.043)**
Log of Life Expectancy at Birth	0.063	0.101	0.138	0.125	0.117
	(0.081)	(0.085)	(0.073)*	(0.070)*	(0.064)*
Tertiary Education	0.001	-0.041	-0.067	-0.093	-0.048
Enrollment Rate $_{(T-1)}$	(0.021)	(0.029)	(0.034)**	(0.034)***	(0.033)
FDI	-0.000	-0.001	-0.001	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)
Education Expenditure	-0.002	-0.001	-0.002	0.000	-0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Trade	0.017	0.019	0.016	0.014	0.011
	(0.011)	(0.013)	(0.011)	(0.012)	(0.010)
Inflation	-0.008	0.005	0.001	0.001	-0.000
	(0.007)	(0.005)	(0.003)	(0.000)**	(0.000)
Institutions	Yes	Yes	Yes	Yes	Yes
Country	FE	FE	FE	FE	FE
Time	Yes	Yes	Yes	Yes	Yes
_cons	0.683	0.642	0.487	0.533	0.442
	(0.320)**	(0.338)*	(0.287)*	(0.275)*	(0.255)*
R^2	0.47	0.46	0.49	0.48	0.46
N	862	835	820	818	799
Number of Countries	71	71	69	70	67

* $p<0.1$; ** $p<0.05$; *** $p<0.01$ Robust standard errors are in parenthesis.

Table 5. Technical efficiency change and primary education

	The Component of TFP Change: Technical Efficiency Change (Imitation)				
Primary Completion rate	-0.006				
(% of relevant age group, t-1)	(0.032)				
Primary Completion rate		0.034			
(% of relevant age group, t-2)		(0.043)			
Primary Completion rate			0.047		
(% of relevant age group, t-3)			(0.039)		
Primary Completion rate				0.080	
(% of relevant age group, t-4)				(0.036)**	
Primary Completion rate					0.031
(% of relevant age group, t-5)					(0.036)
Log of Technology	-0.158	-0.151	-0.132	-0.157	-0.139
Proximity to USA (T-1)	(0.033)***	(0.036)***	(0.033)***	(0.036)***	(0.028)***
Log of Human Capital (t-1)	0.025	-0.012	-0.017	0.004	-0.063
	(0.056)	(0.062)	(0.052)	(0.058)	(0.056)
Log of Life Expectancy at Birth	-0.129	-0.146	-0.173	-0.184	-0.165
	(0.074)*	(0.099)	(0.068)**	(0.055)***	(0.054)***
Tertiary Education	0.117	0.167	0.157	0.228	0.154
Enrollment Rate (T-1)	(0.055)**	(0.052)***	(0.053)***	(0.056)***	(0.050)***
FDI	0.000	0.000	-0.000	-0.000	0.000
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Education Expenditure	-0.007	-0.006	-0.008	-0.009	-0.006
	(0.004)*	(0.004)	(0.004)*	(0.005)**	(0.004)
Trade	-0.014	-0.022	-0.031	-0.018	-0.046
	(0.021)	(0.023)	(0.022)	(0.025)	(0.023)**
Inflation	-0.048	-0.038	-0.021	-0.006	-0.001
	(0.012)***	(0.010)***	(0.006)***	(0.001)***	(0.000)***
Institutions	Yes	Yes	Yes	Yes	Yes
Country	FE	FE	FE	FE	FE
Time	Yes	Yes	Yes	Yes	Yes
_cons	1.508	1.463	1.594	1.561	1.631
	(0.311)***	(0.402)***	(0.283)***	(0.246)***	(0.232)***
R^2	0.27	0.24	0.25	0.26	0.25
N	862	835	820	818	799
Number of Countries	71	71	69	70	67

* $p<0.1$; ** $p<0.05$; *** $p<0.01$ Robust standard errors are in parenthesis.

Table 6. Technical change and lower secondary education

	The Component of TFP Change: Technical Change (Innovation)		
Lower Secondary Completion rate	0.005		
(% of relevant age group, t-1)	(0.029)		
Lower Secondary Completion rate		0.023	
(% of relevant age group, t-2)		(0.024)	
Lower Secondary Completion rate			-0.021
(% of relevant age group, t-3)			(0.025)
Log of Technology	-0.001	0.018	0.016
Proximity to USA $_{(T-1)}$	(0.020)	(0.027)	(0.019)
Log of Human Capital $_{(t-1)}$	0.013	0.013	-0.038
	(0.066)	(0.068)	(0.067)
Log of Life Expectancy at Birth	0.093	0.120	0.204
	(0.058)	(0.061)*	(0.052)***
Tertiary Education	-0.034	-0.095	-0.076
Enrollment rate $_{(T-1)}$	(0.038)	(0.040)**	(0.044)*
FDI	0.001	0.000	0.001
	(0.001)	(0.001)	(0.001)
Education Expenditure	-0.004	-0.002	-0.003
	(0.003)	(0.003)	(0.004)
Trade	0.002	-0.004	0.004
	(0.017)	(0.018)	(0.017)
Inflation	0.011	0.003	0.004
	(0.016)	(0.006)	(0.005)
Institutions	Yes	Yes	Yes
Country	FE	FE	FE
Time	Yes	Yes	Yes
_cons	0.549	0.613	0.274
	(0.224)**	(0.253)**	(0.206)
R^2	0.52	0.51	0.53
N	544	538	524
Number of Countries	59	61	58

* $p<0.1$; ** $p<0.05$; *** $p<0.01$ Robust standard errors are in parenthesis.

Table 7. Technical efficiency change and lower secondary education

	The Component of TFP Change: Technical Efficiency Change (Imitation)		
Lower Secondary Completion rate	-0.026		
(% of relevant age group, t-1)	(0.054)		
Lower Secondary Completion rate		0.046	
(% of relevant age group, t-2)		(0.038)	
Lower Secondary Completion rate			0.067
(% of relevant age group, t-3)			(0.037)*
Log of Technology	-0.185	-0.197	-0.175
Proximity to USA $_{(T-1)}$	(0.058)***	(0.055)***	(0.050)***
Log of Human Capital $_{(t-1)}$	-0.070	-0.046	0.015
	(0.099)	(0.117)	(0.118)
Log of Life Expectancy at Birth	-0.096	-0.157	-0.214
	(0.068)	(0.069)**	(0.057)***
Tertiary Education	0.134	0.210	0.155
Enrollment Rate $_{(T-1)}$	(0.069)*	(0.068)***	(0.071)**
FDI	-0.002	-0.001	0.000
	(0.003)	(0.005)	(0.004)
Education Expenditure	-0.006	-0.010	-0.007
	(0.005)	(0.005)*	(0.007)
Trade	0.015	0.020	0.002
	(0.031)	(0.032)	(0.027)
Inflation	-0.053	-0.052	-0.030
	(0.034)	(0.012)***	(0.012)**
Institutions	Yes	Yes	Yes
Country	FE	FE	FE
Time	Yes	Yes	Yes
_cons	1.417	1.480	1.710
	(0.293)***	(0.290)***	(0.239)***
R^2	0.27	0.26	0.28
N	544	538	524
Number of Countries	59	61	58

* $p<0.1$; ** $p<0.05$; *** $p<0.01$ Robust standard errors are in parenthesis.

VI. Conclusion

Total Factor of Productivity (TFP) indicates a country's productivity level, and sustainable economic growth can be achieved through improvement in TFP. For developing countries, especially, the faster they catch up to technological frontier, the higher output can be generated. As endogenous growth model allows employing unconventional inputs of economy, several researches have been conducted to analyze the determinants in economic growth equation. In line with this paradigm shift, expansion of education has been emphasized because of its contribution to economic growth through direct and indirect channels. In this regard, universal provision of basic education provides an equal opportunity to develop skills and also a platform for transferring social norms and responsibilities. Thus, increasing participation in education would build more immense cohesiveness and competitiveness in society. However, these additional merits have not been fully explored in empirical analysis. Therefore, this study begins with the curiosity about the effect of growing participation in basic education per generation on a country's productivity growth.

While lower secondary education shows a significantly positive impact on TFP growth with a two-year time lag, the evidence supporting the positive relationship between primary education completion rate and TFP growth is not robust. Meanwhile, both primary and lower secondary education are positively associated with imitation, which implies that education strengthens the catching-up effect in a country. As education tends to improve learning ability of labor force, provision of basic education accelerates adoption of technology. Thus, the result suggests that basic education contributes to productivity growth by enhancing adoption of technology.

Furthermore, the weak relationship between technology change (innovation) and education completion rate is also found. This may imply that other factors, such as economic institutions and mobility among high skilled labor, play a much important role in TFP growth than basic education. In the analysis of TC and TEC, components of TFP growth, a contradicting relationship among control variables is also suggested. For example, while tertiary education is negatively associated with TC, it has a positive relationship with TEC. The opposite impacts on TC and TEC countervail each other, which leads smaller improvement in TFP growth. Therefore, the complex relationship between innovation and imitation should be considered with respect to investigating determinants for TFP growth.

Although the fixed effect estimation is free from bias caused by the time-constant country effect, it may suffer from other biases, such as reverse causality. For example, increasing productivity in a country implies a higher return on education investment, and when an increasing return is expected, people would increase investment on education. This may result in higher completion rate. Also, country specific time-variant factors can be correlated with independent variables even when separate intercepts per year are allowed. For example, changing child labor law or changing perception on education in a different country can influence education completion rate overtime. In this case, the result is more likely to be biased.

Despite of its limitation, the research tries to suggest different perspectives in investigating education's effects. Investigating average level of education could not give us the full picture. As more people in same generation are being educated overtime, this improvement in education could create a positive externality on a country's TFP growth through direct and indirect channels. The finding in the analysis suggests that increasing completion rate has a

positive influence on TFP growth through improving technical efficiency. Further research should be followed to trace a possible channel for this positive association, and this may allow us to have a clear understanding on education's influence on productivity growth.

VII.Appendix

Table 8. List of countries

Models	Name of Country
Primary education (71 countries)	Austria, Bangladesh, Benin, Bolivia, Botswana, Burundi, Cameroon, Canada, Central African Republic, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cyprus, Denmark, Ecuador, Egypt, Arab Rep., El Salvador, Fiji, Finland, France, Gabon, Gambia, Ghana, Greece, Guatemala, Honduras, India, Indonesia, Iran, Islamic Rep., Ireland, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Rep., Lesotho, Malawi, Malaysia, Mauritania, Mauritius, Mexico, Morocco, Mozambique, Nepal, Netherlands, New Zealand, Niger, Norway, Panama, Paraguay, Peru, Philippines, Portugal, Rwanda, Senegal, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Syrian Arab Republic, Tanzania, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uruguay, Zambia
Secondary education (60 countries)	Bangladesh, Bolivia, Botswana, Burundi, Central African Republic, Colombia, Congo, Dem. Rep., Congo, Rep., Costa Rica, Cyprus, Ecuador, Egypt, Arab Rep., El Salvador, Fiji, Finland, France, Gabon, Ghana, Greece, Guatemala, Honduras, India, Indonesia, Iran, Islamic Rep., Ireland, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Rep., Lesotho, Malawi, Malaysia, Mauritania, Mauritius, Mexico, Morocco, Mozambique, Nepal, Netherlands, Niger, Norway, Panama, Peru, Philippines, Portugal, Rwanda, Senegal, South Africa, Spain, Sri Lanka, Syrian Arab Republic, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay

*the countries in the analysis may differ as lagged term is employed in the analysis.

Table 9. Data source

Variable	Definition	Source
Total Factor of Productivity	Relative technology distance from USA Adjusted to absolute value based on change in USA (Assumed USA TFP 1969=1)	United Nations Industrial Development Organization
Distance to Frontier	Relative technology distance from USA	United Nations Industrial Development Organization
Primary completion rate, total (% of relevant age group)	Primary completion rate is the number of new entrants (enrollments minus repeaters) in the last grade of primary education, regardless of age, divided by the population at the entrance age for the last grade of primary education.	United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
Lower secondary completion rate, total (% of relevant age group)	Lower secondary education completion rate is measured as the gross intake ratio to the last grade of lower secondary education (general and pre-vocational).	United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
School enrollment, tertiary	Gross enrollment ratio is the ratio of total	United Nations Educational,

(% gross)	enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown.	Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
Inflation, consumer prices (annual %)	Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly.	International Monetary Fund, International Financial Statistics and data files.
Adjusted savings: education expenditure (% of GNI)	Education expenditure refers to the current operating expenditures in education, including wages and salaries and excluding capital investments in buildings and equipment.	World Bank staff estimates using the data from the United Nations Statistics Division's Statistical Yearbook, and the UNESCO Institute for Statistics online database.
Democracy	Subtracting AUTOC score from the DEMOC score	POLITY™ IV PROJECT Political Regime Characteristics and Transitions, 1800-2013
xconst (1~7)	Executive constraints (proxy for property right)	POLITY™ IV PROJECT Political Regime Characteristics and Transitions, 1800-2013
Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	World Bank national accounts data, and OECD National Accounts data files.
Foreign direct investment, net inflows (% of GDP)	This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors, and is divided by GDP.	International Monetary Fund, International Financial Statistics and Balance of Payments databases, World Bank, International Debt Statistics, and World Bank and OECD GDP estimates.
Life expectancy at birth	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.	The World Bank

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