Convergence of Educational Attainment across the World Countries*

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This study investigates into the convergence of the average educational attainment of adult population, which is a representative indicator of human capital, of the world's 146 countries from 1950 to 2010. Using Barro and Lee (2013) data, we test the convergence of educational attainment by the newly developed Phillip and Sul (2007)'s log t-test. The results show that overall convergence of educational attainment is found among the world countries but subgroup of convergence is not detected. The speed of convergence of female educational attainment is higher than that of the total population, and the convergence speed of 146 countries is higher than that of the OECD countries, which mean catching up of educational attainment by female and lower income countries with those of total population and advanced countries.

Key Words: convergence of educational attainment, Phillip and Sul (2007)'s log t test

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I. Introduction

The growth of income and the convergence of income have been one of the most controversial topic in economic literature and the role of human capital has long been emphasized as an important factor in economic growth.

Under traditional Solow growth model, researchers have found human capital playing a significant role in explaining economic growth (Murphy and Chien, 1997). The endogenous theory of growth also emphasizes the role of human capital in growth (Lucas Jr, 1988; Romer, 1994).

Human capital is a combination of knowledge, skills and individual characteristics, which can be produced and can be used in the production as other resources (Becker 2009). As the most important investment in human capital, education and training have been counted (Becker, 2009). In accumulating human capital, education has been regarded as one of the most efficient means to use (Becker, 1962). In this sense, many economist emphasizes the role of human capital in the form of educational attainment (Lucas, 1988; Tamura, 1990; Rebeo, 1992).

In this context, many empirical works on how human capital affects the output and the growth of an economy have been performed by using the average years of schooling of the labor force as the proxy variables for human capital, or at least, as an ordinary input in the production function (Mankiw, Romer, and WeiI, 1992).

Convergence of income levels across the countries has long been one of the main issues in economics (Islam 2003). The theoretical basis for the income convergence starts from Solow (1956) and the empirical results for the convergence of income is mixed. The extensive research has not yet produced a consensus on income convergence, but seems to have more
literature on non convergence side. Durlauf and Quah (1999) and Durlauf, Johnson and Temple (2005) provide excellent overviews on convergence of income.

In the study of income convergence, the issue of convergence of human capital is of great relevance, since the convergence of human capital is related to the productivity convergence and also to growth. Convergence of human capital is believed to play an important role in the process of income convergence. Some empirical works show that human capital convergence is followed by income convergence (Tamura, 1991; Sloane et al., 1999; Becker, 2009), but other works show poor relations between human capital and the productivity growth (Wolff, 2000).

This study wants to test the convergence of human capital across the world countries. Human capital includes not only learning accumulated at school, but also includes skills and knowledge learned in the work place etc. There has not been a clear definition on how to measure human capital, however years of schooling have been used as a proxy variable for measuring human capital in growth empirics (Barro and Lee, 1993). Following the common practice, we want to use the average years of schooling as a proxy variable for human capital.

Up until recent times, the study on the convergence in economics has been carried out by testing the overall convergence of our interest by employing traditional convergence testing methodology, $\beta$ and $\sigma$ convergence tests. Those tests have the drawback that they can only test overall convergence.

Recently, new econometric methodology, so called as Phillips and Sul’s (2007) log t test (hereafter will be referred to as the “PS log t test”), has been developed. PS log t test can analyze the convergence in groups instead of overall convergence and give the estimate of the speed of convergence, which can gives more accurate picture of convergence of the data we are interested in.
To our knowledge, PS log t test has not yet been used in the context of the convergence of human capital. In this study, we want to employ the PS log t test methodology in analyzing the group convergence of educational attainment level instead of overall convergence, which is expected to lead to better understanding of the convergence of the educational attainment levels.

For this end, the remainder of the paper is organized as follows. The next section provides a review of relevant literature on the convergence of educational attainment, while Section III discusses our econometric model used for the convergence test. Then an empirical test is conducted in Section IV, followed by an examination and interpretation of the results. The final section presents the summary of the main findings.

II. Literature review

The convergence of human capital is related with the income growth and income convergence. The human capital convergence or divergence may have an important implication for the issue of relative importance between human and physical capital. There has been a long debate on the relative importance of human capital and physical capital in growth empirics. Some literature gives human capital the most important role in economic growth (Barro, 1991). But some other literature emphasizes the role of physical capital like machinery and equipment (De Long and Summers, 1991, 1993, 1994).

From the study on human capital convergence, we can get some implication for these discussions above. If human capital converges and income converges, then human capital can be inferred as a factor of worldwide income convergence. In this context, endogenous growth models claims that human capital convergence leads to income convergence (Tamura, 1991).
In other way, if human capital diverges and income diverges, then still human capital can also be counted as an important factor of worldwide income divergence, still regarded as a key factor of income growth. In this line of reasoning, Tamura (1991) shows that income convergence arises from human capital convergence in his endogenous growth model.

However, if human capital converges and income diverges, then it can be interpreted that human capital has a very limited role in income growth, implying that the role of human capital in growth is overemphasized, and instead of human capital, physical capital may take more important role than human capital. In the same way, if human capital diverges and income converges, then the role of human capital in growth theory needs to be reconsidered. This is why it is important to study whether human capital converges or not.

Some literature has investigated human capital convergence, but the results are different depending on which proxy is used for estimating human capital.

Barro (1991) showed that using the school enrollment rate as the proxy for the human capital, the growth rate of real per capita GDP is positively related to initial human capital, which means that poor countries tend to catch up with rich countries if the poor countries have high human capital per person. Barro (1996) also showed that the growth rate is stimulated by higher initial schooling and greater starting levels of life expectancy.

Sab and Smith (2001) measured the amount of human capital by life expectancy, the infant survival rate, enrollment rates at primary, secondary, and tertiary levels. With the concept of human capital defined as above, Sab and Smith (2001) finds global and regional human capital convergence in a study with a sample of 100 countries.

Zhang and Li (2002) finds that educational attainment measured by the average years of schooling had increased from 1960 to 1990, but the education gap between the developing and developed countries were widened over the period.
Cuarespo Cuaresma (2006) investigated into the convergence of educational attainment levels and human capital accumulation across the OECD countries using three data sets (Barro-Lee dataset, Cohen-Soto dataset, de la Fuente-Domenech dataset). By using the traditional $\beta$ and $\sigma$ convergence tests, Cuarespo Cuaresma (2006) finds that these three datasets provide contradictory conclusions on both the existence and evolution of convergence of educational attainment in industrialized countries, which shows the fragility of convergence tests on educational attainment depending on the data sets.

Crespo Cuaresma et al. (2013) also tested income convergence in European emerging economies and find that improvement in human capital contribute significantly to the income convergence potential of European emerging economies.

LeSage and Fischer (2008) has emphasized the role of human capital accumulation in the process of income growth and income convergence.

Wolff (2000) shows that positive effect of formal education on productivity growth among OECD countries are spotty at best, This result is unlike to the common belief that convergence in education is one of the motors for productivity convergence among industrialized countries.

Fuente and Domenech (2013) finds that the OECD countries show high growth rates in educational attainment and also a gradual reduction of educational disparities across these countries. In addition, Fuente and Deomenech (2013) claims that years of schooling seem to be a more relevant determinant of income than the stocks of physical and technological capital.

Existing studies show that the answer to the question whether convergence of educational attainment levels across countries depends strongly on the dataset used for the analysis.

We want to add some empirical results on the above discussions on the convergence of human capital by using the most widely used educational attainment dataset (Barro-Lee’s dataset). In other words, we want to investigate whether the educational attainment level
converge across the countries in the world. In this data set, the concept of human capital is measured by the years of completed schooling for persons aged 25 and over. We know that the years of schooling don’t take account of the quality of education and cannot represent the whole aspect of human capital. However, no better indices for measuring human capital is not yet developed and still the average years of schooling has been used as a proxy for human capital.

III. Model for group convergence test

The econometric methodologies we use for testing the convergence of years of schooling among the world countries is PS log t test. Following the notation in PS, we briefly review the log t convergence test and the associated cluster based algorithms.

Let us define panel data for variable $X_{it}$, $i = 1, \ldots, N$ and $t = 1, \ldots, T$ where $N$ and $T$ refer to the number of countries and the sample size respectively. In our study, $X_{it}$ stands for the natural logarithm of the average years of schooling of adult population in individual countries. PS defines the nonlinear transition factor model in a way where the common and idiosyncratic components are separated as

$$X_{it} = \delta_t \mu_t, \quad \text{for all } i, t. \quad \text{eq. (1)}$$

In eq. (1), $X_{it}$ is decomposed into two components, the factor loadings $\delta_t$, which capture idiosyncratic factors and $\mu_t$, which captures common stochastic trends. In this formulation, factor loading $\delta_t$ measures the distance between $X_{it}$ and common factor $\mu_t$. PS formulated idiosyncratic element $\delta_t$ as

$$\delta_t = \delta_i + \frac{\sigma_i \xi_t}{L(t)\alpha}, \quad \text{eq. (2)}$$

where $\xi_t \sim i d(0,1)$ across $i$, $L(t)$ is a slowly varying function such as $bg\ (t)$ and $\alpha$ denotes the speed of convergence.
In testing the convergence of $\delta_k$, PS introduces the relative transition parameter $h_k$ as

$$h_k = \frac{X_k}{\sum_{i=1}^{N} x_k} = \frac{\delta_k}{\sum_{i=1}^{N} \delta_k},$$

eq. (3)

which measures the factor loading coefficient $\delta_k$ in relation to the panel average. Then we can get the cross sectional variance of $h_k$ as

$$H_t = \frac{1}{N} \sum_{i=1}^{N} (h_k - 1)^2.$$  

eq. (4)

The PS log t test is based on the application of this transition coefficient $h_k$ in testing the convergence of the factor loading coefficient $\delta_k$. If $\delta_k \to \delta$ as $t \to \infty$ then $h_k \to 1$ and at the same time $H_t \to 0$, which ensures convergence. To test convergence, $\delta_k$ is assumed to have the semi parametric form as

$$\delta_k = \delta_i + \frac{\sigma \xi_k}{L(t) t^a},$$

eq. (5)

where $\xi_k \sim i i d(0,1)$ across $i$. We then formulate the null hypothesis of convergence

$$H_0 : \delta_i = \delta \text{ and } \alpha \geq 0,$$

against the alternative of no convergence

$$H_A : \delta_i \neq \delta \text{ for all } i \text{ or } \alpha < 0.$$

PS shows we can obtain the following regression equation

$$\log \frac{H_1}{H_t} - 2 \log L(t) = a + b \log t + u_t, \text{ for } t = [rT], [rT] + 1, [rT] + 2, \ldots, T,$$

eq. (6)

where $b = 2\alpha$ and $r$ indicates the fraction of the sample that needs to be discarded for the regression analysis. Under convergence, right hand side of eq. (6) $\log \frac{H_1}{H_t}$ goes to $\infty$, so we can transform the testing of null hypothesis of convergence into testing the eq. (6) as

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1 PS recommend to use 0.3 as the trimming rate $r$. 

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\[ H_0 : b \geq 0 \quad \text{against} \quad H_A : b < 0. \]

If we can reject the overall convergence of the panels through testing eq. (6), we can then go into testing the subgroup convergence of the panels. PS proposes a clustering procedure that involves the stepwise application of the log t regression tests.

The process of testing the subgroup convergence starts by ordering the members by the last observation and finds the core group of which members maximize the t statistic of log t regression. After the core group is detected, add non-core members one by one at a time to the core group until the t statistic does not reject the null of convergence. If adding further non-core members to the core group makes the t statistic to reject the null of convergence, then stop adding non-core members and classify till then identified members as the subgroup members. After detecting the first subgroup members in this way, we can repeat this procedure for another subgroup. The details of the procedure are described in PS.

**IV. Empirical Results**

We use Barro and Lee’s cross country data set which includes the years of completed schooling for persons aged 25 and over (http://www.barrolee.com/). It provides educational attainment data for 146 countries in 5-year intervals from 1950 to 2010. As the dataset is updated every 5 years, we interpolated the data set into yearly basis for 146 countries from 1950 to 2010, to get 60 yearly data points for each 146 countries. With these dataset, we perform the above mentioned eq. (6) PS log t test with the panel of average years of schooling.

As discussed earlier, under the null of convergence, the slope coefficient \( b \) in eq. (6) must be greater than or equal to zero. As the PS log t test is sensitive to the choice of trimming rate \( r \), we applied to the log t convergence test for the range of \( r \in (0.15, 0.35) \). As PS recommend
to use 0.3 as the trimming rate \( r \), we will use the estimated value of log t test that is obtained under the trimming rate 0.3.

The average years of schooling of adult population for 146 countries are shown in Figure 1. As we can find at a glance, the average years of completed schooling of total population in 146 countries show slightly increasing tendency from 1950 to 2010. This figure shows the average years of schooling of the world countries have increased during the 60 years.

*<Figure 1> The Average Years of Completed Schooling of Total Population*

![Graph showing average years of schooling](http://www.barrolee.com/)

Source: [http://www.barrolee.com/](http://www.barrolee.com/)

The PS log t test for 146 countries for the whole population of each country is presented in Table 2. Throughout all the trimming rates, it shows the slope coefficient estimates of log t regression consistently positive. All the resulting t statistics are far above the critical value (i.e. \( t > -1.65 \)), and thus the null of overall convergence is not rejected at all, meaning that there is no sign of divergence among the countries. Therefore, there is no sign of divergence of the
years of schooling and we can conclude that the years of schooling of the 146 countries converge very strongly.

< Table 1 > Overall convergence test results for the total population

<table>
<thead>
<tr>
<th>Trimming rate $r$</th>
<th>$\hat{b}$</th>
<th>$t_{\hat{b}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.150</td>
<td>1.445</td>
<td>13.697</td>
</tr>
<tr>
<td>0.175</td>
<td>1.499</td>
<td>16.174</td>
</tr>
<tr>
<td>0.200</td>
<td>1.594</td>
<td>23.154</td>
</tr>
<tr>
<td>0.225</td>
<td>1.635</td>
<td>28.309</td>
</tr>
<tr>
<td>0.250</td>
<td>1.704</td>
<td>45.511</td>
</tr>
<tr>
<td>0.275</td>
<td>1.733</td>
<td>61.083</td>
</tr>
<tr>
<td>0.300</td>
<td>1.780</td>
<td>140.349</td>
</tr>
<tr>
<td>0.325</td>
<td>1.799</td>
<td>216.420</td>
</tr>
<tr>
<td>0.350</td>
<td>1.824</td>
<td>272.924</td>
</tr>
</tbody>
</table>

It can be interpreted that in the last 60 years, there has been a large effort to spread higher educational institutions all over the world and that may result in the catch up of schooling years all over the world.

We can find similar results in female educational attainment. <Table 2> is the log t convergence test for the years of schooling for female population of 146 countries. The estimated coefficient $\hat{b}$ shows positive sign at all levels of trimming rate $r$ with high t values, which shows very strong overall convergence of female schooling years.
Under the trimming rate \(r = 0.3\), if we compare the result with the total population, then the coefficient \(\hat{b}\) is 2.317, which is far greater than that of the total population 1.780. This means the catching up of female educational attainments to that of total population, reflecting the removal of discrimination against women and liberation of women during the sample period.

<Table 2> Overall convergence test results for the female population

<table>
<thead>
<tr>
<th>Trimming rate (r)</th>
<th>(\hat{b})</th>
<th>(t_{\hat{b}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.150</td>
<td>1.986</td>
<td>20.066</td>
</tr>
<tr>
<td>0.175</td>
<td>2.038</td>
<td>24.751</td>
</tr>
<tr>
<td>0.200</td>
<td>2.127</td>
<td>35.167</td>
</tr>
<tr>
<td>0.225</td>
<td>2.165</td>
<td>41.574</td>
</tr>
<tr>
<td>0.250</td>
<td>2.234</td>
<td>72.258</td>
</tr>
<tr>
<td>0.275</td>
<td>2.264</td>
<td>93.644</td>
</tr>
<tr>
<td>0.300</td>
<td>2.317</td>
<td>130.996</td>
</tr>
<tr>
<td>0.325</td>
<td>2.341</td>
<td>123.012</td>
</tr>
<tr>
<td>0.350</td>
<td>2.280</td>
<td>114.560</td>
</tr>
</tbody>
</table>

In addition, <Table 3> shows the log t convergence test for 33 OECD countries (we add China to OECD countries). This result also shows overall convergence of years of schooling among the OECD countries.
For each cases (total population, female population, total population of OECD countries), the estimated log t regression coefficient $\hat{b}$ is significantly greater than zero, implying that there is a strong tendency towards convergence among the member countries.

In addition, even though the PS subgroup convergence test algorithm can detect subgroup convergence, no sign of subgroup convergence in the PS test is found, which means overall convergence of the educational level found for each of these 3 cases.

What may be the reason of the overall convergence of educational attainment in the world? It may be interpreted as in developing countries, rising incomes, increased demand for more skilled labor, and government investments of considerable resources on building and equipping schools and paying teachers have contributed to global convergence in enrollment rates and
completed years of schooling. Therefore, enrollment rates and years of schooling have risen in most countries.

<Figure 2> shows the average years of completed schooling of adult population of 4 groups, i.e female, male, world and OECD countries). The OECD countries take the highest position in <Figure 2>, which means the highest schooling years. As is expected, the average years of schooling of male population lies higher than that of female population, and we can see very slow tendency reducing the gap between the average schooling years of male and female.

The coefficient estimate $\hat{b}$ is $2\alpha$ in eq. (5) and measures the speed of convergence. Under the trimming rate $r = 0.3$, if we compare the estimation result of $\hat{b}$ for each case, we can get some meaningful results.

<Figure 2> Average Years of Completed Schooling for 4 groups (female, male, world, OECD)

Source: [http://www.barrolee.com/](http://www.barrolee.com/)
First, we find that the schooling years of female has larger speed of convergence than that of the all population. This result is the catching up of female education with the total population education. It can be achieved by the emancipation of women and increasing income accelerate the demand for women’s education during the sample period.

In addition, the whole countries’ convergence speed is larger than the convergence speed of OECD countries. This can be interpreted as the catch up of the world countries in educational attainment level with the OECD countries.

In short, the schooling years of world countries have converged from 1950 to 2010. If we regard schooling years as a proxy for the educational attainment, then it may be claimed that the world educational attainment level has converged, and more over if we consider the educational attainment level as a proxy for human capital, we can claim that human capital around the world has been converged during the 60 years.

This result agrees with Sab and Smith (2001), who finds global and regional human capital convergence. But this result is not consistent with the result of Zhang and Li (2002), who finds that educational attainment gap between the developing and developed countries were widened over the period from 1960 to 1990.

The implication of this result to the growth empirics is that if human capital converges and income diverges, then the role of human capital may have been overemphasized in growth literature, implying that instead of human capital, physical capital need to be given more important role in income growth, which supports De Long and Summers (1991, 1993, 1994) on income growth.
V. Conclusions

We tried to investigate the convergence of educational attainment by using the newly developed PS log t convergence test in this paper.

The years of schooling, which has been used as a measure of educational attainment, shows overall convergence over the world countries. Especially, the schooling years of female has larger speed of convergence than that of the all population, which means the catching up of female education with the total population education. In addition, the whole countries’ convergence speed in educational attainment is larger than the convergence speed of OECD countries. This can be interpreted as the catch up of the world countries in educational attainment level with the OECD countries.

If we understand the years of completed schooling as the amount of human capital, then this result may imply the convergence of human capital across the world countries. In a situation where income of world countries doesn’t converge as is shown in existing growth literature, the convergence of human capital across the countries might imply more importance of the physical capital in growth empirics. We hope this result will enhance the understanding of the factors of economic growth a few steps forward.
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