Human Capital Quality in the Brazilian States

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Abstract

Quality of human capital seems to be an extremely important feature to be disregarded in the evaluation of this factor impacts on income per worker (rate of growth and level). This is the reason for the emergence of many recent studies which includes some variable that takes into account the quality of human capital. The present study's goal is to make an empirical analysis by using a human capital proxy that takes into account quantitative and qualitative aspects of this factor to measure with a higher level of accuracy the human capital direct impacts on Brazilian States output level in the years 1970, 1980, 1991, and 2000. The methods employed are Ordinary Least Squares (OLS), Iteratively Reweighted Least Squares (IRLS) and Panel Data regressions.

Keywords: Human Capital Quality, Income per Worker, Empirical Analysis of the Brazilian States, Iteratively Reweighted Least Squares, Panel Data

JEL Classification: C23, E13, O11, O41, O50

Resumo

A qualidade do capital humano parece ser uma característica de extrema importância para não ser levada em conta na análise dos efeitos deste fator sobre o nível e a taxa de crescimento da renda por trabalhador. Esta é a principal razão para o surgimento de muitos estudos que fazem um esforço no sentido de se introduzir alguma proxy para capital humano que incorpore aspectos qualitativos deste fator. O objetivo do presente estudo é fazer uma análise empírica dos impactos diretos do capital humano sobre o nível e o crescimento da renda por trabalhador nos estados brasileiros através do uso de uma *proxy* que incorpore aspectos quantitativos e qualitativos deste fator. O período de análise é 1970-2000, com dados para os anos 1970, 1980, 1991 e 2000. Os metódos empregados são Mínimos Quadrados Ordinários (MQO), Mínimos Quadrados Ponderados Iterativo e Dados de Painel.

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1. Introduction

Despite the controversy about the human capital effect on economic growth, it seems that this is a crucial factor in the process of development and growth. Some studies, as Romer (1990), Benhabib e Spiegel (1994), Hall e Jones (1998), and Pritchett (2001) cast some doubts about the direct impacts[1] of human capital on income. However, there are great deals of other studies that support the opposite view. Some of them are Krueger (1968), Easterlin (1981), Barro (1991), Mankiw et alii (1992),[2] and Barro e Lee (2001).

Most part of the evidences supporting the view that human capital is a crucial element to increase output in a direct way comes from microeconomic studies, though. A great deal of empirical studies indicates high returns to human capital investments in developing and developed countries. Some potential reasons for this macro-micro "paradox" are model specifications errors and low quality data.

Temple (1999) finds that influential outliers may lead to misleading results. If these observations are omitted, using the method of least trimmed squares, the conclusion is that human capital is more important them it really seems to be. Nelson e Phelps (1966) provides an important alternative by emphasizing the role of human capital in the process of technology diffusion. In their model, returns to education costs are positive if the technology is always improving. The basic hypothesis of the model is the following:

> We suggest that, in a technologically progressive or dynamic economy, production management is a function requiring adaptation to change and that the more educated a manager is, the quicker he will be to introduce new techniques of production. To put the hypothesis simply, educated people make good innovators, so that education speeds the process of technological diffusion (p.70).

Some empirical studies, as Benhabib e Spiegel (1994, 2002), and Islam (1995) provide evidences sustaining this position. International trade is another important channel of technological diffusion because technology is embodied in traded goods. Therefore, when a country buys one good from another one and uses it in the production process, the amount of technology used in the production process is increased (see Keller (2004)). Additionally, Connolly (2003) suggests that the use of foreign capital goods may lower the cost of imitation. Another essential diffusion channel is Foreign Direct Investment (FDI). The reasons to believe that FDI plays an important role in technological diffusion are many. First of all, when a MNE opens a subsidiary in a country it brings some knowledge embodied in physical

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⋆ Submitted in November 2005, accepted in March 2006. We are grateful to Lízia de Figueirêdo, Gabriel Porcile, Maurício Bittencourt, Fábio Gomes, Marcos Flávio da Cunha Resende, and to an anonymous referee for helpful comments.

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[1] By direct way or direct impacts we mean the introduction of human capital in the production function. Introducing human capital in this fashion should capture the effects of this factor in improving workers ability to perform a job.

[2] Henceforth MRW.

capital and persons, and new methods of production (disembodied knowledge). It also brings new knowledge that will be taught to domestic workers employed in the new fabric (labor training). As Stated by Aitken e Harrison (1999): “Several studies have shown that foreign firms initiate more on-the-job training programs than their domestic counterparts.” (p. 605). Additionally, subsidiaries interact with domestic suppliers and some competitors, and they provide high-quality intermediate inputs (Dimelis e Louri 2003). Some studies as Borensztein et alii (1998), Xu (2000), and Dimelis e Louri (2003) show that human capital can interact with international trade and FDI in a way that the higher the level of human capital is in a region, the most it can benefit from diffusion through imports and FDI.

The other problem is the kind of data collected to measure human capital. Most of data sets available take into account only quantitative aspects of this factor, making room for measurement errors when an empirical analysis is carried out. Hanushek e Kimko (2000), and Barro (2000) make use of international mathematics and science tests score to measure qualitative aspects of human capital (TIMMS[3] for students and IALS[4] for adults). They found out that both quality and quantity of human capital positively affects economic growth, but quality is more important. Connolly (2004), using expenditures in education based on the perpetual inventory model as a proxy for quality of human capital, finds that it is an important factor in explaining differences in income level of U.S. States.

The present study’s goal is to make use of a human capital proxy that takes into account quantitative and qualitative aspects of this factor to measure with a higher level of accuracy the human capital direct impacts on Brazilian States output level. The human capital proxy that will be used is years of schooling (h) multiplied by an index of education quality. Because it is a particularly difficult feature to measure, we have made use of three variables related to infra-structure, teaching and student performance quality. The variables are the percentage of teachers holding an undergraduate degree, student performance (pass rate) and number of students per classroom. Each one of these variables was divided by the highest one, *i.e.* by the variable of the State with the highest score. As a result, their range is bounded between zero and one. The index of education quality is composed by the sum of the percentage of teachers holding an undergraduate degree index and student performance index subtracted from the number of student per classroom index. Afterward, they were divided by the highest one, in order that its’ range among States would remain bounded between zero and one[5].

Making use of Brazilian States Human Development Index (HDI) as a proxy to States degree of development, it is possible to see on Figure 1 that both variables are very correlated (0.825), despite the noticeable higher variance of the human capital quality index:

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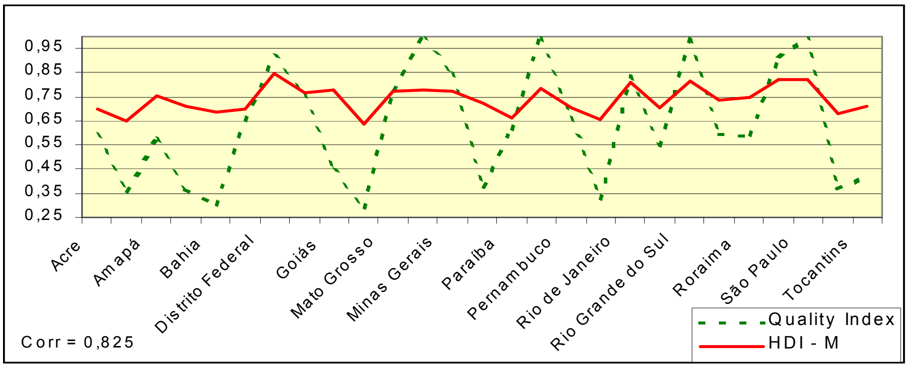
[3] The Third International Mathematics and Science Study in 1994 and 1995.

[4] International Adult Literacy Survey.

[5] See Appendix.



Source: MEC/INEP and IPEA

Fig. 1. Correlation between development (IDH) and quality of education

This result is similar to others studies' conclusions. Using data from the Northeast and Southeast regions of Brazil, Barros et alii (2001) find a negative relation between poverty and quality of education. Better schools' physical infrastructure and teachers' years of schooling seem to be an important factor for improving students' performance at school. Other important factors that impacts positively on students' performance are parents' years of schooling and households' income. Because schools' physical infrastructure and teachers' education are, on average, likely to be better in richer regions and both parents' years of schooling and households' income are, on average, expected to be higher in the same regions when compared to poorer ones, we should believe that the quality of education is better in the rich regions of Brazil.

One may say that parents' years of schooling and households' income are not important elements in the determination of schools' quality of education. However, if more educated and wealthier parents care about their children's education, they will be willing to spend more money to have their kids in good quality schools. Therefore, the demand for good schools will be greater comparing to those regions where parents are not so fortunate, impacting on the quality of school, at least on the private ones. These elements may be important even after controlling for schools' physical infrastructure and teachers' years of schooling since these two proxies for quality of school educational system do not capture all elements determining it.

Even after controlling for the above variables, a dummy variable for the poorest region (the Northeast of Brazil) shows that the performance of the students from this region is worse than the performance of students from Southeast. Maybe this is a consequence of differences in school quality not being captured by the above variables. One problem regarding Barros et alii (2001)' paper is the proxy employed to measure students' performance. It is students' years of schooling, so the proxy used to quantify the performance of a student does not rely on any qualitative measure. A person X with more years of schooling than Y, while they were at school, does not necessarily had a better performance at school. Albernaz et alii (2002) use another proxy to circumvent this problem. Their proxy to assess students' performance at school is based on standardized tests of knowledge provided by *Sistema de Acompanhamento da Educação Básica* (SAEB). Their results are qualitatively similar to those of Barros et alii (2001), the performance of Brazilian schools on the tests depends on the average income level of their students. Once this aspect is taken into account, the school's physical infrastructure and teachers' average years of schooling are important elements to determine students' performance on the tests.

Besides this introduction, this paper includes a brief discussion of some studies about human capital and growth in Brazil. The following section presents the formal model that will be used in the empirical analysis. In the fourth section is the methodology and data that will be employed, and finally, in the fifth, the empirical results.

2. Empirical studies for Brazilian States

Brazilian States empirical analyses are more focused in income distribution and convergence. A good reason for this trend is the high level of regional inequality. Some of these studies make use of human capital as a control variable, but they are hardly concerned with the importance of this factor in the Brazilian States rate of growth or income level. Usually, empirical studies find evidences supporting the existence of absolute convergence in Brazilian States income per capita as in Ferreira (1996) and Azzoni (2001). However, as pointed out by Azzoni (2001), with a great deal of variation in the evolution of inequality over time and across regions.

When some other variables are included as control, the result is an increase in the speed of (conditional) convergence. In addition, when human capital is introduced, it is positive and significant in most of empirical studies. Azzoni et alii (1999)'s results show that Brazilian States income level are positively correlated with human capital. It is also positively correlated with geographic, wealth and participation indicators. Some other studies that examine the impact of human capital in the Brazilian States level or growth of income per capita are Ferreira (2000), Andrade (1997), and Lau et alii (1993). Lau et alii (1993)'s results indicate that one additional year of education per worker increases real output by roughly 20 percent. Thus, average education of the labor force plays a crucial role in Brazilian States income level. Andrade (1997) finds out an even larger impact of human capital on income per capita: one more additional year of working population schooling increases GDP by about 32 percent. Ferreira (2000)'s main concern is to measure the speed of convergence. Besides, his results show that human capital is an important factor to explain Brazilian States income growth rate.

3. The model

3.1. *Steady state*

The production function is the following one

$$Y_t = K_t^{\beta} H_t^{\alpha} \left(A_t L_t\right)^{1-\alpha-\beta} \tag{1}$$

where K_t, H_t e L_t are the level of physical capital, human capital, and labor employed in the production process at time t, while α, β, and $1-\alpha-\beta$ are human capital, physical capital and labor participation on income, respectively. Dividing both sides of Equation (1) by effective units of labor:

$$\hat{y} = \hat{k}^{\beta} \hat{h}^{\alpha} \tag{2}$$

In the above equation, $\hat{y} = Y/AL$, $\hat{k} = K/AL$, and $\hat{h} = H/AL$. Using the same assumptions as Solow (1956), the evolution of these two production factors can be displayed as:

$$\dot{\hat{k}} = s_k \hat{y} - (\delta + n + g)\,\hat{k} \tag{3a}$$

$$\dot{\hat{h}} = s_h \hat{y} - (\delta + n + g)\,\hat{h} \tag{3b}$$

In Equations (3a) and (3b), s_k and s_h are the fraction of income invested in physical and human capital, the dot corresponds to time differential. Rate of growth of working age population is measured by n; while g represents the rate of technological progress. Physical and human capital depreciation rate are assumed to be the same, and they are measured by δ. In the steady state, Equations (3a) and (3b) are equal to zero. The solutions of these two equations when they are equal to zero are given by:

$$\hat{k}^{*} = \left(\frac{s_k^{1-\alpha} s_h^{\alpha}}{\delta + n + g}\right)^{1/1-\alpha-\beta} \tag{4a}$$

$$\hat{h}^{*} = \left(\frac{s_k^{\beta} s_h^{1-\beta}}{\delta + n + g}\right)^{1/1-\alpha-\beta} \tag{4b}$$

The superscript * denotes that the variable under consideration is in the steady State. Substituting both equations into (2) and taking natural logarithms, we have:

$$\ln \hat{y}^* = \left(\frac{\beta}{1-\alpha-\beta}\right)\ln(s_k) + \left(\frac{\alpha}{1-\alpha-\beta}\right)\ln(s_h) - \left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)\ln(\delta+n+g) \tag{5}$$

Or in terms of output per unit of labor (remember that $ln(\hat{y}_t) = lny_t - -lnA_t$),

$$\begin{aligned}&\ln y^* = \ln A_t + \left(\frac{\beta}{1-\alpha-\beta}\right)\ln(s_k) + \left(\frac{\alpha}{1-\alpha-\beta}\right)\ln(s_h) - \left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)\\ &\ln(\delta+n+g)\end{aligned} \tag{6}$$

Output per unit of labor is $y = Y/L$, and the steady state output per unit of labor is represented by y^*. It is assumed that g and δ are constant across States. A_t does not stand for only technology, it also represents resources endowment, climate, institutions, and so on. MRW assume that

$$\ln A_t = a + \epsilon \tag{7}$$

where a is a constant and ϵ stands for countries specificities. Using this equation into (6):

$$\begin{aligned}&\ln(y^*) = a + \left(\frac{\beta}{1-\alpha-\beta}\right)\ln(s_k) + \left(\frac{\alpha}{1-\alpha-\beta}\right)\\ &\ln(s_h) - \left(\frac{\alpha+\beta}{1-\alpha-\beta}\right)\ln(\delta+n+g) + \epsilon\end{aligned} \tag{8}$$

This equation is utilized by MRW in the empirical analysis. However, our measure of human capital is more closely related to stock rather than investment. In this case, we can use Equations (4b) and (8) to find

$$\ln(y^*) = \eta a + \left(\frac{\beta}{1-\beta}\right)\ln(s_k) + \left(\frac{\alpha}{1-\beta}\right)\ln(h^*) - \left(\frac{\beta}{1-\beta}\right)\ln(\delta+n+g) + \epsilon' \tag{9}$$

where $\eta = (1-\alpha-\beta)/(1-\beta)$ and $\epsilon' = \eta\epsilon$.

3.2. *Convergence*

Because States may be out of steady State, it is important to include such situation in the empirical analysis. In the steady State neighborhood, the speed of convergence is given by

$$\frac{d\ln\left(\hat{y}_t\right)}{dt} = \lambda\left[\ln\left(\hat{y}^*\right) - \ln\left(\hat{y}_t\right)\right] \tag{10}$$

where $\lambda = (n+g+\delta)(1-\alpha-\beta)$ and $\hat{y}^*_t$ output per effective unit of labor in the steady State. Equation (10) implies that

$$\ln\left(\hat{y}_t\right) = \left(1-e^{-\lambda t}\right)\ln\left(\hat{y}^{*}\right) + e^{-\lambda t}\ln\left(\hat{y}_0\right) \tag{11}$$

In Equation (11), $\hat{y}_0$ is output per effective unit of labor in the first period. If we subtract $ln(\hat{y}_0)$ from both sides of Equation (11) remember that $ln(\hat{y}_t) = lny_t - -lnA_t$, we have:

$$\ln\left(y_t\right) - \ln\left(y_0\right) = \pi\ln\left(y_t^{*}\right) - \pi\ln\left(y_0\right) + e^{-\lambda t}\left(\ln A_t - \ln A_0\right) \tag{12}$$

where $\pi = (1-e^{-\lambda t})$. From this equation, we can derive three different ones. It depends on which equation we in place of $ln(y_t^{*})$ in (12). Since we do not have a proxy for investment in human capital, we will use only (9). Using (9) into (12), yields:

$$\begin{aligned}\ln\left(y_t\right) - \ln\left(y_0\right) = {} & \pi\eta a + \pi\left(\frac{\beta}{1-\beta}\right)\ln\left(s_k\right) + \pi\left(\frac{\alpha}{1-\beta}\right)\ln\left(h^{*}\right) \\ & - \pi\left(\frac{\beta}{1-\beta}\right)\ln\left(\delta+n+g\right) - \pi\ln\left(y_0\right) + e^{-\lambda t}\left(\ln A_t - \ln A_0\right) + \pi\epsilon'\end{aligned} \tag{13}$$

4. Methodology & Data

Because the error term is a State-specific shift or shock term, one problem in Equations (9) and (13) is the possible correlation between ϵ and at least one of the independent variables s$_k$, h, and n. MRW assume that this is not the case, and they use OLS to estimate the parameters. This choice is criticized by Hall e Jones (1998):

> This assumption seems questionable, as countries that provide incentives for high rates of physical and human capital accumulation are likely to be those that use their inputs productively, particularly if our hypothesis that social infrastructure influences all three components [productivity, physical and human capital] has any merit. (1998,p.13).

Following Islam words "panel data framework provides a better and more natural setting to control for this technology shift term ϵ" (1995,pp.1134–35). This framework provides a better tool to deal with differences in preferences and technology across States, which are difficult to measure, and because the specification of these units of analysis is no longer in the error term, it is less likely to be correlated with some of the independent variables.

In the panel data framework, one has to decide between fixed and random effects. Based on Equation (9), the model that underlies fixed-effects estimation is represented by:

$$\ln\left(y_{it}^{*}\right) = \eta a_i + \left(\frac{\beta}{1-\beta}\right)\ln\left(s_{kit}\right) + \left(\frac{\alpha}{1-\beta}\right)\ln\left(h_{it}^{*}\right) - \left(\frac{\beta}{1-\beta}\right)\ln\left(\delta+n_{it}+g\right) + \epsilon'_{it} \tag{14}$$

where a_i is a dummy variable detaining the specificity of each State.[6] Therefore, this model assumes that differences across units can be captured in a constant that differs across units and this dissimilarity can be estimated by Fixed Effect (FE). If we use Random Effects estimates (RE) based on (9), we would have

$$\ln(y_{it}^*) = \eta a + \left(\frac{\beta}{1-\beta}\right)\ln(s_{kit}) + \left(\frac{\alpha}{1-\beta}\right)\ln(h_{it}^*) - \left(\frac{\beta}{1-\beta}\right)\ln(\delta + n_{it} + g) + u_i + \epsilon_{it}^{'} \tag{15}$$

The element u_i is the random disturbance characterizing the ith observation and it is constant through time. The main drawback of this approach is the assumption that individual effects are uncorrelated with the other regressors. Because our main motivation to use panel-data estimation is that these individual effects can be correlated with the other regressors, fixed-effects estimation seems the most appropriate method. In addition, it is a good approach when the dissimilarities among the units of analysis can be interpreted as parametric changes of the regression function. However, we had problems in making use of FE estimates because of a possible high correlation between the dummy variables and income per worker at the beginning of the period (1970). Thus, we have also estimated RE regressions to compare the results. Hausman tests for fixed and random effects regressions had negative values in some cases probably because of the samples size.

The period of study is composed by the years 1970, 1980, 1991, 2000. The proxy for quantity of human capital is average years of schooling of population over 25. This variable is from IPEA (*Instituto de Pesquisa Aplicada*). The percentage of teachers holding a undergraduate degree, student performance (pass rate) and the number of students per classroom come from MEC/INEP database. Unfortunately, these variables are available only to year 2000. Our assumption is that their difference among Brazilian States are the same in previous years. Working population rate of growth is measured by change in economically active population from *Censo Demográfico* – IBGE (*Instituto Brasileiro de Geografia e Estatística*), the Brazilian Census Bureau. GDP is in constant prices of 2000 and it is from IBGE. There is no available data for Brazilian States investment in physical capital. One proxy that is usually employed in empirical studies is industrial energy consumption from Anuário Estatístico do Brasil – IBGE. The proxy for investment rate is the average growth rate of energy consumption between each two periods. However, Brazilian States industrial energy consumption is not available for 1960 and 2000, so the investment rate proxy for 1970 is the average growth rate of industrial energy consumption in the period 1961-1970 and for 2000 is the average of 1992-1999. For 1980, it is the average of 1971-1980, and for 1991, it is the average 1981-1991. One drawback of using industrial energy consumption is that it does not take into account the primary and tertiary sectors. Therefore, we have used

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[6] We could add a dummy variable for each period, but the main interested is to control for the specificity of each State.

Brazilian States total energy consumption minus residential consumption as a proxy of physical capital.[7]

Using Brazilian States energy consumption we have data for 24 States plus the Federal District for the period under consideration.[8] Thus, the sample in the steady State is composed by 99 observations (one missing) For that reason, we have estimated an unbalanced panel. In the convergence regressions, the sample is composed by 75 observations, since we lose one period of time to calculate the log difference of income per worker.

5. Results

5.1. *Steady state*

The Ordinary Least Square's (OLS) results (pool regression) for the steady State are shown in the three first columns of Table 1. All variables are in natural logarithm. The three first regressions correspond to the specification of Equation (9). The difference among them is the human capital proxy. In the first one, it is used years of schooling (h), in the second, it is years of schooling times our index of education quality (h'), and in the third we look at the individual effects of the two proxies (qualitative and quantitative) of human capital on income per worker.

As expected by Solow's 1956 model, we can see in the first regression that the population growth rate[9] has a negative impact on income per worker, but it is not significant at 5% level. Human and physical capitals have a positive and highly significant impact on income per worker. One per cent increase in years of schooling rise income per worker by 1.18%. Because the average years of schooling in the period of analysis is 3.7, one more year corresponds to a 27% increase in schooling. Therefore, one additional year of schooling increases income per worker by about 32%. This outcome is very close to previous studies' results, as Andrade (1997). The three variables explain a great deal of the income per worker variation across Brazilian States, about 70%.

On the second regression, adding the new human capital proxy (h') increases the coefficient of population growth rate and it turns out to be positive and significant at the 1% level. This result is similar in all fixed effect regressions. These results strongly contradict Solow's model conclusions. Probably, it is related to the population growth rate endogeneity. Figueirêdo e Garcia (2003) found evidences that the income per capita is the main determinant of migration in Brazil for the

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[7] However, the results are quite similar when using industrial energy consumption, so we do not present them.

[8] The Brazilian States of Mato Grosso and Goiás were divided into two different States (Mato Grosso and Mato Grosso do Sul, in the first case, and Goiás and Tocatins, in the second) in the period of analysis. We just sum their outcomes (Mato Grosso + Mato Grosso do Sul, and Goiás + Tocatins) to obtain data that can be compared through time.

[9] Population growth rate is used instead of $n + g + \delta$. If we assume that g and δ are the same in all States, the coefficients will be the same, except for the intercept.

1960-1990 period. Consequently, the States with higher income per capita were the ones which had greater rate of population growth. The coefficient of physical capital experiments a significant decrease and it is significant only at a 10% level, while the significance of human capital coefficient increases slightly. One possible explanation is that physical capital is positive correlated to human capital quality and was explaining part of the effect of this variable on income per worker. The fit of the regression improves marginally.

The third regression shows the result for the two human capital variables regarded separately. Both are important on income per worker, although the impact of quantity is not so important as in the first regression. One more year of schooling with no changes on its quality would have a positive impact of 24% on income per worker. It is close to Lau et alii (1993)'s results (20%). This result is not surprising since, on average, the States with more years of schooling are the ones with better education quality. Therefore, if there is no control for quality, one more year of schooling means more quality, so its impact on income per worker is larger. The physical capital coefficient experiences a puzzling increase and becomes significant at 1% level.

In any of the three regression we could reject the null hypothesis of homocedasticity via Breusch-Pagan statistic and we did not find severe multicollinearity. The Variance Inflation Factor (VIF) was not superior to 5 in any case[10]. Additionally, OLS's results were very close to the ones found via robust regressions (Iteratively Reweighted Least Square – IRLS).

In the fourth regression, the coefficients of human and physical capitals fall drastically. Human capital coefficient remains significant at 5% level in the FE regression and at 1% in the following one, and the physical capital coefficient turns out to be negative, but not significant, and it is positive and significant in the RE regression. One possible explanation for the changes in the coefficients is that human and physical capitals are positively related to each State level of technology. Hence, part of both kinds of capital effect on income per worker is due to the indirect impact through technology, so when we introduce technology via Panel Data estimation, human and physical capital turns out to have less impact on income per worker. In these regressions, the direct impact of human capital is greatly reduced: one more year of schooling would have an influence on income per worker of 6.18% and 17.20% in the FE and RE regressions, respectively. One conclusion is that OLS regressions capture the direct impacts of human capital on income per worker as well as the indirect impacts through technology. The Hausman test fails because the model fitted on these data fails to meet the asymptotic assumptions.

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[10] Multicollinearity is considered to be a problem if the Variance Inflation Factor is more than 10.

Table 1
OLS and Panel data regressions in the steady state case

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	OLS	OLS	OLS	FE	RE	FE	RE	FE	RE
n	-1.439 (1.30)	2.609 (3.21)***	0.422 (0.39)	5.094 (6.78)***	2.214 (2.36)**	5.112 (6.89)***	3.803 (5.99)***		3.477 (4.06)***
h	1.179 (10.69)***		0.895 (7.60)***	0.230 (2.63)**	0.637 (6.09)***				0.453 (4.62)***
h'		0.586 (11.70)**				0.229 (2.64)***	0.412 (6.20)***		
s	2.157 (4.04)***	0.719 (1.68)*	1.542 (3.06)***	$-.095$ (0.27)	0.961 (2.20)**	-0.074 (0.21)	0.454 (1.47)		0.502 (1.28)
q			0.393 (4.58)***					dropped	0.571 (5.17)***
c b	0.568 (3.42)***	1.673 (23.23)***	1.152 (5.83)***	1.829 (14.5)***	1.277 (8.09)***	1.95 (23.82)***	1.792 (20.81)***		1.833 (10.53)***
N	99	99	99	99	99	99	99		99
R^2	0.71	0.73	0.76						
R^{2*}	0.70	0.73	0.75						
R^{2**}				0.49	0.66	0.62	0.72		0.73
χ^2					-52.5		10.38**		
F				13.8***		12.21***			

Notes: t-tests are in parentheses. *Significant at 10%; **significant at 5%; ***significant at 1%. The dependent variable is income *per* worker, n is each State population growth rate, h is years of schooling, h' is years of schooling times HDI, h'' is years of schooling times HDI squared. The variable s is the average growth rate of industrial energy consumption *per* worker, k is industrial energy consumption *per* worker, c is a constant term, R^{2*} is adjusted R square, R^{2**} is overall R square, χ^2 is Hausman test for Fixed *vs.* Random Effect, and F is to test the hypothesis that the dummy variables are all equal.

In the next two regressions, the inclusion of h' slightly increases the significance of human capital coefficient and reduces the significance of physical capital coefficient. There is a visible improvement in the regressions' fit. These results are similar to OLS regressions, so are the conclusions. At 5% level of significance we reject the null hypothesis that RE is the efficient model, but we cannot reject it at 1% level. In the eighth regression, it was not possible to estimate the isolated effects of human capital quality and quantity on income per worker most likely due to multicollinearity between q and the dummy variables. We can make use of the RE regressions to assess the effect of human capital quality. Comparing columns (5) and (9), the introduction of q variable reduces h coefficient, meaning that one additional pure quantitative year of schooling has less impact on income per worker than we would picture if quality is not taken into account. The influence of one more year of schooling falls from 17.20% to 12.23%, a 30% decline. Supposing the same would hold for FE regression (a 30% decline on the human capital coefficient), the impact of one more year of schooling on income per worker would be of 4.32%. The physical capital coefficient declines and turns to be not significant. Thus, its impact on income per worker was due to a possible correlation with human capital quality. In addition, there is an improvement in the regression fit.

One important conclusion from Table 1 is that the direct impact of human capital seems to be much smaller than predict by other studies, but it is important in the determination of the level of output per worker.

5.2. *Convergence*

The results for the conditional convergence cases are shown in Table 2. The regressions are equivalent to the ones in Table 1, except that they are based on Equation (13) and there is one more regression – the first one – to test the incidence of absolute convergence across Brazilian States. We did not find evidences of severe multicollinearity in the OLS regressions, but by means of Breusch-Pagan heteroskedasticity test it was not possible to reject the null hypothesis of homocedasticity, except for the absolute convergence regression. To amend this problem we run robust regressions using Iteratively Reweighted Least Squares (IRLS). This regression method assigns a different weight to each observation. The higher weights are given to better behaved observations (smaller residuals). When the residuals are extreme they can have no weights so that they are not included in the analysis. In situations where the residuals are not well behaved, robust regression (IRLS) results are more trustworthy than OLS.

In the first regression, the income per worker coefficient at the begging of the period is negative and significant at the 1% level, so there is absolute convergence among the Brazilian States in the period of analysis. One average, the States with higher (lower) income per worker in 1970 had lower (higher) income per work growth rate. This is the same result found in other studies for the Brazilian States, as in Ferreira (1996, 2000) and Azzoni (2001).

In the following three regression, the population growth rate is negatively related while human and physical capitals are positively associated to income per worker rate of growth. All of them are significant at 5% and 1% level. The coefficient of income per worker in the previous period is negative and bigger, in absolute value, than in the first regression. As a consequence, when we control for more variables, there is a increase in the speed of convergence. It is not surprising, since when we do not control for any variable besides income in the first period, it is supposed that States/countries have the same steady State. When we allow for differences in the exogenous variables, the steady State of each unit of analysis can be different, increasing the speedy of convergence.[11] The more variables we control for, the more disperse their steady State are allowed to be, augmenting even further the

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[11] It happens because usually countries that are poor have lower steady States, so their rates of income growth are not necessarily bigger than the rates of richer countries.

speed of convergence. The impact of one more year of schooling would be a rise in the rate of income per worker growth by 8%. Because the growth of income per worker was 1.7% during the period of analysis, one more year of schooling would increase it by 0.146% per year.

The inclusion of *h*' changes the results slightly. There are absolute decline in the coefficients of physical and human capital and rate of population growth, but an absolute increase in the coefficient of 1970 income per worker, meaning an increase in the speed of convergence. As before, there is a decrease in the human capital coefficient, but its significance is raised while the significance of physical capital is reduced. The fit of the regressions improves. Looking upon the quantitative and qualitative effects of human capital separately, we see that the effect of h on the rate of income growth is reduced compared to regression (2). One more year of schooling would increase the dependent variable by 0.127%. Quality is also important, it is positive and significant at 5% level. Once more, there is a puzzling increase on the physical capital coefficient and its significance.

We had a problem in the FE regressions, the initial income variable was dropped in all three. Therefore, to assess the effect of this variable on income per worker growth in the Panel Data regressions, we have to rely on the results of RE regressions. In contrast to column (2), physical capital coefficient, in column (5), experiments a decline and it is significant only at a 10% level. There is also a considerable decline in human capital coefficient, and it is significant at 5% level. If we consider only the point estimation, one more year of schooling would have as a consequence, on average, a 0.068% boost in income per worker rate of growth per year, in the transition process. The coefficient of population growth changes sign, but it is not significant. The fit of the FE regression experiment a substantial decline because the level of initial income is not included in the regression. Thus, we have to be careful when putting side by side both models since they are different. The F tests support the use of the FE method in the place of OLS. The use h' instead of h has minor impacts on the results. The sign, size, and significance are almost the same for all variables as well as the R^2.

In the last FE regression, two variables were dropped, so it is the same regression as the one in the column (5). The regressions' results displayed in columns (6) and (8) are very similar. In addition, looking at the results in column (10), there is practically no change when compared to column (6) and the coefficient of q is not significant. Therefore, we can conclude that human capital quality effect on income per worker growth is not relevant in the Panel Data regressions. A reasonable explanation is that human capital quality is being captured by the dummy variables, in the FE regression and by the random terms in the RE regressions or that human capital quality and technology are correlated.

Table 2
OLS and LSDV regressions in the convergence case

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	OLS	IRLS	IRLS	IRLS	FE	RE	FE	RE	FE	RE
n		−3.748 (3.53)***	−2.885 (2.89)***	−3.217 (3.14)***	0.699 (0.80)	−0.436 (0.50)	0.693 (0.80)	−0.100 (0.12)		−.0332 (0.38)
h		0.317 (2.86)***		0.276 (2.63)**	0.149 (2.05)**	0.160 (2.08)**				0.157 (2.05)**
h'			0.183 (3.59)***				0.152 (2.08)**	0.138 (2.25)**		
s		1.173 (2.71)***	0.721 (2.29)**	1.035 (2.54)**	0.541 (1.93)*	0.583 (1.96)**	0.573 (1.98)**	0.533 (2.04)**		0.577 (1.94)*
q				0.146 (2.32)**					dropped	0.094 (0.87)
y_{t-1}	−0.237 (6.02)***	−0.295 (5.59)***	−0.348 (6.25)***	−0.358 (6.21)***	dropped	−0.286 (4.54)***	dropped	−0.347 (4.38)***	dropped	−0.330 (4.05)***
c	1.052 (14.91)***	0.744 (5.43)***	1.115 (16.64)***	0.969 (6.17)***	0.36 (2.87)***	0.872 (6.55)***	0.434 (4.79)***	1.071 (9.61)***		0.998 (5.05)***
N	75	75	75	75	75	75	75	75		75
R^2	0.33	0.43	0.42	0.44						
R^{2*}	0.32	0.40	0.39	0.40						
R^{2**}					0.18	0.36	0.17	0.36		0.37
χ^2										
F					9.53***		9.80***			
λ										

Notes: t-tests are in parentheses. *Significant at 10%; **significant at 5%;

***significant at 1%. The dependent variable is growth of income *per* worker,

n is each State population growth rate,

h is years of schooling, h' is years of schooling times HDI,

h'' is years of schooling times HDI squared.

The variable s is the average growth rate of industrial energy consumption *per* worker,

k is industrial energy consumption *per* worker, y_{t-1} is the level of income *per* worker

in the previous period, c is a constant term,

R^{2*} is adjusted R square, R^{2**} is overall R square, χ^2 is Hausman test for Fixed *vs.*

Random Effect, F is to test the hypothesis that the dummy variables are all equal and

λ is speed of convergence.

6. Conclusions

Quality of human capital seems to be an extremely important characteristic to be ignored in the evaluation of this factor on income per worker (rate of growth and level). This is the reason for the emergence of many recent studies which includes some variable that takes into account the quality of human capital.

In the present study, the inclusion of human capital controlling for the diversity of this factor's quality across Brazilian States to assess its importance on their income level and rate of growth brought important insights. Besides showing that the direct impact of this factor on income per worker in the Brazilian States is smaller than one could conclude from previous results, its significance is increased when considering quality and quantity of this factor in a single variable. When we take into account the individual effect of quality and quantity on income per worker (rate of growth and level), it is possible to verify that one more year of schooling with no changes on its quality would have a smaller impact on the dependent variable since, on average, the States with more years of schooling are the ones with better education quality.

In all cases, both quality and quantity of human capital is significant to explain the disparity in income level across States. Additionally, in the majority of the regressions, it is important in the determination of growth rates during the transition period. The only regression in which human capital is not important to explain variations in the dependent variable is its quality in the RE regression for convergence, most likely because of its correlation to the States level of technology that was captured by the random terms. In addition, its quantity has less effect on income per worker (level and growth rate) in all Panel Data regressions. Our guess is that it is also correlated to each State level of technology. Hence, part of its effect on income per worker is due to the indirect impact via technology, and when we introduce technology via Panel Data estimations, human capital turns out to have less impact on income per worker. In future studies, it is important to assess the importance of human capital on technology level and rate of growth in the Brazilian States and to measure how important it is to explain income per worker level and rate of growth via this channel. By the great reduction in human capital coefficient in the Panel Data regression, its impact on income per worker is almost certainly more important indirectly via technology than directly.

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Appendix

Table A.1
Human capital index

Geographic region	Index of student performance (A)	Index of teachers holding an undergraduate degree (B)	Index of student per Classroom (C)	A+B-C	Composed index
Brasil	0,87	0,79	0,89	0,77	0,73
Rondônia	0,82	0,65	0,83	0,63	0,59
Acre	0,83	0,65	0,85	0,63	0,60
Amazonas	0,85	0,52	0,98	0,39	0,36
Roraima	0,94	0,43	0,75	0,62	0,59
Pará	0,77	0,61	0,99	0,40	0,37
Amapá	0,88	0,60	0,88	0,61	0,57
Tocantins	0,85	0,43	0,84	0,45	0,42
Maranhão	0,84	0,39	0,92	0,31	0,29
Piaui	0,80	0,43	0,89	0,34	0,32
Ceará	0,92	0,65	0,88	0,69	0,65
Rio G.do Norte	0,81	0,63	0,87	0,58	0,54
Paraíba	0,81	0,79	0,94	0,65	0,61
Pernambuco	0,80	0,87	0,97	0,70	0,66
Alagoas	0,77	0,62	1,00	0,38	0,36
Sergipe	0,74	0,61	0,96	0,39	0,36
Bahia	0,74	0,48	0,90	0,32	0,30
Minas Gerais	0,93	0,86	0,90	0,90	0,85
Espírito Santo	0,94	0,72	0,86	0,80	0,76
Rio de Janeiro	0,89	0,88	0,88	0,88	0,83
São Paulo	1,00	1,00	0,94	1,06	1,00
Paraná	0,92	0,99	0,86	1,05	0,99
Santa Catarina	0,96	0,80	0,80	0,96	0,91
Rio G.do Sul	0,88	0,90	0,74	1,04	0,98
Mato G.do Sul	0,83	0,99	0,77	1,05	0,99
Mato Grosso	0,82	0,81	0,80	0,83	0,78
Goiás	0,81	0,55	0,89	0,47	0,44
Distrito Federal	0,88	1,00	0,91	0,97	0,91