The role of quantity vs. quality of education in promoting economic growth

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Foreword

I would like to thank my supervisor Per Thulin for being so patient and supportive during the process of writing this thesis.
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Chapter 1. Introduction

Background

Today scholars and politicians view human capital in general and education in particular as an important source of economic prosperity. Significant government funds are allocated to improve the quality of education. According to the World Bank (World Development Indicators, 2017), over 14 percent of all government expenditures in the world were spent on education to improve both quantity and quality of education in 2013. Therefore, it seems to be very important to understand how and if education can affect economic growth.

Many studies were conducted to show the importance of education for economic growth and development. For example, some classic papers (Schultz, 1961, Denison, 1962) show that education is an important factor for economic growth in western countries. Psacharopoulos (1984) showed that in developing countries the ”share” of education in economic growth varies from 1 percent to 29 percent.

However, education can differ not only in the amount of time a student spend in the classroom, but also it can vary in efficiency level or quality. Therefore, when education is discussed it is important to keep in mind that there are two main measures of education: quality and quantity.

Figure 1 shows that a positive relationship may exist between the amount of years spent in secondary school and economic growth (BarroLee dataset is used for education quantity and Penn World Tables for GDP per capita, years 1980 - 2010, OECD countries).

Hanushek and Woessmann (2008) show that even for developing countries education quantity is more important than quality. They claim that cognitive skills which students develop in secondary school help them learn faster and find better solutions in future life. Today, some international tests of education results (such as PISA) are available so it is possible to compare education quality across the countries. The particular question of interest is whether high test results of some talented students may lead to higher economic growth?

Various scholars using quantity datasets emphasise that education has a significant role in economic growth (Barro (1991), Islam (1995) etc.) There is no single answer for which countries and what type of education measure is more important. The intuition suggests that for OECD countries education quality might play a significant role, because in OECD countries the majority of students are involved in
schooling process and the average schooling time is already quite high. Therefore, the quality of schooling might become more significant for economic growth.

However, according to OECD [2012], there are up to 20 percent of people who are 25-34 years old who have not attained upper secondary school in OECD. Therefore, the education quantity measure (average years in secondary school) might be improved not only by adding an additional year in school but also reducing number of students who drop out from school. It is unclear, if for developed economies nowadays is more important to increase the quality of secondary education (measured by international tests) or increase the quantity of education (measured as an average number of years in secondary school).

Therefore, the purpose of this paper is to investigate whether the quality and quantity of education in OECD countries have an influence on economic growth and how significant it is.

A new dataset 'A New International Database on Education Quality: 1965-2010' by Nadir Altinok et. al., (which is used in this thesis) with quality data is now
available where quality of education is adjusted to make the data comparable between countries. The dataset is based on several international test results which were compared across the countries to get a unique measurement of countries’ education quality. Moreover, it becomes possible with the dataset not only compare the quality measures but also make econometric models because of many available observations for a great number of countries. The dataset provides a number of unique education quality measurements which are used in this study.

Only OECD countries are chosen to perform the analysis for several reasons. First, due to high values of both quality and quantity of education in OECD countries, it is interesting to look at whether one variable has a bigger effect on economic growth than another one, and which affect these two variables might have on each other. Second, more data of higher quality is available for OECD countries.

Sustainability aspects

Education (both quality and quantity) influences the social and economically sustainable development by several ways. First, education might increase labor efficiency in the countries and therefore, might increase the economic growth and be the force of economic development. More education might be a stimulus for creation for more innovation and new technologies which are also a source of economic growth.

Structure of Thesis

This thesis has the following structure:

in Chapter 2 the literature review of previous studies are presented. The concepts of quality and quantity of education are discussed and which education variables were measured by previous studies,

in Chapter 3 the theoretical model and estimation strategy is presented. It is shown how human capital in general and education quality and quantity are incorporated into the augmented Solow model,

in Chapter 4 datasets which are used for estimation are described in this chapter. The elaborative description of education quality dataset is presented (due to importance of understanding how the quality of education became comparable between countries). Summary statistics and correlation matrix are given in this chapter. The empirical results on the basis of the chosen theoretical framework are presented,

finally, in Chapter 5, conclusions and suggestions for future research are presented and discussed.
Chapter 2. Literature review

The Solow (1956) model became a foundation for future research and modelling of economic growth. The model uses labour and physical capital as factors which affect the production function. It was shown that population growth and savings rate can determine a steady-state level of GDP per capita in Solow model. However, this model had some limitations. Barro et al. (1992) argues Solow model did not correctly predict magnitudes of the savings and population growth on income. Rapid technological changes made economists think more about what influence economic growth and how to achieve higher growth of GDP. Kuznets (1973, 1981) emphasised that economies shifted from agricultural production to industrial and service production.

Thus, more educated workers are needed and formal education has more important role in economic development and GDP growth. Earlier Uzawa (1965) included human capital to the production factors. Lucas (1988) used a concept of human capital as well in his classical work. Mankiw, Romer, and Weil (1992) also included human capital variable into the model and found out that such a model fits data better than the original model.

Education is typically viewed as a proxy of human capital. Therefore, numerous studies were performed to estimate the relationship between education and economic growth. However, the results of testing various models are contradictory. Barro (1991) using primary and secondary school enrolment rates and OLS method concludes that education has a significant effect on economic growth. Using secondary enrolment rates and OLS method Mankiw et.al. (1992) also concludes that education is significant for economic growth. However, Nonneman and Vanhoudt (1996) used secondary school enrolment rates and OLS shows insignificance of the human capital for economic growth. By taking Mankiw, Romer and Weil (1992) model and claiming that results of this model for OECD countries are poor, they extended the Mankiw’s model and showed that the results for OECD countries are not significant as they were before. More studies found that education is insignificant for economic growth (Kalaitzidakis et al. (2001), Maasoumi et al. (2007), Henderson (2010)). Kalaitzidakis et al. (2001), for example, use semiparametric partially linear regression approach to capture the effect of nonlinearity of human capital between countries, but they got mixed results for different levels of schooling. They also found that higher levels of schooling of males are important for economic growth, but women’s education is significant only at low levels of schooling.
Education affects economic growth through several channels. Behrman (1990), Psacharopoulos (1994) show that education influence earnings of workers, which increases demand and economic growth. Moreover, Benhabib and Spiegel (1994) show that better educated workers would lead to faster innovations and technological progress. Mankiw, Romer, and Weil (1992) conclude that increase in human capital leads to increase in productivity and thus affects economic growth.

Breton (2004) shows that for developing countries quantity of education is more important, whereas for developed countries quality of education is more significant. Moreover, Breton emphasises that quality measures might be ambiguous (for example, he shows different approaches to education: memorizing more facts vs. creative approach and less material remembered, therefore, quality measures are sometimes misleading). Petrakis and Stamatakis (2002) showed that for developing countries primary and secondary schooling is more important than tertiary education. Taking Barro-Lee education enrolment rates dataset Bils and Klenow (2000) show that schooling explains up to one-third of differences in economic growth between countries.

Multiple studies (Self, Grabovski (2003); Pegkas, Tsamadias (2015)) when examine influence of education on a specific country (taking into account mainly quantity) show high significance of education for economic growth. Pereira and Aubyn(2007) estimate which level of education is more important for Portugal and conclude that increasing education at all level except the tertiary level would lead to economic growth.

Hanushek et. al.(2008) estimate the effects of quality of education rather than quantity of education with cognitive skills. He claims that secondary and primary education teaches students how to learn and formulate basic cognitive abilities which later is a significant factor for learning at workplace and being creative. He finds a positive relationship between quality of schooling and economic growth. Hanushek and Woessmann, L. (2010) elaborate their findings and claim that quality is more important than quantity, and that skills effect is complementary to quality of economic institutions as well. They use 12 international tests which were available in countries which voluntarily participated in them. Total 36 scores of combinations between year-age are available in their analysis. The majority of testing is done in science and math (due to it is easier to construct international tests in local languages for these subjects) and cognitive skills measurements available after these tests are used in Hanushek and Woessmann model.
Most of the previous studies tried to measure education quantity by school enrolment rates. Below table 1 summarises studies mentioned in this section by method and dataset used to perform the studies. As it is possible to see that majority of studies while estimating human capital took education quantity (measured most often as enrolment rates) rather than education quality. Moreover, the results are mixed: depending on variables chosen and method of estimation, different countries might have different education levels that matter to economic growth.

Table 1: Summary of previous studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Data</th>
<th>Quality measures</th>
<th>Quantity measures</th>
<th>Method</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barro (1991)</td>
<td>Primary and secondary school enrolment rates, 1960-1985</td>
<td>Primary and secondary gross enrolment rates in 1960</td>
<td>OLS</td>
<td>Both primary and secondary education are significant</td>
<td></td>
</tr>
<tr>
<td>Mankiw (1992)</td>
<td>Secondary school enrolment rates 1960-1985</td>
<td>Secondary school net enrolment rates</td>
<td>OLS</td>
<td>Education has a significant impact</td>
<td></td>
</tr>
<tr>
<td>Benhabib and Spieg (1994)</td>
<td>Enrolment rates and literacy rates 1960-1985</td>
<td>Adults literacy rate</td>
<td>OLS</td>
<td>Mixed results</td>
<td></td>
</tr>
</tbody>
</table>

It is not easy to measure education quality between countries in the long-run, because of no-existence of a single measurement of education quality. A good variable
which measures education quality could be international test results, which are the same for all countries. Nowadays, such an attempt is made by participating in PISA tests. However, PISA tests are available only for limited number of years.

Nevertheless, thanks to education quality dataset "A New International Database on Education Quality: 1965-2010" by Nadir Altinok et. al. it is possible now to compare countries in the long time horizon. In the dataset the adjustment of different test measures were made. The US participated in the majority of the international tests. Therefore, the adjustment is mainly made by adjusting all other countries to the US. Therefore, a new measure of adjusted test scores is available which might be a good proxy for quality of education. The dataset provides several quality measures for a great number of countries for 45 years. Therefore, it is not only gives the possibility to have comparable quality measures but also make econometrics analysis due to sufficient number of observations availability.

This paper attempts to estimate the influence of education on economic growth in the OECD countries. However, the main difference from the previous studies is that an attempt to use as proxy of human capital not only quantity of education but also quality of education is made.
Chapter 3. Theoretical model

In order to show the theoretical background\(^1\), it is assumed here that human capital in general and education in particular has an influence on economic growth through the increasing labour productivity.

One of the most common model using augmented Solow model is provided by Mankiw at. al. (1992). In this model, technological efficiency is represented as labor efficiency. Also human capital variable is added. Therefore, the production function takes the following form:

\[
Y = K^\alpha H^\beta (AL)^{1-\alpha-\beta} \tag{1}
\]

where \( Y \) represents GDP, \( K \) represents physical capital stock, \( L \) - labour force, \( A \) is labour efficiency, and \( H \) represents human capital.

Rewriting this equation so that it becomes a growth per effective units of labour form, using \( y = Y/AL \) \( k = K/AL \) \( h = H/AL \):

\[
y = k^\alpha h^\beta \tag{2}
\]

According to the Solow model, an economy will reach a steady state, where partial derivatives of the state variables with respect to time are zero. To find such a state, partial derivatives over time are introduced:

Capital accumulation function is given by:

\[
\dot{K} = s_k Y - \delta K \tag{3}
\]

where \( \delta \) is a constant rate at which capital stock depreciates and \( s_k \) is a savings rate.

In the per effective labour unit form:

\[
\dot{k} = s_k y - (n + g + \delta)k \tag{4}
\]

where \( n \) is a population growth rate and \( g \) is a technical progress growth rate.

Human capital accumulation function is given by (for simplicity it is assumed that human and physical capital depreciate at the same rate):

\[
\dot{h} = s_h y - (n + g + \delta)h \tag{5}
\]

where \( s_h \) is a human capital growth rate.

Deriving steady state from equations 2, 4 and 5:

\(^1\)The full derivation of the model in the chapter see in Appendix 1
The purpose of this paper is to estimate the effect of education on economic growth. Therefore, the growth variable is needed rather than GDP in steady state. Therefore, new variables are defined:

\[ k^* = \left( \frac{s_k^{1-\beta} s_h^\beta}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta}} \]  

(6)

\[ h^* = \left( \frac{s_h^\alpha s_h^{1-\alpha}}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta}} \]  

(7)

\[ y^* = \left( k^* \right)^\alpha \left( h^* \right)^\beta \]  

(8)

Inserting these variables in the production function equation 8, taking logs and time derivatives produces the following result:

\[ \frac{\dot{y}}{y} = \alpha \dot{z} + \beta \dot{x} \]  

(11)

Keeping in mind the fact that in steady state time derivatives are zero, equation 11 can be rearranged as following

\[ \ln y_t - \ln y_0 = \frac{\alpha(1 - \exp(-\lambda t))}{1-\alpha-\beta} \ln s_k + \frac{\beta(1 - \exp(-\lambda t))}{1-\alpha-\beta} \ln s_h - \frac{(\alpha + \beta)(1 - \exp(-\lambda t))}{1-\alpha-\beta} \ln(n + g + \delta) - (1 - \exp(-\lambda t)) \ln y_0 \]  

(12)

Human capital variable is assumed to be the following:

\[ s_h = e^{u_1 + u_2 + u_2 u_1} \]  

(13)

where \( u_1 \) is education quantity and \( u_2 \) is education quality.

Thus, equation 12 becomes:

\[ \ln y_t - \ln y_0 = \frac{\alpha(1 - \exp(-\lambda t))}{1-\alpha-\beta} \ln s_k + \frac{\beta(1 - \exp(-\lambda t))}{1-\alpha-\beta} (\gamma_1 u_1 + \gamma_2 u_2 + \gamma_3 u_1 u_2) - \frac{(\alpha + \beta)(1 - \exp(-\lambda t))}{1-\alpha-\beta} \ln(n + g + \delta) - (1 - \exp(-\lambda t)) \ln y_0 \]  

(14)
Therefore, the relationship between education quality and quantity and economic growth is found. $\gamma_1$ and $\gamma_2$ are assumed to have positive signs because it is expected that education quality and quantity have positive influence on GDP growth. It is not possible to make an assumption about $\gamma_3$, because the coefficient might be positive or negative depending on whether quantity's effect is bigger or smaller.
Chapter 4. Empirical Analysis

In this section the methodology of research will be described, including data description, estimation strategy and empirical results.

Estimation

To perform the empirical analysis equation 14 can be modified to the following:

\[ \ln y_{i,t+s} - \ln y_{i,t} = \beta_0 + \beta_1 \ln s_{k,i,t} + E + \beta_3 \ln(n_{i,t} + g + \delta) + \beta_4 \ln y_{i,t} + X' + \varepsilon_{k,i,t} \]  

(15)

where \( t \) and \( s \) stands for time period, \( i \) stands for country;

\[ s_k = \ln(s_{t-4} + s_{t-3} + s_{t-2} + s_{t-1} + s_t)/5) \]  

(16)

\[ n = (\ln(empl_t) - \ln(empl_{t-5}))/5 \]  

(17)

and \( E = \phi_1 u_{1,i,t} + \phi_2 u_{2,i,t} + \phi_3 u_{1,i,t} u_{2,i,t} \), \( X' \) are other control variables in the model.

Following Mankiw, Romer and Weil (1992) it is assumed that \( g + \delta \) equals 0.05 for all countries. The averages are taken to avoid short-term fluctuations influence on the results.

The complete derivation of 14 is shown in the Appendix 1.

To perform empirical analysis a fixed effect model for estimation of panel datasets is chosen. In this model it is assumed that there is country’s heterogeneity which is captured by an intercept (Hill et. al., 2011).

Data description

The data for this paper is acquired from the following datasets:

1. Education quality "A New International Database on Education Quality: 1965-2010" by Nadir Altinok et. al. Their database in the beginning includes 150 countries with quality scores for education. For the purposes of this thesis only 33 OECD countries are left (United Kingdom and Estonia are not included due to lack of data). There are no universal tests which measure the quality of education in all these countries for such a long period, therefore, a new methodology is created by the authors. The methodology is based on the adjustment and anchoring of the different test to make them comparable. These tests include Programme for International Student Assessment (PISA), Progress in International Reading Literacy
Study (PIRLS) etc. The tests are supposed to measure literacy level, reading and mathematics skills of students. If a country participated in all tests then the average score is calculated for this country. If a country participated in only one or two tests then the results compared and anchored to the US which participated in almost all international tests. Therefore, the US due to participation in most of the international tests is a good proxy for adjustment. For countries which can not be anchored to the US the IEA surveys have been chosen for anchoring. Therefore, the quality of education is measured by the performance in the international tests.

For the quality measure of education the proportion of students who reached the level of at least 600 points in the tests (adjusted measure), which therefore, cant take values from 0 to 1. Therefore, the lowest adjusted score the student could get was 600, and the highest adjusted score is 683.94 (out of 700). According to Hanushek and Woessmann (2012), these students would be able to do more for the economic development and technological evolvement. In the database such a level is called "Innovation level".

It is important to notice that the quality measure differs from other previous studies which considered quality measurements of education. One of the most popular quality measure is literacy rates, however, as Breton (2004) notices this quality measure might be misleading, especially in OECD countries. Due to almost complete literacy in OECD countries, another measurement of quality is preferable. Some other studies also use adjusted international test measurements (e.g. Kyriacou (1974-1977) dataset). However, "A New International Database on Education Quality: 1965-2010" by Nadir Altinok et. al. is the first dataset which includes this long period for almost all countries comparable to each other. Moreover, it includes many variables which is possible to use in the studies (e.g. women’s scores, results in rural areas vs. results in urban areas etc). The quality measurement which is used in this study represents the proportion of students who achieved extraordinary results in tests.

2. Education quantity estimators were taken from Barro-Lee Educational Attainment Data. The dataset contains observations for education quantity from 1950 to 2010. For the quantity of education the average years of secondary schooling for people who are 25 and more years old were taken. The variable is taken because it is one of the most common measures of the quantity of education. 3. Penn World tables 9.0 are used to obtain the following variables:
   - average annual growth rate of real GDP per person engaged over the coming five years;
   - average annual growth rate of number of workers over the last five years;
   - natural logarithm of growth rate of labor force, depreciation rate and techno-
logical progress over the last five years, where capital depreciation rate plus labour
growth rate is assumed 0.05 for all countries;
- logarithm of GDP, 5 year lag;
- trading or openness (import share + export share, average over 5 years).
4. World Bank dataset "World Development Indicators" for some additional
control variables:
- gross capital formation (share of GDP), average over 5 years as a proxy for
investments as a percentage of GDP; par - government expenditures as a percentage
of GDP, average over 5 years.
   Mercan and Sezer (2014) include government expenditures in their model as an
important factor which might influence economic growth. Sachs & Warner (1999),
Hanushek and Woessmann (2008) include trading variable in their models as a control
variable in similar studies. Barro and Sala-i-Martin (2004) include change in trade
terms as a control variable in their study. It is expected that trading has a positive
effect on economic growth. However, government expenditures might have positive
or negative effect on economic growth.

Table 2 summarises the variables and its descriptions.
Due to missing data in quality and quantity measures, the number of observations
in the final dataset is significantly decreased to 150 observations. Most observations
for the first part of the panel (years 1965 - 1990) are missing. Therefore, in the
dataset there are 33 OECD countries. On the figure 2 countries which are included
in the analysis are shown. Years 1965 - 2005 are analysed in this paper.

![Figure 2: Countries which are included in the analysis](image)
Table 2: Variables in the model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual growth rate</td>
<td>Average annual growth rate of real GDP per person engaged over the coming five years</td>
<td>Penn World tables 9.0</td>
</tr>
<tr>
<td>Growth rate of work force</td>
<td>Average annual growth rate of number of persons engaged over the last five years, $n \ln(n + g + \delta)$, Natural logarithm of growth rate of labor force, depreciation rate and technological progress over the last five years, where capital depreciation rate plus technological progress are assumed 0.05 for all countries</td>
<td>Penn World tables 9.0</td>
</tr>
<tr>
<td>Effective depreciation</td>
<td>$\ln(n + g + \delta)$, Natural logarithm of growth rate of labor force, depreciation rate and technological progress over the last five years, where capital depreciation rate plus technological progress are assumed 0.05 for all countries</td>
<td>Penn World tables 9.0</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>GDP per capita</td>
<td>Penn World tables 9.0</td>
</tr>
<tr>
<td>Government expenditures</td>
<td>Total government expenditures as percentage of GDP average over last 5 years, natural logarithm</td>
<td>World Bank Development Indicators</td>
</tr>
<tr>
<td>Trading</td>
<td>Import share of GDP + Export share of GDP, average over last 5 years</td>
<td>Penn World Tables 9.0</td>
</tr>
<tr>
<td>Gross capital formation</td>
<td>Natural logarithm of gross capital formation share of GDP, average over last 5 years</td>
<td>World Bank Development Indicators</td>
</tr>
<tr>
<td>Quality of education</td>
<td>Proportion of students who reached the level of 600 points in the tests</td>
<td>Education quality &quot;A New International Database on Education Quality: 1965-2010&quot; by Nadir Alkinok et. al.</td>
</tr>
<tr>
<td>Quantity of education</td>
<td>Average years of secondary schooling for people who are 25 and more years old</td>
<td>Barro-Lee Educational Attainment Data</td>
</tr>
<tr>
<td>Interaction variable</td>
<td>Quality * Quantity</td>
<td></td>
</tr>
</tbody>
</table>

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Table 3 shows descriptive statistics of the data which are used for the regression. From the summary, it is visible that the maximum proportion of students who achieved highest results is 0.751 in South Korea in 2010 and minimum is 0.038 in Chile in 2000. When it comes to average number of years of schooling the maximum level is 13.126 years in United States in 2010 whereas the minimum is 5.17 in Italy in 1970.

Table 3: Summary statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual growth rate</td>
<td>0.022</td>
<td>0.019</td>
<td>-0.019</td>
<td>0.083</td>
</tr>
<tr>
<td>Gross capital formation</td>
<td>-1.434</td>
<td>0.149</td>
<td>-1.795</td>
<td>-1.068</td>
</tr>
<tr>
<td>GDP per capita</td>
<td>10.926</td>
<td>0.351</td>
<td>9.516</td>
<td>11.683</td>
</tr>
<tr>
<td>Effective depreciation</td>
<td>-2.862</td>
<td>0.229</td>
<td>-4.32</td>
<td>-2.329</td>
</tr>
<tr>
<td>Quantity of education</td>
<td>9.788</td>
<td>1.831</td>
<td>5.17</td>
<td>13.126</td>
</tr>
<tr>
<td>Quality of education</td>
<td>0.352</td>
<td>0.143</td>
<td>0.038</td>
<td>0.751</td>
</tr>
<tr>
<td>Interaction variable</td>
<td>3.496</td>
<td>1.6</td>
<td>0.334</td>
<td>8.212</td>
</tr>
<tr>
<td>Government expenditures</td>
<td>-1.691</td>
<td>0.248</td>
<td>-2.245</td>
<td>-0.968</td>
</tr>
<tr>
<td>Trading</td>
<td>-2.603</td>
<td>1.187</td>
<td>-6.064</td>
<td>0.133</td>
</tr>
</tbody>
</table>

Table 4 is a correlation matrix between the variables. It is visible from the table that quality and quantity measures are negatively correlated with economic growth rate. However, quality and quantity measures are positively correlated with GDP per capita. GDP per capita has strong correlation with gross capital formation which indicates that multicollinearity exists.
Table 4: Cross-correlation table

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Annual growth rate</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Gross capital formation</td>
<td>0.12</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. GDP per capita</td>
<td>-0.5</td>
<td>-0.39</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Effective depreciation</td>
<td>-0.12</td>
<td>0.02</td>
<td>0.16</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Quantity of education</td>
<td>-0.14</td>
<td>-0.09</td>
<td>0.4</td>
<td>0.04</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Quality of education</td>
<td>-0.04</td>
<td>0.31</td>
<td>0.09</td>
<td>-0.15</td>
<td>0.21</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Interaction variable</td>
<td>-0.08</td>
<td>0.24</td>
<td>0.21</td>
<td>-0.14</td>
<td>0.53</td>
<td>0.93</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Government expenditures</td>
<td>-0.2</td>
<td>-0.29</td>
<td>0.23</td>
<td>-0.18</td>
<td>0.23</td>
<td>0.00</td>
<td>0.06</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9. Trading</td>
<td>-0.06</td>
<td>-0.19</td>
<td>0.36</td>
<td>0.03</td>
<td>0.14</td>
<td>0.05</td>
<td>0.11</td>
<td>0.28</td>
<td>1</td>
</tr>
</tbody>
</table>

**Empirical results**

The theoretical model which was described in the previous chapter is the basis for the regression. Table 5 presents the results of the regression estimation with fixed effects. Heteroskedasticity might be a problem, therefore the robust standard errors are used.

In order to test, whether fixed or random effects should be used in the OLS model, Hausman test is performed. Testing for fixed and random effects the basic specification (without control variables) of the model, gives \( \chi^2 = 0.0107 \) which suggests that fixed effect model should be used.

First, the relationship is estimated without control variables and then control variables are added in order to see how the results are affected. The results of estimation suggest that education quality and education quantity are significant in basic model at 10% and 1% respectively. After adding control variables to the model, education quantity is significant at 5% level and education quality is significant at 10% level. Interaction variable is significant in the basic model at 10% level. Trading variable is significant at 5% level.

The interaction variable is significant at 10% level for the basic model so the effect of education quality on GDP growth depends on education quantity level and the other way around. This means that the higher the level of quantity the smaller effect does the quantity have on growth.

Table 6 shows robustness tests which were done by dividing the dataset by two
subsets. The first column shows the regression with dataset from 1970 to 1990 years, and the second column shows years 1995 - 2005. Such a division is made in order to check whether one of the subsets would have different results due to less observations available or other reasons.

Performing the robustness test shows that the results have changed significantly from the previous model. First of all, education quality is no longer significant for both periods. Education quantity is also insignificant in both models. The control variable of trading became significant for year 1995-2005 at 1% level.

As other studies such as Barro(1991), Mankiw (1992), Self & Grabovski (2003) have shown, the human capital is significant. However, mixed results regarding education quantity significance are obtained as well as many other researches (Kalaitzidakis et al. (2001), Maasoumi et al. (2007)). As it was mentioned before, previous studies which used other quality of education measurements got mixed results(Benhabib and Spiegal, 1994), (Hanushek and Woessman, 2008). The results of this thesis are also mixed.
Table 5: Regression table

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual growth rate of real GDP per person engaged over the coming five years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross capital formation</td>
<td>$-0.0295$</td>
<td>$-0.0272$</td>
</tr>
<tr>
<td></td>
<td>($-1.97$)</td>
<td>($-1.62$)</td>
</tr>
<tr>
<td>Lagged GDP per capita</td>
<td>$-0.0647^{***}$</td>
<td>$-0.0648^{***}$</td>
</tr>
<tr>
<td></td>
<td>($-5.95$)</td>
<td>($-6.43$)</td>
</tr>
<tr>
<td>Effective depreciation</td>
<td>$-0.00198$</td>
<td>$-0.00637$</td>
</tr>
<tr>
<td></td>
<td>($-0.19$)</td>
<td>($-0.66$)</td>
</tr>
<tr>
<td>Education quantity</td>
<td>$0.0132^{***}$</td>
<td>$0.00857^{**}$</td>
</tr>
<tr>
<td></td>
<td>(5.75)</td>
<td>(2.82)</td>
</tr>
<tr>
<td>Education quality</td>
<td>$0.101^{*}$</td>
<td>$0.101^{*}$</td>
</tr>
<tr>
<td></td>
<td>(2.41)</td>
<td>(2.25)</td>
</tr>
<tr>
<td>Interaction variable</td>
<td>$-0.0105^{*}$</td>
<td>$-0.00951$</td>
</tr>
<tr>
<td></td>
<td>($-2.28$)</td>
<td>($-1.88$)</td>
</tr>
<tr>
<td>Government expenditures</td>
<td></td>
<td>$0.00459$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.31)</td>
</tr>
<tr>
<td>Trading</td>
<td></td>
<td>$0.0131^{**}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.09)</td>
</tr>
<tr>
<td>Constant</td>
<td>$0.553^{***}$</td>
<td>$0.629^{***}$</td>
</tr>
<tr>
<td></td>
<td>(5.11)</td>
<td>(5.20)</td>
</tr>
<tr>
<td>Observations</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>R2</td>
<td>0.26</td>
<td>0.31</td>
</tr>
</tbody>
</table>

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Table 6: Regression table

<table>
<thead>
<tr>
<th></th>
<th>(1) Average annual growth rate of real GDP per person engaged over the coming five years (1970-1990)</th>
<th>(2) Average annual growth rate of real GDP per person engaged over the coming five years (1995-2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross capital formation</td>
<td>−0.00480 (−0.14)</td>
<td>0.0263 (0.97)</td>
</tr>
<tr>
<td>Lagged GDP per capita</td>
<td>−0.0586 (−1.52)</td>
<td>−0.137*** (−6.75)</td>
</tr>
<tr>
<td>Effective depreciation</td>
<td>−0.0172 (−1.08)</td>
<td>−0.00445 (−0.51)</td>
</tr>
<tr>
<td>Education quantity</td>
<td>0.0227 (1.67)</td>
<td>0.00357 (0.76)</td>
</tr>
<tr>
<td>Education quality</td>
<td>0.0448 (0.64)</td>
<td>0.0275 (0.25)</td>
</tr>
<tr>
<td>Interaction variable</td>
<td>−0.00705 (−0.90)</td>
<td>−0.00477 (−0.42)</td>
</tr>
<tr>
<td>Government expenditures</td>
<td>−0.0220 (−1.04)</td>
<td>0.0299 (0.65)</td>
</tr>
<tr>
<td>Trading</td>
<td>−0.0103 (−0.57)</td>
<td>0.0285*** (5.49)</td>
</tr>
<tr>
<td>Constant</td>
<td>0.333 (1.23)</td>
<td>1.643*** (6.11)</td>
</tr>
</tbody>
</table>

Observations | 57 | 93 |
R2           | 0.19 | 0.53 |

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Chapter 5. Summary and suggestion for future research

In this chapter the summary from the empirical analysis in the previous chapter is given. Finally, some suggestions for future research are presented.

Conclusion

This paper made an attempt to investigate whether the quality of education significantly affects the economic growth of OECD countries. To do so the data between 1965 and 2010 from several datasets was used. The quality of education was measured as a proportion of students in the country which achieved very high levels (600 points and above) in the tests. "A New International Database on Education Quality: 1965-2010" by Nadir Altinok et. al. dataset was used to obtain comparable data for education quality. In order to estimate the model, the OLS estimation with fixed effects is used. Moreover, to solve the problem with heteroskedasticity, robust standard errors are used.

Although many studies previously tried to investigate how and to which extent education affects economic growth, it is problematic to estimate quality of education due to lack a unified measure of such a variable. However, the "A New International Database on Education Quality: 1965-2010" by Nadir Altinok et. al. adjusts the score level in the international tests for all countries, so that it becomes possible to estimate the quality of education between countries.

The data which is used in this study is limited and more adjustments can be made in the future when bigger datasets are available. The potential limitation of the data for quality of education is that adjustments made might have some inaccuracies and distortions which make them less reliable. The variable which was used for education quality is the proportion of students who achieved extraordinary results in the test. Estimation of general level of quality in a unified test might potentially provide different results.

Suggestions for future research

The estimation of the model provided in this paper shows that quantity and quality of education are not consistently significant in all performed models. As it was mentioned in the previous sections, there are two ways to increase the quantity of
education: through increasing number of years in secondary school for all students or to ensure that all students complete the secondary school.

The main limitation of this thesis is small amount of observations and unbalanced panel. Therefore, when more observations are available it is possible to make more studies about whether quality and quantity of education affect economic growth.

Moreover, the variables which are used for quantity and quality of education can be more narrow if a researcher wants to estimate the effects of education for men, women, urban or rural education. The data for developing countries was incomplete and short, therefore, with the availability of new observations, it would be possible to include more countries in the analysis.

Dividing the dataset by two subsets also shows that the regression with early years (1970-1990) is worse than the regression with years 1995 - 2005. It is shown in the 6 that years 1985-1990 have 57 observations and 1995-2005 have 93 observations. Therefore, it is visible that less data are available for earlier periods. Therefore, longer time periods and better adjustments will improve the quality of results.
References


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Appendix 1: Derivation of formulas

In this appendix the complete derivation of equation 14.

\[ Y = K^\alpha H^\beta (AL)^{1-\alpha-\beta} \]  \hspace{2cm} (18)

where \( Y \) represents GDP, \( K \) represents physical capital stock, \( L \) - labour force, \( A \) is labour efficiency, and \( H \) represents human capital.

Rewriting this equation so that it becomes a growth per effective units of labour form, using \( y = Y/AL \) \( k = K/AL \) \( h = H/AL \):

\[ y = k^\alpha h^\beta \] \hspace{2cm} (19)

According to the Solow model, an economy will reach a steady state, where partial derivatives of the state variables with respect to time are zero. To find such a state, partial derivatives over time are introduced:

Capital accumulation function is given by:

\[ \dot{K} = s_k Y - \delta K \] \hspace{2cm} (20)

where \( \delta \) is a constant rate at which capital stock depreciates.

In the per effective labour unit form:

\[ \dot{k} = s_k y - (n + g + \delta)k \] \hspace{2cm} (21)

Human capital accumulation function is given by:

\[ \dot{h} = s_h y - (n + g + \delta)h \] \hspace{2cm} (22)

Deriving steady state from equations 2, 21 and 22:

\[ k^* = \left( \frac{s_k^{1-\beta} s_h^\beta}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta}} \] \hspace{2cm} (23)

\[ h^* = \left( \frac{s_h^\alpha s_k^{1-\alpha}}{n + g + \delta} \right)^{\frac{1}{1-\alpha-\beta}} \] \hspace{2cm} (24)

\[ y^* = \left( k^* \right)^\alpha \left( h^* \right)^\beta \] \hspace{2cm} (25)

The purpose of this paper is to estimate the effect of education on the economic growth. Therefore, the growth variable is needed rather than GDP in steady state.
Therefore, new variables are defined:

\[
\dot{z} = \dot{k}/k = s_k k^{-(1-\alpha)} h^{\beta} - (n + g + \delta) \quad (26)
\]

\[
\dot{x} = \dot{h}/h = s_h h^{\alpha} h^{-(1-\beta)} - (n + g + \delta) \quad (27)
\]

which can be rewritten as following:

\[
\dot{z} = s_k e^{-(1-\alpha)\ln k} e^{\beta \ln h} - (n + g + \delta) \quad (28)
\]

\[
\dot{x} = s_h e^{\alpha \ln k} e^{-(1-\beta)\ln h} - (n + g + \delta) \quad (29)
\]

Inserting these variables in the production function equation 25, taking logs and time derivatives produces the following result:

\[
\dot{y}/y = \alpha \dot{z} + \beta \dot{x} \quad (30)
\]

Using the Taylor approximation of 31:

\[
\dot{y}/y = \alpha (-\gamma(1-\alpha)) s_k e^{-(1-\alpha)\ln k} e^{\beta \ln h} (\ln k - \ln k^*) + \beta s_h e^{-(1-\alpha)\ln h} e^{\beta \ln h} (\ln h - \ln h^*) + \gamma s_k e^{\alpha \ln k} e^{-(1-\beta)\ln h} (\ln h - \ln h^*) \quad (31)
\]

Using 29 and 28 and keeping in mind the fact that in steady state time derivatives are zero, the equation 31 can be rearranged as following:

\[
\dot{y}/y = (\alpha \beta (n+g+\delta) - \alpha (1-\alpha) (n+g+\delta)) (\ln k - \ln k^*) + (\alpha \beta (n+g+\delta) - \beta (1-\beta) (n+g+\delta)) (\ln h - \ln h^*) \quad (32)
\]

Which can be simplified to:

\[
\dot{y}/y = \lambda (\ln y^* - \ln y), \quad (33)
\]

where \(\lambda = (1 - \alpha - \beta) (n + g + \delta)\).

In fact, 34 is a first order equation:

\[
\dot{v_t} = \lambda (v^* - v_t), \quad (34)
\]

where \(v_t = y_t\). Solving this equation:

\[
v_t = v^* + e^{-\lambda t} v_0 - e^{-\lambda t} v^* \quad (35)
\]

If \(v_0\) is subtracted from both sides of 35:

\[
v_t - v_0 = (1 - e^{-\lambda t} v^*) - (1 - e^{-\lambda t}) v_0, \quad (36)
\]
which is the same as:

\[
\ln y_t - \ln y_0 = (1 - e^{1-\lambda t}) \ln y^* - (1 - e^{-\lambda t}) \ln y_0, \tag{37}
\]

Plugging in the steady state derivatives in 37 and making simplifications:

\[
\begin{align*}
\ln y_t - \ln y_0 &= \frac{\alpha(1 - \exp(-\lambda t))}{1 - \alpha - \beta} \ln s_k + \frac{\beta(1 - \exp(-\lambda t))}{1 - \alpha - \beta} \ln s_h - \\
&\quad \frac{(\alpha + \beta)(1 - \exp(-\lambda t))}{1 - \alpha - \beta} \ln(n + g + \delta) - (1 - \exp(-\lambda t)) \ln y_0.
\end{align*}
\]

Human capital variable (education) is assumed to have the following function:

\[
s_h = e^{\gamma_1 u_1 + \gamma_2 u_2 + \gamma_3 u_1 u_2} \tag{39}
\]

where \(u_1\) is education quantity and \(u_2\) is education quality.

Therefore, the relationship between education quality and quantity and economic growth is found. \(\gamma_1, \gamma_2, \gamma_3\) are assumed to have positive signs because it is expected that education quality and quantity have positive influence on GDP growth, and at fixed amount of, say, quantity, more quality of education will give higher influence on GDP growth.