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The relative importance of total factor productivity and factors of production in income per worker: Evidence from the Brazilian states

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Abstract

Income per worker gap in different regions of Brazil is stunning. To assess the relative importance of factor of production and total factor productivity (TFP) in those income per worker disparities, development accounting exercises were carried out for the 1970, 1980, 1990, 2000 and 2010 years. In 1970, both types of capital stocks and TPF gaps were associated with the Brazilian states lower relative income in comparison to São Paulo state. Over the decades up to the year 2000, the Brazilian states have experienced a relevant capital deepening process, which account for income per work catching-up. However, the TFP gaps in relation to the reference state remain almost stable and their reduction is fundamental to the maintenance of the Brazilians states income per worker catching-up process. The conclusions remain similar when the analysis is conducted by means of distinct *proxies* of physical capital. When considering the human capital qualitative aspect, we noticed a greater human capital gap among the Brazilian states in relation to São Paulo State and, as a consequence, a reduction in the TFP relative gap.
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Keywords: Development accounting; Economic growth; Total factor productivity; Brazilian states

Resumo

O diferencial de renda por trabalhador em diferentes regiões do Brasil é impressionante. Para avaliar a importância relativa dos fatores de produção e da produtividade total dos fatores (PTF) na disparidade de renda por trabalhado, exercícios de contabilidade do desenvolvimento foram realizados para 1970, 1980, 1990, 2000 e 2010. Em 1970, a renda por trabalhador dos estados brasileiros em relação ao paulista era inferior devido às defasagens existentes em ambos os tipos de capital e da PTF. Ao longo das décadas até 2000, os estados brasileiros experimentaram um processo relevante de aprofundamento de capital físico, que acabou levando a um processo de "*catching-up*". No entanto, as defasagens da PTF em relação ao estado de referência permaneceram praticamente estáveis em todo o período, sendo que a sua redução é fundamental para que os estados brasileiros mantenham o processo de

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"*catching-up*" da renda por trabalho. As conclusões são semelhantes quando a análise é feita com distintas *proxies* de capital físico. Ao considerar o aspecto qualitativo do capital humano, notamos uma maior defasagem de capital humano dos estados brasileiros em relação ao Estado de São Paulo e, como consequência, uma redução nos diferenciais da PTF.
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Palavras-chave: Contabilidade do desenvolvimento; Crescimento Econômico; Produtividade total dos fatores; Estados brasileiros

1. Introduction

In 1970, the average citizen of the richest state of Brazil – São Paulo – was 10.5 times richer than the average citizen of Piauí, its poorest state. In 2010, regional dispersion in Brazil has declined: per capita income in the state of São Paulo was 4 times higher than in Maranhão, which is now poorer than Piauí.

Despite the strong decrease in regional income inequality, it is still higher than among regions of developed countries, while lower than among regions of poor countries. As examples, the richest state of India (Goa) was seven times richer than its poorest state (Bihar), in 2014. On the other hand, among the US states, the maximum difference in per capita income was 2, in 2014 (Alaska and Mississippi).

Why has this difference decreased from 1970 to 2010? Is the decline in income inequality sustainable? These are important questions that motivated the present study. The main objective was to decompose the Brazilian states product per worker in the following components: capital-output ratio, human capital per worker, and total factor productivity (TFP).

The product decomposition exercise was crucial to assess the contribution of each factor of production into the fall of income inequality among the Brazilian states. Understanding their roles in the evolution of income per worker is crucial to guide economic policies aimed to foster growth and improve interstate income distribution. Taking into account various measures of physical capital and *proxies* to capture human capital qualitative aspect was important to give more reliability to the product decomposition results.

It had been challenging to perform the level accounting exercises due to the lack of physical capital estimates for the Brazilian states in the national accounts. The stock of physical capital at the state level is only available for 1970, 1975, 1980 and 1985 (Reis et al., 2005), based on the industrial census, which was interrupted. Our second motivation was to construct *proxies* for 1990, 2000 and 2010 that could help to understand the recent period of the Brazilian economic history.[2]

The third motivation was to improve the empirical estimation of the human capital *proxy*, which is our concern since 2005, and now has a widespread recognition with the study of Hanushek and Wößmann (2007). According to the authors' knowledge there are no development decomposition studies for the Brazilian states that capture human capital qualitative aspect. To accomplish this aim it was employed a *proxy* for the Brazilian states human capital elaborated by the Brazilian Institute of Applied Economics (IPEA) available for 1980, 1991 and 2000. This variable was developed based on the annual income expected values associated with education and experience. The advantage in using such *proxy* is that it already captures the real return of the market for the educational system quality since it is based on the actual wages return. The second *proxy* was a multiplicative term between years of schooling of the population over 24 years and each state Basic Education Development Index (IDEB) score in 2005. Here is made an assumption that quality and quantity are perfect substitutes since state A with the same quantity as state B, but twice its quality has twice of state B human capital. This assumption is the same as in Lucas (1988) and it seems to be reasonable as a first approximation.

The development (or level) accounting exercises were based on Solow (1957) and Hall and Jones (1999), applied to study the evolution of output per worker, production factors and TFP, in the case of the Brazilian states with respect to São Paulo state (reference state). The study employed data available on the censuses years: 1970, 1980, 1991, 2000 and 2010.

[2] Those physical capital *proxies* were partially elaborated by Figueirêdo and Resende (2013) to study economic growth process of Minas Gerais state.

There are many studies investigating the effects of TFP and factors of production on the evolution of the Brazilian Gross Domestic Product (GDP). Some examples are Alston et al. (2010), Barbosa Filho et al. (2010), Bonelli and Levy (2010), Ferreira et al. (2008), Bacha and Bonelli (2005), Gomes et al. (2003), and Bonelli and Fonseca (1998). However, few development accounting exercises were carried out for the Brazilian states.

The empirical results of the present paper indicate that the Brazilian states GDPs per worker are approaching the level of São Paulo basically through the increasing in capital-output and capital-labor ratios (capital deepening process). The relative human capital and relative TFP variations were very small in the Brazilian states average, from 1970 to 2010.

When introducing the IPEA *proxy* to capture human capital qualitative aspect, the results are almost the same since it is highly correlated with the pure quantitative human capital *proxy*. One difference is that the human capital gaps of the Brazilian states in relation to the reference one become smaller over the period. With the second human capital *proxy*, each state gap in relation to the reference one increases. This is because the states with higher quantities of human capital are precisely those with better quality (higher IDEB mean score). For example, São Paulo state is among those with higher quantity of human capital and it is the one with better quality, according to 2005 IDEB scores.

As a result, when this production factor qualitative aspect is considered, a gap reduction of the Brazilian States TFP in relation to the reference state takes place since its quality difference, when it is not considered in the decomposition exercises, ends up being captured by TFP. Even with the inclusion of human capital qualitative aspects, TFP continues as the main variable to account for income differentials among the Brazilian states, which complies with other empirical studies with the Brazilian states data, such as Ferreira (2010), Bonelli and Levy (2010) and Tavares et al. (2001).

When using different *proxies* to measure the physical capital stock, certain regularities are noticed in the results, such as the relative increase in capital-output and capital-labor ratios, from 1970 to 2000. The exception is when it is employed a physical capital *proxy* based on the Brazilian states industrial electric energy consumption, indicating that it does not accurately captures the productive physical capital in the Brazilian states. The *proxy* based on the industrial energy consumption may underestimate the productive physical capital of the Brazilian states in relation to the reference state. The most appropriate *proxies* seem to be those based on the studies of Reis et al. (2005) and on the methodology of Coelho (2006).

In addition to this introduction, in the second section is presented the methodology, the data, its corresponding sources, and the development accounting exercises results, according to the Hall and Jones (1999) methodology. In the third section the results with the human capital *proxies* that capture its qualitative aspect are presented. In the following section, the results with different *proxies* for physical capital are exhibited.

2. Development accounting for the Brazilian states

In this section, the development accounting results (or level accounting) of the Brazilian states output per worker are presented. Following Hall and Jones (1999), the accounting method decomposes differences in output per worker into differences in capital-output ratio rather than in capital-labor ratio. Capital-output intensification is associated, according to the Solow model (theoretical reference of this development account exercise), to transitional periods, i.e., when the economy grows at higher rates than technological progress due to shocks in the determinants of long term income per worker or by higher marginal productivity of capital. In the long term, the capital-output ratio stability is expected since both variables grow at the same pace.

Hall and Jones (1999) highlight two reasons for working with the capital-output ratio decomposition: (i) since, in the steady state, K and Y grow at the same rate, we can infer that the economy is in its steady state when their growth rates are due to technological progress and labor growth; and (ii) if there is an exogenous growth in productivity without changing the investment rate, the K/L ratio will grow over time as a result of an increase in productivity. In this case, part of the capital-labor ratio growth reflects productivity growth which would be attributed to physical capital accumulation, while in Hall and Jones (1999) decomposition this effect is captured only by the TFP term.

2.1. Level decomposition of output per worker

The development decomposition departs from the following specification of the Cobb–Douglas production function with constant returns to scale:

$$Y_i = K_i^{\alpha}(A_i H_i)^{1-\alpha} \tag{1}$$

in which Y, A, K, H denote, respectively, output, Harrod-neutral productivity, physical capital stock, and human capital stock. Dividing both sides of Eq. (1) by $(L^{1-\alpha}Y^{\alpha})$, the production function is expressed in terms of output per worker:

$$y_i = \left(\frac{K_i}{Y_i}\right)^{\alpha/(1-\alpha)} A_i h_i \tag{2}$$

In which $y_i \equiv Y_i/L_i$; $k_i \equiv K_i/L_i$; $h_i \equiv H_i/L_i$, and following Mincer (1974), $h = e^{\phi\mu}$. It is assumed $\phi = 0.10$,[3] and μ is the years of schooling of the population with 25 years old or more. Thus,

$$A_i = \frac{y_i}{\kappa_i^{\alpha/(1-\alpha)} h_i} \tag{3}$$

In which $\kappa_i = K_i/Y_i$. Another possibility to carry out the accounting exercise is according to the following equation:

$$y_i = k_i^{\alpha}(h_i A_i)^{1-\alpha} \tag{4}$$

Eq. (4) can be expressed as:

$$A_i = \frac{y_i^{1/(1-\alpha)}}{k_i^{\alpha/(1-\alpha)} h_i} \tag{5}$$

The decomposition exercises based on Eq. (5) are named capital-labor decomposition, while those based on Eq. (2) are named capital-output decomposition. The first informs that output per worker (y_i) is a function of capital-labor ratio, human capital per worker, h, and of TFP or residual, A. The human capital per worker is a function of the educational return average rate (ϕ) and years of schooling (μ). In the Cobb–Douglas specification, α is the physical capital share in income since it is assumed perfect competition in the economy.

The output (Y) is the state GDP at 2000 constant prices (R$ thousand) from the Brazilian Institute of Geography and Statistic (IBGE). Employed workers were used for the calculation of GDP per worker (y_i), which was elaborated by the Institute of Applied Economic Research (IPEA) based on the demographic censuses.[4] Human capital is measured as the average school years of the population with 25 years or more from IPEA.

The main capital stock (K_1) *proxy* was based on the companies private capital stock (machinery and equipment and non-residential constructions) available on IPEA website (http://www.ipeadata.gov.br/), based on Reis et al. (2005) for the years 1970 and 1980. It was updated in the present study for the years 1990 and 2000, following the methodology of Coelho (2006). We consider this one as the most reliable *proxy*, since it is based on the most consistent physical capital data (Reis et al., 2005). The assumption that underlies this *proxy* is that, in the long run, residential capital is a constant share of total capital, which is reasonable through arbitrage process, i.e. through the exit and/or entry of firms in the markets. Estimates with other measures of physical capital were carried over and the complete decomposition exercise results are in Annex 1.

The residential capital (KR_i) and total private capital (KTP_i) variables of state i are available from IPEA and employed to calculate $K_{1i,t}$. The ratio among these capital stocks (KTP_i/KR_i) is assumed to be constant and equal to that of 1985. For 1990 and 2000, only residential capital (KR_i) is available for the Brazilian states. Assuming that the ratio remains constant, it is possible to recover each state total private capital stock (KTP_i) for 1990 to 2000. Finally, to reach the non-residential private capital stock ($K_{1i,t}$), it is necessary to subtract residential capital stock from total private capital stock:

$$K_{1i,t} = [KR_{i,t} * (KTP_{i,1985}/KR_{i,1985})] - KR_{i,t} \tag{6}$$

In relation to the parameter of capital participation in income, it is assumed $\alpha = 0.4$, in line with previous studies for the Brazilian economy, such as Pereira (2012), Barbosa Filho et al. (2010), Coelho and Figueiredo (2007) and Gomes et al. (2003).

[3] It is assumed $\phi = 0.10$ since many studies for the Brazilian economy estimates a value close to it, e.g. Sachsida et al. (2004) and Nakabashi and Assahide (2015).

[4] In the census, it was considered as occupied or employed the person who worked in the last 12 months preceding the census reference date, or part of it. The person who did not work in the last 12 months preceding the census reference date but that, in the last 2 months, took some action to find work, was considered as unoccupied or unemployed in the censuses of 1991, 2000 and 2010. http://www.ipeadata.gov.br/.

Table 1
Development accounting exercise in relation to São Paulo state.

State	1970					2000					
	Rank	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Rank	ΔRank	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
RJ	2	0.93	0.71	1.07	1.22	1	1	1.01	0.86	1.04	1.13
SP	1	1.00	1.00	1.00	1.00	2	−1	1.00	1.00	1.00	1.00
AM	9	0.40	0.62	0.88	0.75	3	6	0.88	0.82	0.88	1.22
RS	4	0.61	1.18	0.99	0.52	4	0	0.76	1.34	0.96	0.60
SC	6	0.49	1.18	0.94	0.44	5	1	0.72	1.49	0.94	0.51
ES	8	0.41	1.14	0.89	0.41	6	2	0.67	2.83	0.91	0.26
PR	11	0.38	1.17	0.88	0.37	7	4	0.66	1.53	0.92	0.47
MG	10	0.38	1.10	0.90	0.39	8	2	0.60	1.83	0.88	0.37
MS	12	0.36	1.56	0.87	0.27	9	3	0.57	2.11	0.89	0.30
AP	3	0.61	1.32	0.89	0.52	10	−7	0.55	1.38	0.92	0.43
MT	13	0.33	1.10	0.86	0.35	11	2	0.54	2.04	0.87	0.30
PE	15	0.31	1.13	0.85	0.33	12	3	0.45	1.05	0.84	0.51
BA	18	0.26	1.15	0.82	0.28	13	5	0.43	2.09	0.79	0.26
GO	16	0.31	1.33	0.86	0.27	14	2	0.42	1.89	0.89	0.25
RO	5	0.49	0.73	0.86	0.79	15	−10	0.41	1.64	0.82	0.31
RN	21	0.21	1.21	0.82	0.21	16	5	0.41	1.52	0.83	0.33
SE	19	0.26	1.11	0.82	0.29	17	2	0.39	1.73	0.81	0.28
RR	7	0.46	0.91	0.89	0.56	18	−11	0.38	1.25	0.89	0.35
AC	14	0.32	0.69	0.82	0.56	19	−5	0.37	1.01	0.80	0.46
PA	17	0.28	0.87	0.89	0.37	20	−3	0.37	1.59	0.83	0.28
CE	22	0.18	1.10	0.82	0.20	21	1	0.33	1.19	0.78	0.35
AL	20	0.22	1.00	0.80	0.28	22	−2	0.32	1.90	0.76	0.22
PB	23	0.17	1.23	0.81	0.17	23	0	0.31	1.10	0.78	0.36
TO	24	0.15	1.44	0.79	0.13	24	0	0.24	2.91	0.80	0.10
PI	26	0.12	1.18	0.79	0.13	25	1	0.21	1.59	0.75	0.18
MA	25	0.13	0.73	0.79	0.23	26	−1	0.20	2.43	0.75	0.11
Average		0.38	1.07	0.87	0.42			0.51	1.62	0.86	0.42
Standard deviation		0.22	0.24	0.07	0.27			0.23	0.55	0.08	0.28

Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) data and the methodology of Coelho (2006) for 1990 and 2000.

Each state output per worker decomposition into the three multiplicative terms of Eq. (2) for 1970 and 2000 are presented in Table 1. The TFP is calculated as a residual (see Eq. (3)). All terms are expressed as ratios to São Paulo state values. The multiplication of the fourth, fifth and sixth columns of Table 1 results in the third column values. In Table 1, it is interesting to note that most of the states have caught up to the São Paulo state's output per worker (Y/L) basically through physical capital deepening between 1970 and 2000.

Minas Gerais state results, for example, indicate that it had 38% of São Paulo output per worker, in 1970, and 60% in 2000. In 1970 and 2000, the physical capital intensity (K/Y) was 110% and 183% in relation to the reference state, respectively. Human capital per worker (H/L) was close to that of São Paulo, in 1970 (90%), and the distance remained stable over the period (88% in 2000). The TFP also remained quite stable from 1970 (39%) to 2000 (37%).

In Table 1, last row, the simple averages of all variables for the Brazilian states in relation to the reference one are presented. The states relative income average increased from 38% to 51%, between 1970 and 2000. In the beginning of the period, physical relative capital intensity was 107%, and, at the end of the period, it was considerably higher: 162%. When comparing the evolutions of the relative distances of human capital and TFP, they were almost constant over the decades. Therefore, the decomposition exercise indicates that (sigma) income convergence was largely due to relative physical capital deepening.

Despite the convergence, three states, all in the North Region of Brazil, are examples of "growth disasters": Amapá, Rondônia, and Roraima. Amapá had the third highest GDP per worker, in 1970, and it had reached the tenth position, in 2000. This means a loss of seven positions, which can be noticed in the eighth column of Table 1 (ΔRank). Rondônia had lost ten positions and Roraima eleven, in the same time span. What accounts for these "growth disasters" is, above all, TFP relative decline.

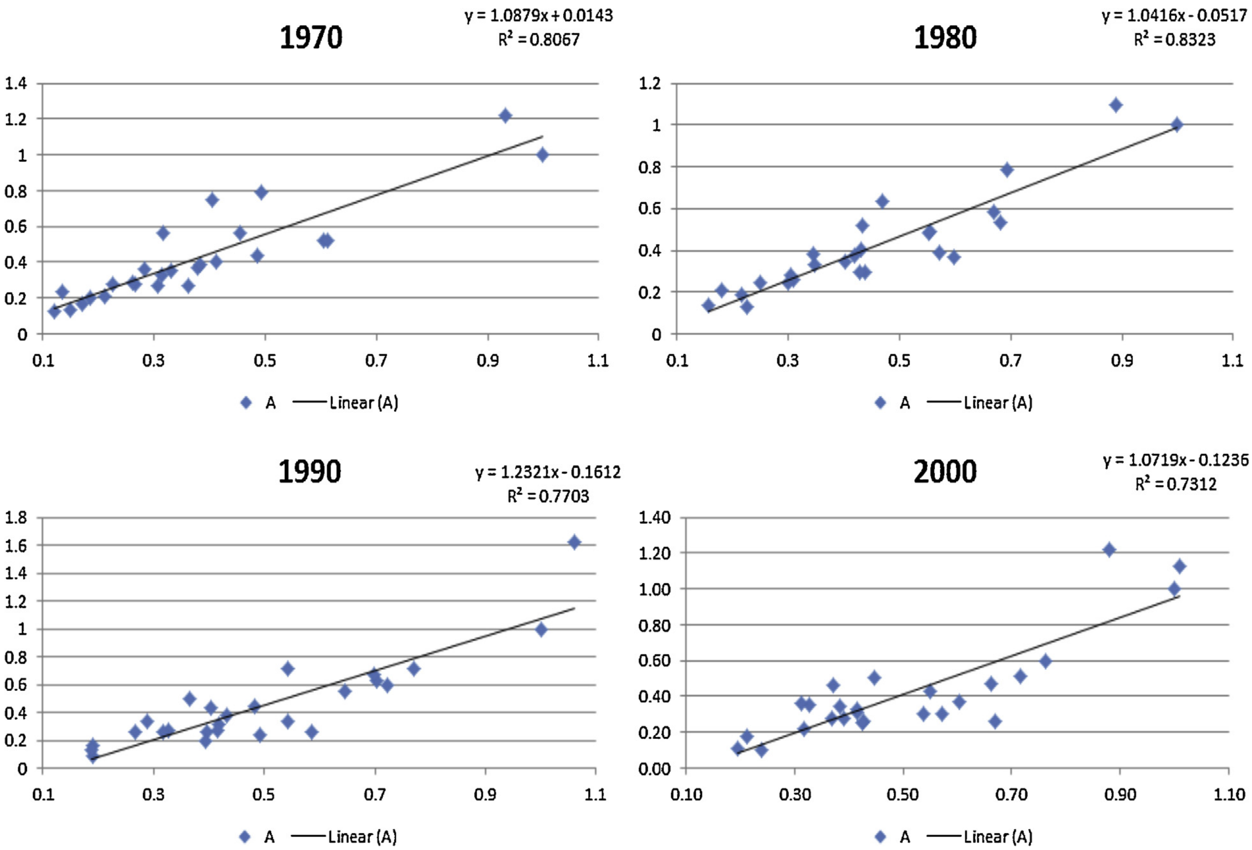

Fig. 1. Development accounting comparing with the state of São Paulo values.
Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) and the methodology of Coelho (2006) for 1990 and 2000 data.

Some states such as Amazonas, Paraná, Bahia and Rio Grande do Norte stood out positively since they managed to reduce the distance of their GDP per worker in relation to the reference state and to the average of the Brazilian states. In all cases, except in Bahia, which gained positions exclusively based on capital-output intensification, TFP relative evolution was crucial to elucidate their performance. In view of that, despite the considerable catching-up process of the Brazilian states GDP per worker level in relation to that of the reference state, which occurred mainly as a result of relative physical capital deepening, their ranking change was primarily due to TFP relative variation.

In this study, the causes of this relative TFP gap among the Brazilian states were not discussed because it is a very complex issue that should be addressed in a separate paper. Nevertheless, one of the potential elements to understand this phenomenon is the differential in their infrastructure quality. Some indexes point to São Paulo state infrastructure superiority compared to other Brazilian states, as in the Brazilian highways assessment reports conducted by the National Confederation of Transport (CNT, 2001, 2002).

Using a measure of public and private capital ratio, Mussolini and Teles (2010) find evidence of the infrastructure quality on TFP determination in Brazil. Another potential source of the relative TFP gap is the difference in human capital per worker across regions. Some empirical studies points to the importance of human capital on income per capita growth through its interaction with TFP as Fraga and Bacha, 2013, Hanushek and Woessmann (2012), Marinho and Silva (2009), Xu et al. (2008), and Nakabashi and Figueiredo (2008).

In Fig. 1, GDP per worker (horizontal axis) and TFP (vertical axis) in the Brazilian states are plotted. The states with higher relative levels of TFP are those closer to the reference state GDP per worker. This relationship is valid in the four years of analysis and it is quite stable over the time. The correlation between the two series is 0.86 when the four periods are jointly considered.

Table 2
Simple correlation among TFP, factors of production and income per worker.

	A	*K*/*Y*	*K*/*L*	*H*/*L*	*Y*/*L*
A	1.00				
K/*Y*	−0.54	1.00			
K/*L*	0.01	0.68	1.00		
H/*L*	0.68	−0.27	0.34	1.00	
Y/*L*	0.86	−0.21	0.45	0.84	1.00

Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) data and the methodology of Coelho (2006), for 1990 and 2000.

The simple correlation coefficients of the development decomposition variables are presented in Table 2. Product per worker is highly correlated with TFP and human capital per worker. The correlation between physical capital and income, both per worker, is positive, but the latter is negatively correlated with capital-output ratio.

It also important to mention the positive and high correlation between human capital and TFP, indicating that human capital accumulation may be an essential strategy to foster TFP evolution. In addition, physical capital accumulation does not seem to be positively related to productivity in the Brazilian states which is in line with the previous results indicating a catching-up process in relation to São Paulo state via physical capital accumulation without a decrease in TFP gap.

This is only a brief and superficial analysis of the connection among these variables. To understand the interaction among them and other elements that affect the Brazilian states relative productivity is crucial to economic policies and more thoughtful studies in this direction will be carried out in future analysis.

In the above results, it is quite interesting to observe that the capital deepening process with respect to São Paulo state intensifies through time. According to Mankiw et al. (1992) augmented Solow's model, it would be expected that the Brazilian states with higher saving rate and lower labor growth rate would be those with a greater capital-output ratio in the steady-state (see Annex 2 – Eq. (A.6)). However, the labor force growth rate was more expressive in other Brazilian states comparing to the reference state. In São Paulo state, the labor force growth from 1970 to 2000 was of 143.7%, while in the Brazilian states simple average it was of 248.7%, in the same period.

The saving rate or the investment rate were not assessed in the present study, but the intensification in capital-labor ratio in the Brazilian States average in relation to São Paulo State (see Table 5) even with a faster labor growth in the former indicates that they had higher investment rates in the period. This relative physical capital distribution in the Brazilian states took place in a process of fast industrial product participation gain in GDP of Brazil from 1970 to 1985, with a reversal of this process after 1985.

One potential candidate to explain the dispersion of physical capital is the adoption of economic policies to stimulate regional development via physical capital investments. These types of economic policies can increase physical capital stock artificially and, as a consequence, reduce aggregate regional productivity. The physical capital relative distribution that took place from 1970 to 2000 among the Brazilian states is of central importance to understand Brazilian states growth process and deserves future analyses.

3. Human capital *proxies* to capture its qualitative aspect

A point to be considered when using *proxies* for human capital in the development accounting exercises is its substantial quality gap among states. If this is the case, a purely quantitative *proxy* tends to underestimate the human capital gap among the states if those with superior quantity are the same with better quality. In this section, human capital *proxies* to capture its qualitative aspect are used to observe how the results change.

3.1. IPEA proxy for human capital

In this section, two *proxies* for human capital qualitative aspect were considered. This is an important aspect to take into account since human capital quality can be very different among regions. For example, Schoellman (2013) introduced a *proxy* that captures human capital qualitative aspect to assess its importance on wages of North American workers. The author employed the wage return of each school year of the immigrants in the United States to measure the

Table 3
Development accounting results in relation to São Paulo state – IPEA.

State	1980		1990		2000	
	H/*L*	*A*	*H*/*L*	*A*	*H*/*L*	*A*
RJ	1.24	0.96	1.15	0.65	1.06	1.10
SP	1.00	1.00	1.00	1.00	1.00	1.00
AM	0.87	0.79	0.95	1.49	0.91	1.18
RS	0.94	0.56	0.88	0.65	0.84	0.68
SC	0.87	0.64	0.85	0.71	0.80	0.60
ES	0.92	0.38	0.87	0.26	0.82	0.29
PR	0.82	0.53	0.84	0.59	0.84	0.51
MG	0.89	0.48	0.84	0.36	0.84	0.39
MS	0.80	0.40	0.85	0.25	0.82	0.33
AP	1.01	0.56	1.00	0.65	1.04	0.38
MT	0.80	0.31	0.83	0.21	0.81	0.32
PE	0.85	0.33	0.91	0.39	0.90	0.47
BA	0.74	0.37	0.78	0.27	0.80	0.26
GO	0.89	0.29	0.86	0.27	0.82	0.27
RO	0.65	0.66	0.75	0.43	0.69	0.36
RN	0.86	0.23	0.90	0.25	0.92	0.30
SE	0.79	0.26	0.84	0.31	0.82	0.28
RR	0.84	0.43	0.90	0.73	0.84	0.37
AC	0.72	0.43	0.77	0.52	0.77	0.47
PA	0.88	0.37	0.86	0.44	0.81	0.29
CE	0.76	0.25	0.76	0.28	0.78	0.35
AL	0.74	0.29	0.79	0.26	0.81	0.21
PB	0.83	0.18	0.83	0.31	0.79	0.36
TO	0.71	0.14	0.74	0.09	0.79	0.10
PI	0.72	0.15	0.72	0.17	0.72	0.19
MA	0.65	0.24	0.71	0.13	0.71	0.11
Average	0.84	0.43	0.85	0.45	0.84	0.43
Standard deviation	0.13	0.23	0.10	0.31	0.09	0.28

Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) data and the methodology of Coelho (2006) for 1990 and 2000.

educational quality gap between the countries. The assumption was that the education return gap reflects the immigrant origin country educational system quality.

Since this sort of data is not available for the Brazilian states, one possibility to capture qualitative aspects of human capital is to use the *proxy* for the Brazilian states human capital elaborated by the Brazilian Institute of Applied Economics (IPEA) available for 1980, 1991 and 2000. It is in constant values (R$ of 2000). This variable was developed based on the annual income expected values associated with the education and experience (age) of the active age population (15–65 years), with a discount rate of 10% per year.[5] The advantage in using such *proxy* is that it already captures the real return of the educational system quality since it is based on the wages return (in accordance to the individuals' years of schooling and experience). On the other hand, it is also affected by the supply and demand of the human capital factor, in addition to its interaction with other production factors and productivity.

Barbosa Filho et al. (2010) had a similar strategy to construct a human capital *proxy* to calculate TFP evolution in Brazil from 1992 to 2007. The authors calculated human capital marginal productivity to build their human capital *proxy* and found results that changed the conclusions of other studies: while merely quantitative *proxies* show a considerable increase of this production factor in the period, the same did not occur with its marginal productivity.

In Table 3, the development accounting exercises were carried out with the IPEA *proxy* for human capital instead of average school years of the population with 25 years or more. The GDP per worker and the capital-output ratio results

[5] The human capital stock is calculated by the difference between the income obtained in the labor market and the estimate of that obtained by a worker with no schooling and experience. For estimating the expected future income, the return coefficient to education and experience were estimated using the demographic census data for the years 1980, 1991 and 2000.

were not presented because they are the same as in the previous exercise. The Brazilian states human capital gap with regard to the reference state using the *proxy* elaborated with years of schooling is very similar: about 84% in relation to the reference state. Rio de Janeiro (RJ) and Amapá (AP) have higher level of human capital relative to the reference state in the three years considered.

It is worth noting the relative stability of each state human capital level in relation to São Paulo state in this long period of time (20 years). Therefore, these results provide additional evidence of this variable relative stability over time across states even when its qualitative aspect is taken into account, supporting the hypothesis that relative human capital quality across Brazilian states was stable over considerable time span, as was considered in the next decomposition exercise.

Because the human capital gap of the Brazilian states in relation to the reference one is similar in relation to the previous decomposition exercise, the TFP gap is also similar. This result was expected by the high correlation between the first *proxy* used for human capital (which only measures quantitative aspects) and the one employed in the current decomposition exercise (elaborated by IPEA): 0.71.

In 2000, the average human capital was 84% of the reference state, whereas it was 86% in the previous decomposition exercise. Therefore, there is a little increase in the average human capital gap that results in a minor TFP average gap reduction from 58% (1–0.42)[6] to 57% (1–0.43),[7] in the same year.

An even greater TFP relative variation among the Brazilian states in relation to human capital occurs as presented in the last row of Table 3. In addition, the human capital gap has turned out to be more homogenous across the Brazilian states over the period as can be checked by the standard deviation reduction. The opposite takes place with TFP.

3.2. *Proxy to capture human capital quality based on IDEB*

The second *proxy* that captures human capital qualitative aspect is a multiplicative term between each state years of schooling of the population over 24 years and the its average Basic Education Development Index (IDEB) mean score in 2005 (simple average of the fifth, ninth years and twelfth years of school).[8] In other words, the Brazilian States educational system quality was measured as the state's IDEB mean score. IDEB was created in 2005 by Anísio Teixeira National Institute of Educational Studies and Research (INEP) to evaluate students test performance in Brazil. As a first approximation, it seems reasonable to assume some form of interaction between human capital qualitative and quantitative aspects in a way that we have one variable capturing both its qualitative and quantitative aspects. In addition, it is possible to assess its quantitative and qualitative aspects individually using natural logarithm in both side of Eqs. (1) and (4), for example.[9] This assumption is taken from Lucas (1988) growth model.

Another assumption for the construction of the *proxy* is that the quality gap across states does not change over time, which is necessary since the tests evaluating students' performance are recent. We consider it to be a reasonable assumption since it takes a long time to change the school system of a whole Brazilian state in relation to other states, and even more time for the children under the new school system to enter into the labor force in a way to have a relevant influence on its quality. The high correlation between quantitative and qualitative aspects of human capital, as presented in Fig. 2, and the stability in the quantitative feature of human capital among the Brazilian states (see Table 1) give empirical support to that assumption.

The positive relationship between average IDEB score (vertical axis) and the quantitative *proxy* for human capital[10] (horizontal axis) for the Brazilian states is shown in the top left side of Fig. 2. The correlation coefficient between the two variables is 0.73, indicating the higher the amount of human capital of a state, the better is the quality of its workers education. The two variables are classified in ascending order according to each state average IDEB (vertical

[6] See second last row and last column of Table 1.

[7] See second last row and last column of Table 3.

[8] For example, if z is a Brazilian state average IDEB score, then its human capital is $z * h$, where $h = e^{(0.10*u)}$, and u is the average school years of its population with 25 years or more. As the other variables, this one has been also normalized in relation to São Paulo state.

[9] It is important in decomposition and econometric studies to analyze human capital qualitative and quantitative aspects separately to support public policies. This exercise was not carried out in the present paper since the objective of the different human capital *proxies* employment was to check for the results robustness. It would be important to measure its distinct effects in future studies.

[10] Average value of each state in the four decades analyzed, i.e., average value of h considering the years 1970, 1980, 1990 and 2000.

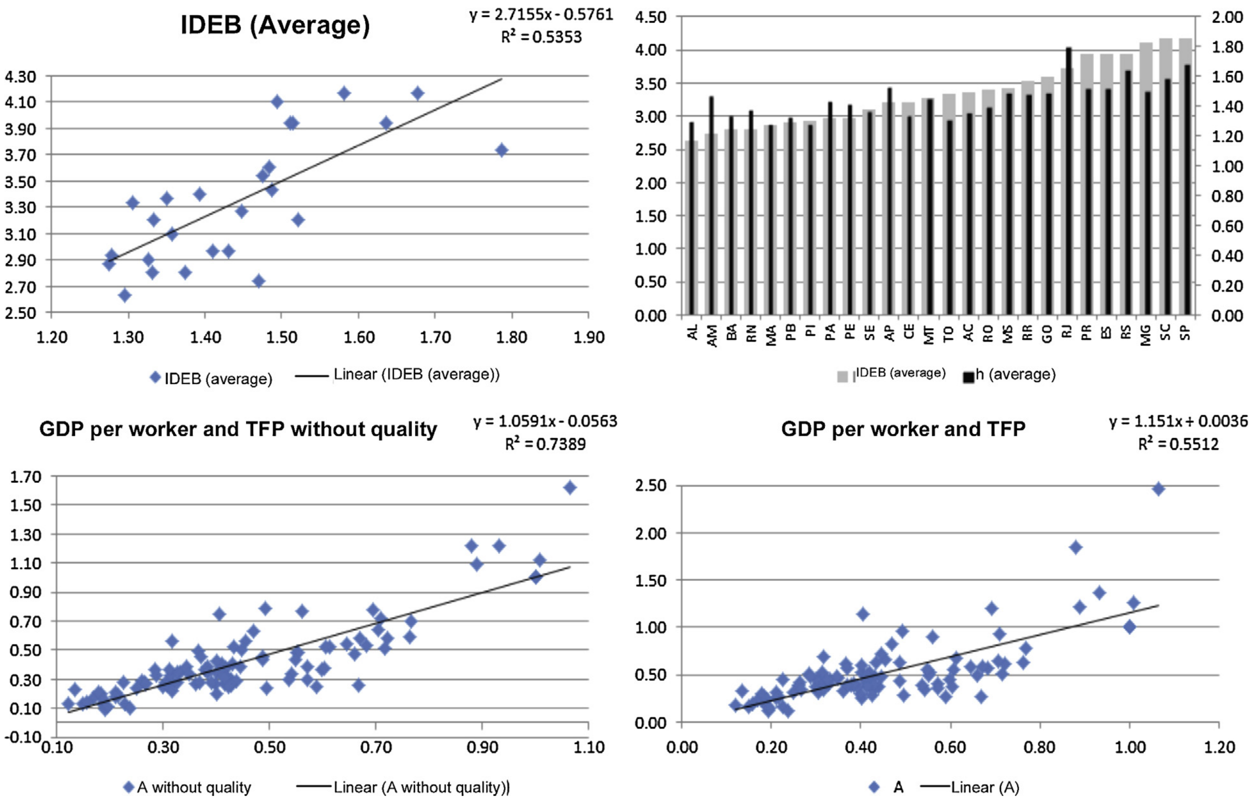

Fig. 2. Education quality by IDEB, TFP and GDP per worker in the Brazilian states comparing with São Paulo.
Source: Authors' elaboration based on IBGE, IPEA, INEP, Reis et al. (2005) data and the methodology of Coelho (2006) for 1990 and 2000.

left axis) in the upper right side of the same figure. The state with the lowest average IDEB is Alagoas, while the state with the highest average IDEB is São Paulo.

The positive correlation between the two variables measuring human capital (quantity and quality) implies that the human capital gap among the states is greater in relation to the first exercise with a purely quantitative *proxy*. In the bottom of Fig. 2, we observe that the association between GDP per worker and TFP of each state is lower when human capital quality is considered. This is so because part of the GDP per worker differential across states, captured by TFP term in the first decomposition exercise (in Table 1), was accounting for the educational system quality gap. In fact, the correlation coefficient between the two variables decreases from 0.86 to 0.75.

The development accounting results with this human capital *proxy* are presented in Table 4. The GDP per worker and the capital-output ratio results were not presented because they are the same as in the first decomposition exercise. The results point to an increase in the Brazilian states human capital gap in relation to that of São Paulo state because the latter had the highest IDEB average score in 2005. Even the state of Rio de Janeiro with the highest value of the working age population years of schooling had a lower level of human capital when considered this composite human capital *proxy*.

On the states average, the human capital ratio decreases from 86% to 70% compared to the reference state, which represents a relevant increase in this production factor gap. Even with a different *proxy* to capture human capital quality, Schoellman (2013) empirical results lead to a similar conclusion. His results indicated that taking into account human capital qualitative aspect increased its contribution to explain the income gap across countries.

In the present study, due to the human capital gap increase, the Brazilian states TFP average goes from 42% to 52% compared to that of São Paulo state, in the majority of the years. However, the Brazilian states TFP average gap is still substantial, explaining the majority of the product per worker gap of the Brazilian states in relation to the reference one.

In relation to the development accounting exercises conducted previously with the three human capital *proxies*, the most important results are the relative stability of this variable (comparing to São Paulo) over time, the relevance of

Table 4
Development accounting exercise in relation to São Paulo state – IDEB.

State	1970		1980		1990		2000	
	H/L	*A*	*H/L*	*A*	*H/L*	*A*	*H/L*	*A*
RJ	0.96	1.36	0.97	1.22	0.96	0.79	0.93	1.26
SP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
AM	0.58	1.14	0.58	1.19	0.57	2.47	0.58	1.85
RS	0.93	0.55	0.93	0.56	0.92	0.62	0.90	0.63
SC	0.94	0.44	0.95	0.59	0.94	0.64	0.94	0.51
ES	0.84	0.43	0.85	0.41	0.85	0.27	0.86	0.28
PR	0.83	0.39	0.85	0.52	0.85	0.58	0.87	0.50
MG	0.88	0.40	0.88	0.49	0.87	0.34	0.87	0.38
MS	0.72	0.32	0.72	0.44	0.74	0.29	0.74	0.37
AP	0.68	0.68	0.69	0.82	0.69	0.93	0.71	0.56
MT	0.67	0.45	0.67	0.37	0.67	0.26	0.69	0.38
PE	0.61	0.46	0.60	0.47	0.59	0.60	0.60	0.71
BA	0.55	0.42	0.53	0.52	0.52	0.40	0.53	0.39
GO	0.74	0.31	0.77	0.34	0.77	0.31	0.77	0.29
RO	0.70	0.97	0.67	0.64	0.67	0.48	0.67	0.38
RN	0.55	0.32	0.54	0.37	0.55	0.41	0.56	0.49
SE	0.61	0.39	0.60	0.35	0.60	0.43	0.60	0.38
RR	0.75	0.66	0.74	0.48	0.73	0.90	0.75	0.41
AC	0.66	0.69	0.65	0.47	0.65	0.61	0.64	0.57
PA	0.63	0.51	0.62	0.53	0.59	0.64	0.59	0.39
CE	0.63	0.27	0.61	0.32	0.60	0.35	0.60	0.46
AL	0.51	0.45	0.49	0.44	0.48	0.42	0.48	0.35
PB	0.56	0.25	0.55	0.27	0.55	0.47	0.54	0.52
TO	0.63	0.16	0.60	0.16	0.61	0.11	0.64	0.13
PI	0.56	0.18	0.54	0.20	0.53	0.23	0.53	0.25
MA	0.55	0.34	0.53	0.30	0.51	0.18	0.52	0.16
Average	0.70	0.52	0.70	0.52	0.69	0.57	0.70	0.52

Source: Authors' elaboration based on IBGE, IPEA, INEP, Reis et al. (2005) data and the methodology of Coelho (2006) for 1990 and 2000.

human capital qualitative aspect and of TFP to understand income per worker differential across the Brazilian states. Additionally, part of what is into TFP in the first decomposition exercise is the quality differential of the Brazilian states educational systems that was not taken into account.

4. Decomposition exercises with different physical capital *proxies*

Another difficulty for carrying out the development accounting exercises for Brazil or for its states is the lack of proper measure of physical capital stock. Due to this difficulty, some authors have made efforts in order to estimate this variable, such as Hofman (1992), who estimated it for Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela from 1950 to 1989. Morandi (2011), Morandi and Reis (2004), Pinheiro and Matesco (1989), and Doellinger and Bonelli (1987) had estimated the physical capital stock for the Brazilian economy. Coelho (2006) estimated it for the Brazilian municipalities and Kroth and Dias (2012) for the municipalities of the Brazilian Southern states. Ferreira (2010) estimated the physical capital stock for the Brazilian states. Their estimations were based on the perpetual inventory method, which is very sensitive to the values of the initial year of the Brazilian series.

The Brazilian states capital stock estimated by Reis et al. (2005) is available for 1970 and 1980. However, it is not for 1990 and 2000. For this reason, we extended their estimations to 2000 by means of Coelho (2006)'s methodology. The latter calculated the ratio between total private capital (KTP), i.e. machinery and equipment plus non-residential and residential capital, and the residential capital (KR) for each Brazilian municipality, in 1985 ($KTP_{i,1985}/KR_{i,1985}$). The author assumed that this ratio remains constant through time and with the IPEA series for the municipalities' residential capital, Coelho (2006) estimated the Brazilian municipalities' total capital for 1990 and 2000.

IPEA also provides data for residential capital for each Brazilian state in the same years (1990 and 2000). Using the 1985 ratio, we can retrieve the private total capital for 1990 and 2000 ($K_{1,1990}$ and $K_{1,2000}$) for each state, according to Eq. (6). This capital stock series is named K_1 and it is the *proxy* used in the previously development accounting exercises. To test how much of our result depends on this *proxy*, the development accounting exercises were carried out with various alternatives *proxies* for physical capital, such as:

(a) $K_{2i,t}$ – Total non-residential private capital of the Brazilian economy ($KTNR_t$) distributed according to each state residential capital ($KR_{i,t}$) in relation to the Brazilian total residential capital (KTR_t), i.e. the companies' private capital in year t for the Brazilian entire economy distributed among the states according to the ratio of their residential capital to the Brazilian economy residential capital, as in the following equation:

$$K_{2i,t} = (KR_{i,t}/KTR_t) * KTNR_t \tag{7}$$

The hypothesis here is that the markets are efficient, e.g., if a state has more residential capital than others, it is going to have more of the other types of physical capital since the marginal product of capital must be the same in the different segments.

(b) $K_{3i,t}$ – Total non-residential private capital of the Brazilian economy ($KTNR_t$) distributed according to each state industrial energy consumption ($KIEC_{i,t}$) in relation to the Brazilian total industrial energy consumption ($KTIEC_t$), as in the following equation:

$$K_{3i,t} = (KIEC_{i,t}/KTIEC_t) * KTNR_t \tag{8}$$

(c) $K_{4i,t}$ – Each state companies total capital estimated by Reis et al. (2005) for 1970 and 1980 ($KReis_i$). The data has been updated according to the industrial energy consumption growth of each state ($KIEC_i$), as suggested by these authors, as in Eq. (10). The term $\Delta KIEC_{i,(80,t)}$ stands for the variation of industrial energy consumption of state i from 1980 to year t.

$$K_{4i,t} = KReis_{i,t} * [1 + (\Delta KIEC_{i,(80,t)}/KIEC_{i,80})] \tag{9}$$

(d) $K_{5i,t}$ – Each state companies and families machinery and equipment estimated by Reis et al. (2005) available for 1970 and 1980 ($KReis2_i$). This *proxy* focuses on a narrower definition of physical capital: machines and equipment. This *proxy* is interesting because of its proximity to the concept of physical capital in the production function, but non-residential construction, not included in its estimation, corresponds to a significant private total capital share.

(e) $K_{6i,t}$ – Total capital (private capital – machinery, equipment and non-residential capital, plus residential capital). From Reis et al. (2005) for years 1970 and 1980 and updated as in $K_{1i,t}$, excluding the last term ($KR_{i,t}$).

(f) $K_{7i,t}$ – Residential capital by state was not available for 2010 and we had first to construct it ($KRest_{i,t}$). We assumed that total residential capital (KTR_t) is distributed among the Brazilian states according to the share of each state residential energy consumption ($KREC_{i,t}$) in Brazilian total residential energy consumption ($KTREC_{i,t}$), as in Eq. (10):

$$KRest_{i,t} = (KREC_{i,t}/KTREC_t) * KTR_t \tag{10}$$

in which KTR_t is the total residential capital for Brazil in year t (2000 and 2010) and $KRest_{i,t}$ is the estimated residential capital for state i in 2000 and 2010. Then we could use the methodology from Coelho (2006), for 2000 and 2010, as in Eq. (11):

$$K_{7i,t} = [KRest_{i,t} * (KTP_{i,1985}/KR_{i,1985})] - KRest_{i,t} \tag{11}$$

This series was estimated to examine the physical capital relative behavior from 2000 to 2010, that is, to check if the relative deepening physical capital process had persisted to 2010.

Table 5 shows the relative evolution of capital and TFP of the Brazilian states average in relation to the reference state, in 1970, 1980, 1990 and 2000. With K_7, the estimates go to 2010. The difference between Table 5 top and bottom is that in the former the Brazilian states mean relative capital evolution is based on their simple average while, in the latter, their mean relative capital evolution are weighted by each state employed population participation on the Brazilian total employed population.

Table 5
Development accounting with different *proxies* for physical capital – Hall and Jones (1999) (capital-output) methodology.

	$(K/Y)^{\alpha/(1-\alpha)}$					A				
	1970	1980	1990	2000	2010	1970	1980	1990	2000	2010
Simple average										
K_1	1.07	1.34	1.51	1.62		0.42	0.43	0.45	0.42	
K_2	1.12	1.02	0.97	1.03		0.39	0.54	0.65	0.60	
K_3	0.53	0.69	0.92	0.96		1.15	1.28	1.03	0.95	
K_4	1.07	1.42	1.65	1.85		0.42	0.42	0.42	0.43	
K_5	0.75	1.16				0.58	0.47			
K_6	1.22	1.31	1.32	1.42	1.44	0.38	0.43	0.50	0.46	0.46
K_7				1.78	1.78				0.39	0.39
Weighted average										
K_1	1.05	1.20	1.38	1.45		0.57	0.61	0.57	0.59	
K_2	1.15	1.05	1.03	1.05		0.51	0.65	0.69	0.71	
K_3	0.75	0.90	1.09	1.11		0.82	0.86	0.75	0.78	
K_4	1.05	1.27	1.50	1.61		0.57	0.59	0.54	0.58	
K_5	0.86	1.12				0.65	0.64			
K_6	1.20	1.20	1.26	1.31	1.26	0.51	0.60	0.60	0.61	0.62
K_7				1.45	1.49				0.59	0.57

Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) data and the methodology of Coelho (2006) for 1990 and 2000.

In order to check how much the results depend on K_1, the decomposition exercises were performed with the six above mentioned physical capital *proxies*. It is important to check two findings with these other *proxies*: (1) if the capital deepening process with respect to São Paulo has occurred, in the period 1970–2000, while relative TFP remained stable; (2) if the capital deepening and convergence processes have been sustained from 2000 to 2010.

In Table 5, with the exception of the decomposition results with K_2, the capital deepening process and the TFP relatively stability thought time with respect to São Paulo state took place. It is important to observe that K_2 does not present the same pattern as K_1 even from 1970 to 1980; period in which the latter was constructed with censuses data by Reis et al. (2005), casting doubt in K_2 reliability as a physical capital *proxy*.

The decomposition results with K_4 are similar to those with K_1. The average values of capital-output ratio are similar, and they present an increasing path over the decades. Additionally, TFP is relatively stable over the time. This result is important since these *proxies* are based on the best information available in the first two years (Reis et al., 2005) and the methodologies suggested by Reis et al. (2005) and by Coelho (2006) were employed to estimate the capital stocks in 1990 and 2000.

It is interesting to observe the results with K_3, since this is a very used *proxy* for physical capital in the Brazilian growth literature. Since K_1 and K_4 are based on censuses data, they are more reliable than the other physical capital *proxies*. If this is so, despite K_3 presents the same capital/output ratio tendency, it underestimates the physical capital stock of the Brazilian states in relation to the reference one. As a consequence, Brazilian states TFP are higher than that of the reference state, but falling over time due to the strong capital-output ratio expansion. Other studies do not corroborate with the Brazilian state average TFP being greater than that of São Paulo state, such as Ferreira (2010) and Tavares et al. (2001). However, the results with the weighted averages – which seem to be more appropriate because it takes into account the weight of each Brazilian state in measuring its mean – reinforce the ones with the other physical capital *proxies*.

The decomposition exercise with K_5, also based in Reis et al. (2005) considering only machinery and equipment, shows again that a strong relative capital deepening process has taken place in the Brazilian "Economic Miracle" from 1970 to 1980. On the other hand, TFP gap in relation to the reference state increased in the same period of time. However, this series was interrupted in 1985.

The results with K_6 show a similar pattern of relative Brazilian states mean capital-output ratio expansion in relation to São Paulo state from 1970 to 2000, but at a slower pace in relation to K_1, K_3, and K_4. Because of this, there is a relative TFP catching up in the same period of time. Nevertheless, from 2000 to 2010 capital-output and TFP ratios remain relatively stable. With K_7, the conclusions are practically the same. In other words, the capital deepening has stopped, without any change in the path of total factor productivity.

The above results indicate that an important part of the state's catching-up up to 2000 does not result from productivity increases, which would keep the relative capital-output ratio constant. The growth has been based on a capital deepening process in part as a growth economic strategy adopted by the Brazilian states. Additionally, from 2000 to 2010, the catching-up process was interrupted since the relative capital deepening came to a halt without improvements on relative TFP or human capital per worker.

For the maintenance of the Brazilian states catching-up process in relation to the reference state, it will be necessary to promote their human capital accumulation and to foster public policies that stimulate TFP evolution since the relative capital deepening process does not seem to be adequate and likely to be sustained. In other words, it is imperial to focus on public policies to enhance the quality of the Brazilian states educational systems and to promote their TFP relative evolution to reduce regional income inequality in Brazil.

5. Conclusions

The income level per worker decomposition was carried out according to two methodologies: based on capital-output decomposition and capital-labor decomposition. The exercises were carried out for 1970, 1980, 1990, and 2000. They were extended to 2010 to infer about the capital-output and TFP patterns in more recent period. Unfortunately, the most reliable physical capital *proxy* is not available for 2010.

With both methodologies, it is concluded that the Brazilian states income per worker differentials in relation to São Paulo state arise mainly from Total factor productivity (TFP) gap. In 1970, the Brazilian states had a lower GDP per worker than São Paulo from differentials of capital per worker stock (physical and human), and TFP. In the thirty years of the empirical analysis, a strong growth in relative capital stock took place, especially in poorer states, reducing the income per worker inequalities in Brazil (beta convergence). However, no progress was made in reducing the relative inequality in TFP.

Despite the human capital smaller gap among the Brazilian states in relation to São Paulo state, there was also no convergence of this production factor. When controlling for its quality, the results indicate the possibility of a greater gap in this production factor among the Brazilian states. On average, the human capital gap in the Brazilian states average was 30% in relation to São Paulo state, in 2000.

Another important finding is that the relative capital deepening process ceased from 2000 to 2010, while relative income per worker remains stable. The Brazilian states capacity to catch-up was restricted, on average, to the physical capital accumulation process, at least in the period studied. Due to the marginal product of capital decrease in this development strategy, as pointed out by Solow's model, it is essential for the Brazilian states to promote public policies that foster their TFP and human capital accumulation for the maintenance of the catching-up process.

Future studies focusing on the relevant variables that promote TFP and human capital progress, and in understanding the relationship among production factors and productivity, e.g. investment in infrastructure, are essential to understand the reasons for the Brazilian states growth and to give support for public policies aimed to maintain the catching-up process and to reduce regional income inequality in Brazil since the physical capital deepening strategy seems to have been exhausted.

Annex 1. Decomposition exercises with alternative *proxies* to extend the analysis to 2010

Table A1
Development accounting exercise in relation to São Paulo state with K_6.

State	1970				2000				2010			
	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
SP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RJ	0.93	0.97	1.07	0.90	1.01	0.94	1.04	1.04	0.89	0.91	1.02	0.96
MT	0.33	1.10	0.86	0.35	0.54	1.63	0.87	0.38	0.74	1.77	0.83	0.50
ES	0.41	1.32	0.89	0.35	0.66	2.23	0.91	0.33	0.70	1.90	0.91	0.40
RS	0.60	1.19	0.99	0.51	0.76	1.20	0.96	0.66	0.69	1.21	0.90	0.63

Table A1 (*Continued*)

State	1970				2000				2010			
	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
SC	0.48	1.23	0.94	0.42	0.71	1.32	0.94	0.58	0.68	1.27	0.95	0.57
AM	0.40	0.74	0.88	0.62	0.88	0.72	0.88	1.39	0.67	1.12	0.89	0.68
PR	0.38	1.21	0.88	0.35	0.66	1.36	0.92	0.53	0.64	1.24	0.93	0.56
RR	0.46	0.92	0.89	0.56	0.38	1.16	0.89	0.37	0.61	1.47	0.85	0.49
MS	0.36	1.43	0.87	0.29	0.57	1.68	0.89	0.38	0.56	1.84	0.88	0.35
MG	0.38	1.38	0.90	0.31	0.60	1.57	0.88	0.43	0.55	1.22	0.88	0.52
AP	0.61	1.13	0.89	0.61	0.55	1.16	0.92	0.51	0.54	1.96	0.97	0.29
GO	0.30	1.43	0.86	0.25	0.42	1.67	0.89	0.29	0.54	1.35	0.89	0.45
RO	0.51	0.77	0.86	0.77	0.42	1.36	0.82	0.37	0.51	1.63	0.77	0.40
AC	0.31	0.78	0.82	0.49	0.37	0.96	0.80	0.48	0.49	1.21	0.80	0.51
TO	0.15	1.50	0.79	0.12	0.24	2.33	0.80	0.13	0.46	1.93	0.85	0.28
SE	0.26	1.37	0.82	0.23	0.39	1.48	0.81	0.33	0.42	1.45	0.84	0.35
BA	0.26	1.32	0.82	0.24	0.43	1.73	0.79	0.31	0.42	1.69	0.78	0.32
PE	0.31	1.32	0.85	0.28	0.45	1.08	0.84	0.50	0.42	1.17	0.80	0.44
RN	0.21	1.46	0.82	0.17	0.41	1.41	0.83	0.35	0.40	1.60	0.80	0.32
PA	0.28	1.03	0.89	0.31	0.37	1.38	0.83	0.32	0.36	1.57	0.81	0.28
PB	0.17	1.59	0.81	0.13	0.31	1.12	0.78	0.36	0.35	0.94	0.73	0.51
CE	0.18	1.40	0.82	0.16	0.33	1.20	0.78	0.35	0.35	1.11	0.80	0.40
AL	0.22	1.33	0.80	0.21	0.32	1.66	0.76	0.25	0.34	1.55	0.71	0.31
MA	0.13	1.16	0.79	0.14	0.19	2.01	0.75	0.13	0.30	2.06	0.78	0.19
PI	0.12	1.54	0.79	0.10	0.21	1.45	0.75	0.19	0.28	1.39	0.75	0.27
Average	0.37	1.22	0.87	0.38	0.51	1.42	0.86	0.46	0.54	1.44	0.85	0.46
SD	0.22	0.24	0.07	0.24	0.23	0.39	0.08	0.29	0.18	0.33	0.08	0.20

Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) data and the methodology of Coelho (2006) for 1990, 2000 and 2010.
SD, standard deviation.

Table A2
Development accounting exercise in relation to São Paulo state with K_7.

State	2000				2010			
	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
SP	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
RJ	1.01	0.86	1.04	1.14	0.89	0.85	1.02	1.03
MT	0.54	2.76	0.87	0.22	0.74	2.32	0.83	0.38
ES	0.66	2.56	0.91	0.29	0.70	2.56	0.91	0.30
RS	0.76	1.27	0.96	0.62	0.69	1.38	0.90	0.56
SC	0.71	1.40	0.94	0.54	0.68	1.51	0.95	0.47
AM	0.88	1.18	0.88	0.85	0.67	1.36	0.89	0.56
PR	0.66	1.38	0.92	0.52	0.64	1.44	0.93	0.48
RR	0.38	1.88	0.89	0.23	0.61	1.56	0.85	0.46
MS	0.57	2.75	0.89	0.23	0.56	2.57	0.88	0.25
MG	0.60	1.67	0.88	0.41	0.55	1.60	0.88	0.39
AP	0.55	2.39	0.92	0.25	0.54	2.53	0.97	0.22
GO	0.42	1.91	0.89	0.25	0.54	1.67	0.89	0.36
RO	0.42	2.10	0.82	0.24	0.51	2.21	0.77	0.30
AC	0.37	1.48	0.80	0.32	0.49	1.36	0.80	0.45
TO	0.24	3.42	0.80	0.09	0.46	2.64	0.85	0.20
SE	0.39	1.86	0.81	0.26	0.42	1.98	0.84	0.25
BA	0.43	1.92	0.79	0.28	0.42	2.26	0.78	0.24
PE	0.45	1.06	0.84	0.50	0.42	1.23	0.80	0.42
RN	0.41	1.47	0.83	0.34	0.40	1.75	0.80	0.29
PA	0.37	1.72	0.83	0.26	0.36	1.84	0.81	0.24
PB	0.31	1.12	0.78	0.36	0.35	1.19	0.73	0.41
CE	0.33	1.15	0.78	0.36	0.35	1.21	0.80	0.36

Table A2 (*Continued*)

State	2000				2010			
	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A	Y/L	$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
AL	0.32	1.81	0.76	0.23	0.34	1.91	0.71	0.25
MA	0.19	2.49	0.75	0.10	0.30	2.63	0.78	0.15
PI	0.21	1.79	0.75	0.16	0.28	1.79	0.75	0.21
Mean	0.51	1.78	0.86	0.39	0.54	1.78	0.85	0.39
SD	0.23	0.64	0.08	0.26	0.18	0.54	0.08	0.21

Source: Authors' elaboration based on IBGE, IPEA, Reis et al. (2005) data and the methodology of Coelho (2006), for 1990, 2000 and 2010. SD, standard deviation.

Annex 2. A theoretic model

Following Mankiw et al. (1992), one possible production function with human capital would be:

$$Y_{it} = K_{it}^{\beta} H_{it}^{\alpha} (A_{it} L_{it})^{1-\alpha-\beta} \tag{A.1}$$

where K_{it}, H_{it} and L_{it} 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 Eq. (1) by effective units of labor:

$$\hat{y}_{it} = \hat{k}_{it}^{\beta} \hat{h}_{it}^{\alpha} \tag{A.2}$$

In the above equation, $\hat{y}_{it} = Y_{it}/A_{it}L_{it}$, $\hat{k}_{it} = K_{it}/A_{it}L_{it}$, and $\hat{h}_{it} = H_{it}/A_{it}L_{it}$. Using the same assumptions as Solow (1957), the evolution of these two production factors can be displayed as:

$$\dot{\hat{k}}_{it} = s_{k,i}\hat{y}_{it} - (\delta + n_i + g)\hat{k}_{it} \tag{A.3a}$$

$$\dot{\hat{h}}_{it} = s_{h,i}\hat{y}_{it} - (\delta + n_i + g)\hat{h}_{it} \tag{A.3b}$$

In Eqs. (A.3a) and (A.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, Eqs. (A.3a) and (A.3b) are equal to zero. The solutions of these two equations when they are equal to zero are given by:

$$\hat{k}_i^* = \left(\frac{s_{ki}^{1-\alpha} s_{hi}^{\alpha}}{\delta + n_i + g} \right)^{1/(1-\alpha-\beta)} \tag{A.4a}$$

$$\hat{h}_i^* = \left(\frac{s_{ki}^{\beta} s_{hi}^{1-\beta}}{\delta + n_i + g} \right)^{1/(1-\alpha-\beta)} \tag{A.4b}$$

Substituting Eqs. (A.4a) and (A.4b) into (A.2):

$$\hat{y}_i^* = \left(\frac{s_{ki}^{\beta} s_{hi}^{\alpha}}{(\delta + n_i + g)^{\alpha+\beta}} \right)^{1/(1-\alpha-\beta)} \tag{A.5}$$

By Eqs. (A.4a) and (A.5):

$$\frac{\hat{k}_i^*}{\hat{y}_i^*} = \frac{K_i}{Y_i} = \frac{s_{ki}}{\delta + n_i + g} \tag{A.6}$$

Therefore, the capital-output ratio is determined by the saving rate and labor force growth rate in the steady-state, assuming the same depreciation rate and TFP growth rate across Brazilian states.

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