Growth and Capital Mobility among Brazilian States: An Analysis of the Period 1970-2000[1]

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Resumo

O objetivo deste trabalho é testar um modelo de crescimento regional para os estados brasileiros utilizando dados recentemente publicados de produto regional e estoque de capital para o período entre 1970 e 2000. O uso de uma proxy para o estoque de capital permitiu que fosse possível testar a função de produção e a mobilidade de capital por meio de regressões econométricas. Argumenta-se que as taxas de crescimento do estoque de capital tiveram um impacto positivo e significante nas taxas de crescimento do produto per capita. Por outro lado, as regressões não foram conclusivas quanto ao impacto do capital humano no crescimento econômico. De forma similar a trabalhos anteriores, um processo de convergência de renda foi identificado para o período como um todo. Este processo foi especialmente acentuado durante a década de 1980 e parece ter cessado na década de 1990. Argumenta-se ainda que as diferenças nas taxas de retorno do capital e a disponibilidade de incentivos fiscais em nível federal tiveram um impacto positivo e, em alguns casos, significante nos movimentos inter-regionais de capital entre os estados brasileiros no período entre 1970 e 2000.

Palavras -chave: Crescimento econômico; Crescimento regional; Mobilidade de capital; Estoque de Capital; Convergência; Brasil.

Abstract

The aim of this paper is to test a neoclassical model of regional growth for Brazilian states using recently published data on the states' GDP and residential capital stock for the period between 1970 and 2000. The use of a proxy for the capital stock allowed the production function, along with the capital mobility among Brazilian states, to be econometrically tested. It is argued that the rates of growth of the capital stock have a positive and significant impact on the rates of growth of the output per capita. On the other hand, the regressions were inconclusive about the impact of human capital on economic growth. Consistently with other previous works, a convergence process was identified for the entire period. The convergence movement was especially strong during the 1980s and seems to have ceased in the 1990s. It is also argued that both the differences in rates of return on capital and the availability of fiscal incentives at the federal level had an expected, positive, and sometimes significant impact on the inter-regional movements of capital among Brazilian states in the period between 1970 and 2000.

Key words: Economic Growth; Regional Growth; Capital Mobility; Capital Stock; Convergence; Brazil.

Introduction

Growth models have been widely used to compare the performance of countries and understand why some of them are rich and others are poor (Jones, 2000; Barro and Sala-i-Martin, 2004). These models are typically tested using econometric regressions (Barro, 1991; Levine and Renelt, 1992; Mankiw et al., 1992) on cross-sectional, time series, and panel data. Several of these papers address the relationship between some specific variable, such as human capital (Pritchett, 2001), institutions (Rodrik et al., 2002), openness to international trade (Alesina et al., 2003), financial intermediation (Levine, 1997), and growth. Regardless the model, the econometric techniques, and the variables used, these studies usually focus on countries and do not consider explicitly any factor mobility among them. There are, of course, exceptions (Barro et al., 1995), but not yet widely used in the empirical works. That means that in the usual models each country is

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endowed with some factors (capital, labor and others), which do not move from country to country as a consequence of their relative prices.

Regional growth models, i.e., models that address growth of subnational spaces, however, have to face this additional issue, because the assumption of no factor mobility would be hardly sustainable in this context. A few papers dealt with structural neoclassical regional growth models (Smith, 1975, and Ghali et al., 1978). The lack of data, however, makes these models more difficult to test than the growth models that use countries as units of analysis. In fact, data on growth are barely available for states in many countries, not to mention the data of the right hand side of the growth models, like capital stock. As a result, most econometric studies on regional growth focus on the issue of convergence, but do not address the factors behind it.

On the other hand, the issue of convergence and, more broadly, of regional inequalities, is fundamental not only for academic purposes but also to support policy formulation, especially in countries marked by high levels of regional inequalities such as Brazil. In fact, back in the 1960s Williamson (1968) concluded that Brazil had the highest regional inequalities level in a wide cross-country comparison. Not surprisingly, regional convergence has been a recurrent subject in the papers about economic growth in Brazil[3], but relatively few studies tried to identify, using econometrical procedures, the reasons behind the movements of convergence or divergence among Brazilian states. Some exceptions are Azzoni et al. (1999) who, using household data, tried to identify the role of what they call geographical variables in explaining differences in per capita income among Brazilian states, and Barros and Vergolino (1998) who focused on the role of education in the process of economic growth in the Northeastern region. As a consequence of the nature of the data used, however, these papers are limited either in time (Azzoni et al., 1999, focused on the period 1981-1996) or regionally (Barros and Vergolino, 1998, focused on only one macro-region of the country).

This paper tests a neoclassical model of regional growth for Brazilian states using some data recently published by the Brazilian Institute of Geography and Statistic (*Instituto Brasileiro de Geografia e Estatística* – IBGE) and the Institute for Applied Economic Research (*Instituto de Pesquisa Econômica Aplicada* – IPEA). The availability of a proxy for the capital stock allowed the production function, along with the capital mobility among Brazilian states, to be econometrically tested. In the model, capital is supposed to move inter-regionally as a result (i) of differences in rates of return in the beginning of the period and (ii) of fiscal incentives given during the period. Econometric tests are also performed to check if labor movements responded to differences in initial levels of the marginal product of labor among Brazilian states during the period. Besides this introduction, this paper is structured in three more sections. Section 2 discusses a growth model with factor mobility based upon the previous works by Smith (1975) and Ghali et al. (1978). Section 3 presents the data and the main results of the regressions. The conclusions of the paper are presented in Section 4.

The Model

This section summarizes a growth model where there is factor mobility among regions providing the basis for the econometric tests performed in Section 3. The models presented here are essentially based upon Smith (1975) and Ghali et al. (1978).

The Production Function

In a closed economy i with perfectly competitive markets and constant returns technology, the aggregate output $Y_{i,t}$ in period t is a function of the stock of capital $K_{i,t}$ and labor as $L_{i,t}$ in the neoclassical growth models (SOLOW, 1956):

$$Y_{i,t} = f(K_{i,t}, L_{i,t}e^{\rho t}) \qquad (1)$$

where $e^{\rho t}$ takes into account the effect of exogenous labor-augmenting technical progress.

If a Cobb-Douglass production function is assumed, the aggregate output $Y_{i,t}$ is given by equation (2) below:

$$Y_{i,t} = K^{\alpha}_{i,t}(L_{i,t}e^{\rho t})^{\beta} \qquad (2)$$

Applying logarithms to both sides of equation (2), and taking the derivatives with respect to t, the rate of growth of the aggregate output is then obtained as shown below:

$$\log Y_{i,t} = \log K^{\alpha}_{i,t} + \log L^{\beta}_{i,t} + \log e^{\beta\rho t}$$
$$\frac{d\log Y_{i,t}}{dt} = \alpha\frac{d\log K_{i,t}}{dt} + \beta\frac{d\log L_{i,t}}{dt} + \frac{d(\beta\rho t)}{dt}$$
$$\hat{Y}_{i,t} = \alpha\hat{K}_{i,t} + \beta\hat{L}_{i,t} + \beta\rho \qquad (3)$$

Where $\hat{Y}_{i,t} \equiv d\log Y_{i,t}/dt$ is the rate of growth of the aggregate output, $\hat{K}_{i,t} \equiv d\log K_{i,t}/dt$ is the rate of growth of the capital stock, $\hat{L}_{i,t} \equiv d\log L_{i,t}/dt$ and is the rate of growth of the labor stock. Of course, the usual caveats of the neoclassical growth models apply to the model proposed so far[4]. Nevertheless, the usual assumption of constant returns to scale $\alpha + \beta = 1$ (i.e.,) did not have to be applied to obtain equation (3).

Equation (2) can be also written in per capita terms. Assuming that the participation rate of the labor force in the total population is constant, and dividing both sides of equation (2) by $L_{i,t}$, the aggregate output per

[3] See, for example, Ferreira and Diniz (1995) and Azzoni (2001).

[4] The typical assumptions include (i) fatores substituíveis e perfeitamente divisíveis; (ii) retornos marginais decrescentes para cada fator; e (iii) algum tipo de elasticidade positiva de substituição entre os fatores de produção. For a more extensive discussion, see, for example, Jones (2000) and Barro and Sala-i-Martin (1995).

capita may be obtained as shown in equation (4) below:

$$\frac{Y_{i,t}}{L_{i,t}} \equiv y_{i,t} = K^{\alpha}_{i,t} L^{\beta-1}_{i,t} e^{\beta\rho t} \qquad (4)$$

The rate of growth of the output per capita $\hat{y}_{i,t}$ is given then by the following equation:

$$\frac{Y_{i,t}}{L_{i,t}} \equiv y_{i,t} = K^{\alpha}_{i,t} L^{\beta-1}_{i,t} e^{\beta\rho t} \qquad (5)$$

If constant returns to scale are assumed, $\alpha + \beta = 1$ and equation (5) reduces to equation (6) below:

$$\hat{y}_{i,t} = \alpha \hat{K}_{i,t} + (\beta - 1)\hat{L}_{i,t} + \beta\rho \qquad (6)$$

In contrast to equation (3), the assumption of constant returns to scale lies behind equation (6). It is necessary now to obtain definitions both to $\hat{K}_{i,t}$ and $\hat{L}_{i,t}$ in order to fully propose the structural model.

The Rate of Growth of the Capital Stock

The rate of accumulation of capital $\dot{K}_{i,t} \equiv dK_{i,t}/dt$ in region *i* in period *t* is given by equation (7):

$$\frac{dK_{i,t}}{dt} \equiv \dot{K}_{i,t} = I_{i,t} - D_{i,t} \qquad (7)$$

where $I_{i,t}$ is the investment in region *i* and $D_{i,t}$ is the depreciation of its capital stock. In the traditional neoclassical growth models, total savings in region i are assumed to be equal to the investments in region *i*. It is assumed that an exogenous constant ratio s_i of the total income $Y_{i,t}$ is saved, so that the total investment, in these models, is given by the equation below:

$$I_{i,t} = s_i Y_{i,t} \qquad (8)$$

On the other hand, depreciation is assumed to be a constant ratio δ_i of the capital stock itself, as shown in the following equation:

$$D_{i,t} = \delta_i K_{i,t} \qquad (9)$$

As a consequence, in the Solow growth model, the rate of accumulation of capital is given by equation (10) below:

$$\frac{dK_{i,t}}{dt} \equiv \dot{K}_{i,t} = s_i Y_{i,t} - \delta_i K_{i,t} \qquad (10)$$

After some algebraic manipulation, equation (10) can be written in per capita terms as well. The rate of capital accumulation per capita $\dot{k}_{i,t}$ in region *i* is then given by equation (11):

$$\dot{k}_{i,t} = s_i y_{i,t} - (\delta_i + \hat{L}_{i,t}) k_{i,t} \qquad (11)$$

In regional growth models (or, in a broader sense, in models where economies are not closed), however, there may be production factor mobility as a consequence of different returns offered and the absence of institutional barriers to interregional movements[5]. As pointed out by Nijkamp and Poot (1998, p. 18), "the impact of this reallocation depends on the assumed characteristics of the model of interacting economies". In a pure neoclassical model there would be convergence among all regions, as both capital and labor would respond to price differentials immediately. Not surprisingly, in these models, large countries are nothing but points with no geographical dispersion of output or production factors.

If perfect competition is assumed, the return on capital in region i $R_{i,t}$ may be obtained from its marginal product, as shown in equations (12) below:

$$R_{i,t} = \frac{\partial Y_{i,t}}{\partial K_{i,t}} = \frac{\partial\left[K^{\alpha}_{i,t}(L_{i,t}e^{\rho t})^{\beta}\right]}{\partial K_{i,t}} = \alpha K^{(\alpha-1)}_{i,t}(L_{i,t}e^{\rho t})^{\beta} \qquad (12)$$

But since $(L_{i,t}e^{\rho t})^{\beta} = Y_{i,t}/K^{\alpha}_{i,t}$, equation (12) can be rewritten as follows:

$$R_{i,t} = \alpha K^{(\alpha-1)}_{i,t} \frac{Y_{i,t}}{K^{\alpha}_{i,t}} = \alpha K^{(\alpha-1-\alpha)}_{i,t} Y_{i,t} = \alpha \frac{Y_{i,t}}{K_{i,t}} \qquad (13)$$

Of course, the average rate of return on capital for all regions $R_{a,t}$ is given by equation (14) below:

$$R_{a,t} = \alpha \frac{Y_{a,t}}{K_{a,t}} \qquad (14)$$

To capture the interregional movements of capital, Smith (1975, p. 167) defines the Net Capital Movement to region *i* ($N_{i,t}$) as a positive function of the differential rates of return on capital, as shown in the following equation[6]:

$$N_{i,t} = \nu (R_{i,t} - R_{a,t}) K_{i,t} \qquad (15)$$

where ν is a positive constant. Smith (1975, p. 167) multiplies the return differential by the capital stock $K_{i,t}$ included as a scale factor. In practice, it is assumed that a region having a larger capital stock should present more investment opportunities at a given difference in the returns on capital. Smith (1975, p. 167) points out that the net capital movements for all regions may not sum to zero because of capital flow from and to the country. When capital mobility is taken into account, equation (10) becomes

$$\frac{dK_{i,t}}{dt} \equiv \dot{K}_{i,t} =$$
$$= sY_{i,t} + \nu (R_{i,t} - R_{a,t}) K_{i,t} - \delta_i K_{i,t} = \qquad (16)$$
$$= sY_{i,t} + \left[\nu (R_{i,t} - R_{a,t}) - \delta_i\right] K_{i,t}$$

The rate of growth of the capital stock $\hat{K}_{i,t} \equiv \dot{K}_{i,t}/K_{i,t}$ can be then obtained simply dividing both sides of equation (16) by $K_{i,t}$:

$$\hat{K}_{i,t} \equiv \frac{\dot{K}_{i,t}}{K_{i,t}} = s_i \frac{Y_{i,t}}{K_{i,t}} + \left[\nu (R_{i,t} - R_{a,t}) - \delta\right] \qquad (17)$$

Now replacing $R_{i,t}$ and $R_{a,t}$ in equation (17) by their definitions given by equations (13) and (14), a definition of $\hat{K}_{i,t}$ as a function of the

[5] In practice, it is assumed that capital is perfectly divisible and mobile with no costs.
[6] Smith (1975) does not use time subscripts in his equations.

output per unit of capital stock can be obtained:

$$\hat{K}_{i,t} = s_i \frac{Y_{i,t}}{K_{i,t}} + v\alpha \frac{Y_{i,t}}{K_{i,t}} - v\alpha \frac{Y_{a,t}}{K_{a,t}} - \delta_i$$
$$\hat{K}_{i,t} = (s_i + v\alpha)\frac{Y_{i,t}}{K_{i,t}} - \left(v\alpha \frac{Y_{a,t}}{K_{a,t}} + \delta_i \right) \tag{18}$$

As pointed out by Smith (1975), equation (18) is similar to Solow's (1956) equation for the rate of growth of the capital stock shown below:

$$\hat{K}_{i,t} = s_i \frac{Y_{i,t}}{K_{i,t}} - \delta_i \tag{19}$$

Provided that v and α are positive constants, $s + v\alpha > s$. As a consequence, the coefficient of $Y_{it} / K_{i,t}$ in equation (18) is larger than the one in equation (19).

A different approach to Smith's (1975) was proposed by Ghali et al. (1978) and Giarratani and Soeroso (1985), who simply consider that the rate of growth of the capital stock in region i is a function of the difference between the return on capital in region i $R_{i,t-1}$ and the return on capital for all regions $R_{a,t-1}$, as well as of the difference between the rate of growth in region i $\hat{Y}_{i,t-1}$ and the average rate of growth for all regions $\hat{Y}_{a,t-1}$, always lagged by one year, as shown in the equations below:

$$\hat{K}_{i,t} = \gamma_0 + \gamma_1 \overline{R}_{i,t-1} + \gamma_2 \overline{Y}_{i,t-1} \tag{20}$$

where

$$\overline{R}_{i,t-1} = \frac{R_{i,t-1} - R_{a,t-1}}{R_{a,t-1}} \tag{21}$$

and

$$\overline{Y}_{i,t-1} = \frac{\hat{Y}_{i,t-1} - \hat{Y}_{a,t-1}}{\hat{Y}_{a,t-1}} \tag{22}$$

The Rate of Growth of the Labor Stock

The rate of accumulation of the labor stock $\dot{L}_{i,t} \equiv dL_{i,t} / dt$ in region i in period t is given by its natural increase plus the net migration, as shown in equation (23):

$$\frac{dL_{i,t}}{dt} \equiv \dot{L}_{i,t} = \frac{L_{i,t}}{P_{i,t}} \left(\frac{dP_{i,t}}{dt} + \frac{dM_{i,t}}{dt} \right) =$$
$$= \frac{L_{i,t}}{P_{i,t}} \left(\dot{P}_{i,t} + \dot{M}_{i,t} \right) \tag{23}$$

where $P_{i,t}$ stands for the population and $M_{i,t}$ for the net migration to region i in period t. The participation rate $L_{i,t} / P_{i,t}$ is assumed constant and the same for all regions. Smith (1975) also assumes that the natural rate of growth of the population $n = \dot{P}_{i,t} / P_{i,t}$ is constant and the same for all regions. Dividing equation (23) by $P_{i,t}$ and defining $\hat{M}_{i,t} = \dot{M}_{i,t} / P_{i,t}$ as the net migration rate, the following equation is obtained:

$$\hat{L}_{i,t} \equiv \frac{\dot{L}_{i,t}}{L_{i,t}} = n + \hat{M}_{i,t} \tag{24}$$

Smith (1975) assumes that the net migration rate $\hat{M}_{i,t}$ is a function of the differences in wage $W_{i,t}$ between region i and the average $W_{a,t}$ for the country, as shown in equation (25) below:

$$\hat{M}_{i,t} = \lambda (W_{i,t} - W_{a,t}) \tag{25}$$

where λ is a constant greater than zero. If perfect competition is assumed, the $W_{i,t}$ is given by the marginal product of labor, as shown in equation (26) below:

$$W_{i,t} = \frac{\partial Y_{i,t}}{\partial L_{i,t}} = \frac{\partial \left[K^{\alpha}_{i,t} (L_{i,t} e^{\rho t})^{\beta} \right]}{\partial L_{i,t}} =$$
$$= K^{\alpha}_{i,t} e^{\rho\beta t} \beta K^{(\beta-1)}_{i,t} \tag{26}$$

But since , $K^{\alpha}_{i,t} e^{\rho\beta t} = Y_{i,t} / L^{\beta}_{i,t}$ equation (26) can be rewritten as follows:

$$W_{i,t} = Y_{i,t} L^{-\beta}_{i,t} \beta L^{(\beta-1)}_{i,t} = \beta \frac{Y_{i,t}}{L_{i,t}} \tag{27}$$

Accordingly, the average rate wage for all regions $W_{a,t}$ is given by equation (28):

$$W_{a,t} = \beta \frac{Y_{a,t}}{L_{a,t}} \tag{28}$$

Now replacing , $\hat{M}_{i,t}$, $W_{i,t}$ and $W_{a,t}$ in equation (24) by their definitions given by equations (25), 27 and 28, the rate of growth of the labor stock can be expressed as a function of the ratio $Y_{i,t} / L_{i,t}$ as shown in equation (29):

$$\hat{L}_{i,t} = n + \lambda (W_{i,t} - W_{a,t}) =$$
$$= n + \lambda\beta \left(\frac{Y_{i,t}}{L_{i,t}} - \frac{Y_{a,t}}{L_{a,t}} \right) = \tag{29}$$
$$= n + \lambda\beta \left(y_{i,t} - y_{a,t} \right) = n + \lambda\beta \tilde{y}_{i,t}$$

where $\tilde{y}_{i,t}$ is the difference between the output per capita in region i and the average output per capita in the country. In practice, equation (29) simply states that regions with higher levels of output per capita would attract labor from regions with lower levels of output per capita. However, it is assumed that the natural rate of growth of the population is the same for all regions. This might be a quite unrealistic assumption for the Brazilian case, as fertility tends to be higher in the poorer regions, as discussed in Section 3.4.

Similarly to their equation proposed for the rate of growth of the capital stock, Ghali et al. (1978) and Giarratani and Soeroso (1985) express the rate of growth of the labor stock in region i as a function of the difference between the wages in the region and the average wages, as well as of the difference between the rate of growth in the region and the average rate of growth for all regions, lagged by one year, as shown in the equations below:

$$\hat{L}_{i,t} = \gamma_0 + \delta_1 \overline{W}_{i,t-1} + \delta_2 \overline{Y}_{i,t-1} \tag{30}$$

Where

$$\overline{W}_{i,t-1} = \frac{W_{i,t-1} - W_{a,t-1}}{W_{a,t-1}} \tag{31}$$

The equations describing the rates of growth of the output per

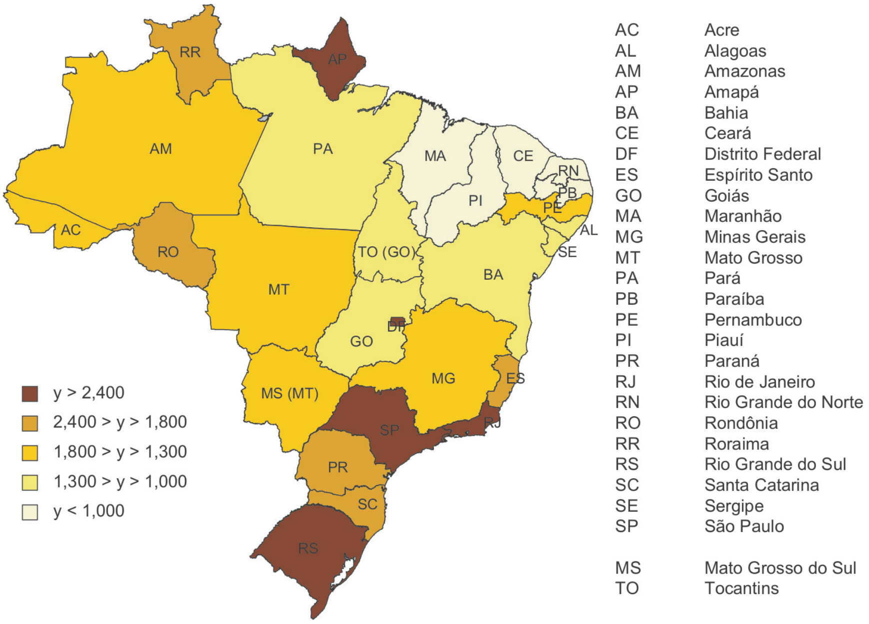

Figure 1: Output per Capita – 1970

Source: Elaborated by the author.

capita, of the capital, and of the labor stock form then a structural model. Equations (5), (18), (24), and (25) form the basis of Smith's (1975) model. On the other hand, equations (3), (20) and (30) have been used by Ghali et al. (1978) and Giarratani and Soeroso (1985) to study regional growth in the US and in Indonesia, respectively. Although these models are conceptually elegant, they have not been directly tested for the Brazilian case at the state level due to the lack of data, especially on the capital stock. The use of a proxy for this variable allows then the models to be econometrically tested. This is the aim of the following section.

Data and Results

This section presents the data and reports the results of the regressions run for the Brazilian case at the state level in the period between 1970 and 2000. Smith's (1975) model has been used as a basis, but some additional features have been considered in the regressions, as shown in the next sections.

Output per Capita

Based upon the aggregate output for 25 Brazilian states[7] in 1970, 1980, 1990 and 2000 and their estimated populations[8], the output per capita and its rate of growth for each decade and for the entire period were calculated. In figure 1 below the inequalities among Brazilian states in 1970 become quite evident. In the map, states with higher levels of output per capita have darker colors, and states with lower levels of output per capita have brighter colors.

As it can be seen, the higher levels of output per capita were observed in the southern states (Rio Grande do Sul, Santa Catarina and Paraná), in three (São Paulo, Rio de Janeiro and Espírito Santo) out of four southeastern states (those ones plus Minas Gerais) and in the Federal District. The higher levels of output per capita observed in three states of the Northern region (Amapá, Roraima and Rondônia) are probably explained by their very low population at that time. As a matter of fact, in 1970 those states were federal territories and their total population did not reach 300,000 inhabitants. On the other hand, nine out the eleven poorest states are precisely the ones of the Northeastern region[9].

Figure 2 reports the rates of growth of the output per capita between 1970 and 2000 in a similar way: the higher the rates of growth, the darker the color the state has in the picture.

A preliminary analysis suggests that, in an unconditional convergence process, figure 2 would be expected to be the photographical negative of figure 1. This pattern, however, cannot be fully observed. Although some poor states like Rio Grande do Norte or Paraíba did grow faster in the period, and some rich states like São Paulo grew slowly, there is no clear evidence that this behavior was followed by all the Brazilian states in the period. In fact, Paraná, a quite rich state in 1970, had high rates of growth in the following 30 years as whole and, on the other hand, Maranhão, which was very poor in 1970, had a low rate of growth in the 30 years that followed. These patterns are econometrically explored in the next sections.

The Production Function

To estimate equation (5), besides the data discussed above, data on the rate of growth of the capital stock

[7] Data were not available for the states of Mato Grosso do Sul and Tocantins, as they were created later. These states were considered, in the series, together with the states of Mato Grosso and Goiás, respectively. The Federal District was considered a state in the series.

[8] Both series are provided by the Brazilian Institute of Geography and Statistic (IBGE) and are available on its website http://www.ibge.gov.br. Population in 1990 was interpolated, as data were available only for 1980 and 1991.

[9] These states are BA, SE, AL, PE, PB, RN, CE, PI, and MA.

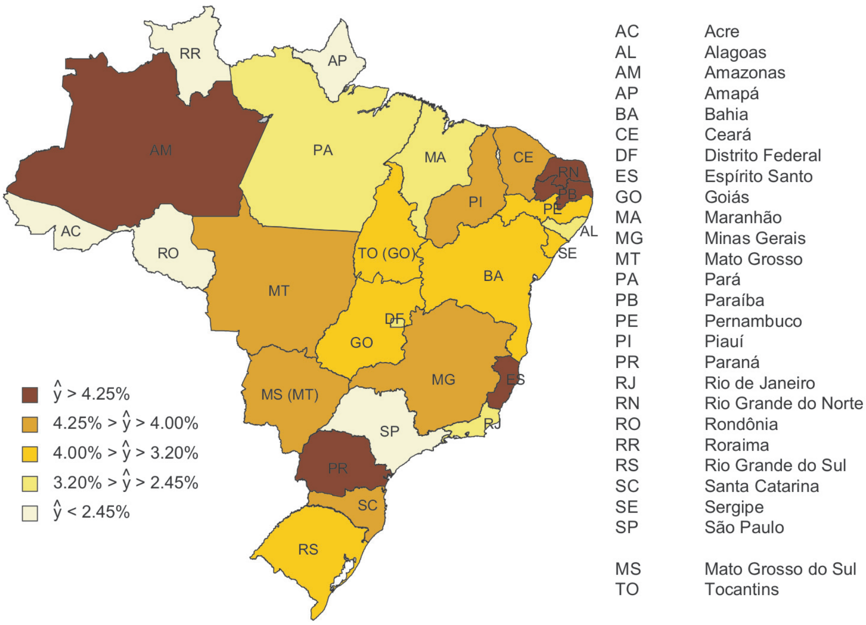

Figure 2: Rates of Growth of the Output per Capita – 1970/2000

Source: Elaborated by the author.

must be obtained. In regional growth models, this variable is usually estimated from the rate of growth of non-wage income[10]. As these data were not available for the Brazilian states, the residential capital stock estimated by Institute for Applied Economic Research (IPEA) was used as proxy of the productive capital stock. The residential capital stock is defined as the present value of the perpetual cash flows of monthly rents discounted at a 0.75% monthly rate[11]. The rationale for the use of the residential capital stock as a proxy of the productive capital stock for the Brazilian states is the high level of correlation exhibited by these variables at the national level. In fact, a regression of the net fixed capital stock against the residential capital stock for the years of 1970, 1980, 1990, and 2000 at the national level presented an R^2 above 90%.

Along with the rates of growth of the capital stock and labor stock, three additional variables were included in the regressions:

- A proxy for education, in order to take into account the differences in human capital among Brazilian states[12];
- The initial level of output per capita, intended to capture any movements of convergence among Brazilian states in the period.

Both the initial levels and the rates of accumulation of education have been used in the regressions. Initial levels were tested based upon the assumption that rates of growth might be affected by the available stock of human capital at the beginning of each period. Rates of accumulation, calculated linearly between two points, were used to capture any association between rates of growth of the output per capita and increases in human capital at the same period, although this relationship has not proven robust in previous cross-country studies (PRITCHETT, 2001).

The augmented growth model to be estimated was then

$$gry = a_0 + a_1 grK + a_2 grL + + a_3 grH + a_4 H_0 + a_5 \log y_0 + \varepsilon \qquad 32)$$

where *gry* is the rate of growth of the output per capita, *grK* is the rate of growth of the capital stock, *grL* is the rate of growth of the labor stock, *grH* is the rate of accumulation of human capital, H_0 is the initial level of human capital, and $logy_0$ is the initial level of output per capita. A total of eight models have been estimated: Model 1, using only *grK* and *grL* (in this case, $a_1 = \alpha$ and $a_2 = \beta - 1$ in equation 5), Models 2, 3, and 4, that, besides *grK* and *grL*, include *grH*, H_0, and $logy_0$, respectively, Models 5, 6, and 7, that besides *grK* and *grL*, include pairs of the variables *grH*, H_0, and $logy_0$, and finally Model 8, that includes all variables in the regression. The results obtained for the 1970s are reported in table 1.

The results obtained for Model 1 might be considered quite reasonable. Though the R^2 is less than 0.5, the coefficients both for the rate of growth of the capital stock and for the rate of growth of the labor stock are significant[13], as well as the constant term (reflecting technical change during the period). However, the coefficient obtained for *grK* (almost 0.9) seems too high when compared with the usual share of capital in output (usually between 0.3 and 0.4). The inclusion of *grH*, H_0, or $logy_0$ in Models 2, 3, and 4 does not bring about significant improvements to the results. Besides, all the coefficients for those variables are not significant and the adjusted R^2 for Models 2 and 4 are smaller than the one obtained in Model 1 (the

[10] Smith (1975), Ghali et al. (1978), and Giarratani and Soeroso (1985) followed Borts and Stein (1964) in this procedure.

[11] The data are available on the Institute's website (http://www.ipeadata.gov.br), where more details on the calculation of the residential capital stocks for the Brazilian states can be found.

[12] The proxy used for human capital was the percentage of the population above 25 years old that have 8 or more years of schooling. Again, these data are available on the IPEA's website (http://www.ipeadata.gov.br).

[13] Unless otherwise noted, "significant" is used in this paper to mean "significant at a 95% confidence level".

Table 1: Correlates of the Rate of Growth of the Output per Capita (*gry*) for the Decade of 1970

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	5.030804	5.7317	5.453028	5.241645	6.18739	5.991825	5.468394	6.178949
	(4.11)	(4.04)	(4.34)	(4.13)	(4.28)	(4.08)	(4.27)	(4.19)
grk	0.891974	0.847472	0.90915	0.870775	0.863511	0.82254	0.949906	0.900806
	(3.48)	(3.25)	(3.58)	(3.34)	(3.36)	(3.11)	(3.53)	(3.28)
grL	-0.83513	-0.81199	-0.82207	-0.79555	-0.79784	-0.76826	-0.86614	-0.83742
	(-4.43)	(-4.27)	(-4.41)	(-4.03)	(-4.25)	(-3.85)	(-4.18)	(-4.00)
grH		-0.00533			-0.00551	-0.00558		-0.00535
		(-0.98)			(-1.03)	(-1.02)		(-0.98)
H0			-0.08852		-0.09051		-0.15132	-0.14581
			(-1.23)		(-1.26)		(-1.09)	(-1.05)
logy0				-0.42882		-0.46201	0.577943	0.509488
				(-0.75)		(-0.8)	(0.53)	(0.47)
N	25	25	25	25	25	25	25	25
F	9.86	6.88	7.23	6.63	5.7	5.24	5.31	4.43
Prob>F	0.0009	0.0021	0.0016	0.0025	0.0031	0.0047	0.0044	0.0077
R squared	0.4727	0.4958	0.5082	0.4863	0.5329	0.5115	0.5151	0.5382
Adj. R squared	0.4247	0.4237	0.4380	0.4129	0.4395	0.4138	0.4181	0.4167

Note: t-statistics in parentheses.

Table 2: Correlates of the Rate of Growth of the Output per Capita (*gry*) for the Decade of 1980

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	0.295073	0.136285	2.775799	2.162408	3.7431	2.722015	2.808889	3.801119
	(0.38)	(0.13)	(2.93)	(2.21)	(2.95)	(2.07)	(2.87)	(2.89)
grk	0.086411	0.092847	-0.28988	-0.0891	-0.36597	-0.12053	-0.28016	-0.35481
	(0.37)	(0.39)	(-1.34)	(-0.42)	(-1.63)	(-0.54)	(-1.25)	(-1.52)
grL	0.421072	0.41378	0.883346	0.647301	0.974362	0.685324	0.872852	0.962469
	(1.23)	(1.17)	(2.86)	(2.05)	(3.07)	(2.11)	(2.73)	(2.94)
grH		0.001918			-0.00768	-0.00478		-0.0078
		(0.24)			(-1.13)	(-0.65)		(-1.12)
H0			-0.16275		-0.18452		-0.14816	-0.16626
			(-3.50)		(-3.69)		(-1.92)	(-2.12)
logy0				-1.43725		-1.56332	-0.19668	-0.2508
				(-2.68)		(-2.71)	(-0.24)	(-0.31)
N	25	25	25	25	25	25	25	25
F	1.52	0.99	5.62	3.69	4.6	2.8	4.04	3.53
Prob>F	0.2417	0.4179	0.0054	0.0281	0.0085	0.0539	0.0146	0.02
R squared	0.1211	0.1236	0.4454	0.3452	0.4789	0.3588	0.447	0.4815
Adj. R squared	0.0412	-0.0016	0.3662	0.2517	0.3747	0.2305	0.3364	0.3451

Note: t-statistics in parentheses.

Table 3: Correlates of the Rate of Growth of the Output per Capita (*gry*) for the Decade of 1990

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	1.447774	0.985507	-0.9766	0.892978	-1.24059	0.337368	-0.36703	-0.51351
	(1.37)	(0.89)	(-0.85)	(0.65)	(-1.06)	(0.24)	(-0.38)	(-0.50)
grk	0.333964	0.325313	0.387161	0.362945	0.378483	0.357846	0.281213	0.282047
	(1.68)	(1.65)	(2.32)	(1.75)	(2.28)	(1.75)	(1.98)	(1.96)
grL	-1.19244	-1.29083	-1.37384	-1.25843	-1.44271	-1.36966	-1.19342	-1.2326
	(-3.85)	(-4.08)	(-5.19)	(-3.80)	(-5.35)	(-4.06)	(-5.29)	(-5.16)
grH		0.008612			0.006631	0.00896		0.002993
		(1.25)			(1.14)	(1.28)		(0.59)
H0			0.102752		0.098856		0.206436	0.200028
			(3.25)		(3.13)		(5.03)	(4.64)
logy0				0.367092		0.416521	-2.02201	-1.93134
				(0.64)		(0.73)	(-3.28)	(-2.99)
N	25	25	25	25	25	25	25	25
F	7.71	5.79	10.88	5.14	8.6	4.38	14.65	11.41
Prob>F	0.0029	0.0048	0.0002	0.0081	0.0003	0.0105	0	0
R squared	0.4121	0.4525	0.6086	0.4232	0.6323	0.4668	0.7456	0.7502
Adj. R squared	0.3586	0.3743	0.5526	0.3408	0.5587	0.3601	0.6947	0.6844

Note: t-statistics in parentheses.

improvement obtained in Model 3, by its turn, might be considered too small). The negative coefficient obtained both for *grH* and H_0 seem to contradict the expectation of a positive impact of education on growth. As these coefficients are not significant, it can be affirmed that the regressions are inconclusive about the impact of education on growth for the Brazilian states during the 1970s. Although the negative coefficient obtained for $logy_0$ in Model 4 might suggest a convergence process, its t-statistic is too low to support this proposition for the decade[14]. The inclusion of combinations of the variables *grH*, H_0, and $logy_0$ (Models 5 to 8) also does not bring about significant improvements to the results obtained in Model 1. In fact, except for Model 5, where a slightly improvement can be noticed, all the adjusted R^2 for these models fell below the value obtained for Model 1. In short, it can be affirmed that, during the 1970s, the rate of growth of the output per capita was strongly associated with the rate of growth of the capital stock and the rate of growth of the labor stock, and the inclusion of additional variables to the model to take into account both differences in human capital or a convergence process do not bring about improvements to the results.

The same regressions were run for the 1980s, and table 2 below reports the results obtained.

The reasonable adjustment obtained for Model 1 in the 1970s was not repeated in the 1980s. The R^2 obtained is very low and none of the coefficients is significant. Although the inclusion of *grH* in Model 2 slightly improves R^2, the adjusted R^2 is too low (actually negative), indicating that the model does not fit the data well. Results do improve with the inclusion of H_0 in Model 3. Not only R^2 reaches a reasonable value, but also the coefficients for both *grL* and H_0 are significant. However, the initial levels of education presented an unexpected significant negative coefficient when regressed against the subsequent rates of growth of the output per capita during the 1980s. A possible explanation for this unexpected result is in the next model. In fact, Model 4 shows that, during the 1980s, a convergence process was observed, as shown by the negative and significant coefficient obtained for $logy_0$. The high correlation between education levels and output per capita levels for Brazilian states might then explain why a negative coefficient was obtained for H_0 in Model 3. Models 5, 6, 7, and 8 just confirm these conclusions. To sum up, the decade is marked by a convergence process, but the reasons behind it are not clear.

Table 3 presents the results obtained for the 1990s.

Focusing on Model 1, if the results for the 1970 were considered reasonable and the ones for the 1980 were

[14] However, when regressions weighted by the initial economic size of the states Yi,0 is run for Model 5, the coefficient obtained for logy 0 turns out to be negative and significant (actually, its t-statistic reaches -3.35). This result suggests that some small states could have strongly affected the results of ordinary least square regressions and is also a consequence of the low rates of growth of the state of São Paulo during the decade along with its high weigh in this kind of regression.

Table 4: Correlates of the Rate of Growth of the Output per Capita (*gry*) for the Decades of 1970, 1980, and 1990 (Random Effects)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	1.328471	1.163077	4.664189	5.180393	4.721443	5.533613	5.173807	5.390999
	(1.35)	(0.97)	(5.00)	(5.14)	(4.28)	(4.61)	(5.28)	(4.61)
grk	0.441341	0.441731	0.526725	0.250221	0.526677	0.247194	0.409503	0.405258
	(2.08)	(2.07)	(3.12)	(1.44)	(3.09)	(1.41)	(2.23)	(2.19)
grL	-0.09006	-0.09349	-0.26115	0.050736	-0.26019	0.058799	-0.13515	-0.12741
	(-0.36	(-0.37)	(-1.30)	(0.25)	(-1.29)	(0.29)	(-0.63)	(-0.59)
grH		0.002007			-0.00066	-0.00372		-0.00229
		(0.24)			(-0.10)	(-0.55)		(-0.34)
H0			-0.22402		-0.22423		-0.14193	-0.1398
			(-6.56)		(-6.51)		(-2.27)	(-2.21)
logy0				-3.0492		-3.08595	-1.37102	-1.41874
				(-6.24)		(-6.22)	(-1.56)	(-1.58)
N	75	75	75	75	75	75	75	75
F	2.84	1.89	17.34	15.86	12.82	11.85	13.87	10.98
Prob>F	0.0648	0.1391	0.000	0.000	0.0000	0.0000	0.0000	0.0000
R squared	0.0732	0.0739	0.4228	0.4012	0.4229	0.4037	0.4422	0.4431
Adj. R squared	0.0474	0.0348	0.3984	0.3759	0.3899	0.3697	0.4103	0.4028

Note: t-statistics in parentheses.

not, the 1990s seem to be in-between. In fact, the value obtained for R^2 in Model 1 (0.4121) cannot be considered low when compared with other similar regressions reported for the US (Smith, 1975, and Ghali et al., 1978) and Indonesia (Giarratani and Soeroso, 1985). Besides, the coefficient for *grK* is almost significant at a 90% confidence level, and its value seems quite reasonable. However, the value obtained for *grL* is unexpected, as it suggests a negative value for β. The improvement obtained with the inclusion of *grH* might be considered low, as the value for the adjusted R^2 is only slightly higher. Besides, the coefficient for *grH* is not significant. On the other hand, the initial level of education H_0 has a positive and significant, impact on growth. Interestingly, the 1990s were the only analyzed decade for which $logy_0$ presented a positive coefficient in Model 4. Its low t-statistic, however, does not support a proposition of a divergence process during the decade. The inclusion of *grH* to Model 3 (i.e., Model 5) results in a slightly higher adjusted R^2 and in a not significant coefficient for this variable. Model 6 seems no better than Models 3 or 5. Model 7 and 8, however, exhibit very good results. Not only the adjusted R^2 in both cases is near 0.7, but also significant coefficients were obtained for all variables (except for *grH* in Model 8). The coefficients obtained for $logy_0$ in these Models are negative and significant. It means that, when controlling for the initial levels of education, a conditional convergence process was observed among Brazilian states during the 1990s. Besides, during the decade, the association between growth of the output per capita and growth of the capital stock is reaffirmed.

Additional panel regressions for Models 1 to 8 were run for the three decades using random effects. The results are reported in table 4.

The low values obtained for R^2 in Model 1 and Model 2 suggest that the model and its augmented version that includes *grH* are not capable, by themselves, of explaining the growth of the output per capita in Brazilian states during the period 1970-2000 (however, the coefficient for *grK* is significant in both cases). The inclusion of H_0 or $logy_0$ (Models 3 and 4) clearly improves the results. As in the 1980s, the coefficient obtained for H_0 in Model 3 is negative and significant. Again, the explanation is that this variable, when used in a model that does not include $logy_0$, reflects any movements of convergence (as H_0 and $logy_0$ are associated for the Brazilian states). Model 4 clearly shows a convergence process among the Brazilian states if the period is taken as a whole. This conclusion is consistent with previous works, such as Azzoni (2001). Models 5 and 6 do no better than Models 3 and 4, respectively. Models 7 and 8 again suggest a convergence process, but only at a 85% confidence level (as a result of the presence, in the same regressions, of both H_0 and $logy_0$).

To sum up, the regressions run for the production function led to the following conclusions:

- The rates of growth of the capital stock do have a positive and significant impact on the rates of growth of the output per capita. This conclusion is also supported by the results obtained for each decade separately, as shown previously.
- There was a convergence process if the period between 1970 and 2000 is taken as a whole. The process was especially strong during the 1980s and seems to cease in the 1990s.
- Although a positive correlation between initial levels of human capital and rates of growth of the output per capita was expected, the fact is that the regressions are inconclusive about this relationship. This is probably a consequence of the high correlation between education levels and output per capita levels for Brazilian states.
- Improvements in educational levels in the states do not seem to be associated with higher rates of growth of the output per capita. In fact, not only are the coefficients obtained for *grH* not significant but they also change their signal throughout the regressions. Again, the regressions presented for each decade separately support the results obtained for the entire period. This conclusion, though apparently contradictory to the common sense, is consistent with the results of several cross-country analyses (see, for example, Pritchett, 2001).

Capital Stock

In the previous section, it was argued that the rates of growth of the capital stock have a positive and significant impact on the rates of growth of the output per capita. In this section, some tests are performed to identify the factors that could be behind higher levels of growth of the capital stock in opened economies. As shown in Section 2.2, Smith (1975) suggests that these movements would be a function of the differential rates of return on capital. In practice, in Smith's (1975) model, capital movements would be a consequence of differences in the ratio $Y_{i,t} / K_{i,t}$ across regions. As the regressions run in this paper are for entire decades, it was assumed that capital movements during each decade would result from differences in the ratio $Y_{i,t}/K_{i,t}$ in the beginning of the decade. Besides, two dummy variables to take into account fiscal incentives given to the states in the Northern, Northeastern, and Center-Western regions of the country during the 1970s and the 1980s were used. It was then assumed that the special federal incentives for investments were effective in the 1970s and 1980s, and then they were assumed to have ceased from the 1990s onwards. Although the institutions that provided these incentives continued to exist after that moment, it was assumed that from the mid 1980s onwards, due to the fiscal crisis observed in Brazil, these incentives were no longer effective. In practice, these two variables were set at 1 for the states in the mentioned regions in the 1970s and 1980s. In the model proposed here, it is supposed that fiscal incentives would positively affect the expected return of new investments and, by doing so, they would cause capital movements along with differences in the ratio $Y_{i,t} / K_{i,t}$ in the beginning of the period. As a result, the econometrical equation to be tested for the 1970s is shown below:

$$grK = a_0 + a_1 Y_0 K_0 + a_2 Inc_{70} + \varepsilon \qquad (33)$$

where Y_0K_0 is the ratio in the beginning of the period and Inc_{70} is a dummy for the federal fiscal incentives program as described above. Similarly, the econometrical equation to be tested for the 1980s is

$$grK = a_0 + a_1 Y_0 K_0 + a_2 Inc_{80} + \varepsilon \qquad (34)$$

where Inc_{80} is a dummy for the federal fiscal incentives program during the 1980s. As no incentives were assumed to have taken place during the 1990s, the econometrical equation to be tested for this decade is simply

$$grK = a_0 + a_1 Y_0 K_0 + \varepsilon \qquad (35)$$

The results are presented in table 5.

Table 5: Correlates of the Rates of Growth of the Capital Stock (*grK*) for the Decades of 1970, 1980, and 1990

	1970 Model 1	1970 Model 2	1980 Model 1	1980 Model 2	1990 Model 1
Constant	3.710661	3.014351	0.324715	-0.58144	4.945513
	1.89	1.53	0.28	-0.5	5.36
Y0K0	3.955612	3.47923	2.456941	2.346851	1.047874
	1.47	1.31	2.49	2.57	1.62
Inc70		1.435929			
		1.48			
Inc80				1.434242	
				2.2	
N	25	25	25	25	25
F	2.15	2.23	6.2	6.03	2.63
Prob>F	0.1559	0.1318	0.0204	0.0082	0.1184
R squared	0.0856	0.1683	0.2124	0.3541	0.1027
Adj. R squared	0.0458	0.0927	0.1781	0.2954	0.0636

Note: t-statistics in parentheses.

Table 6: Correlates of the Rates of Growth of the Labor Stock (*grL*) for the Decades of 1970, 1980, and 1990

	1970s	1980s	1990s	1970-2000
Constant	3.965315	2.169383	2.242814	2.80052
	(5.87)	(7.93)	(8.34)	(10.31)
$\tilde{y}$	0.5989057	0.0114468	0.0708266	0.1586465
	(1.37)	(0.12)	(0.70)	(1.43)
N	25	25	25	75
F	1.87	0.01	0.49	2.03
Prob>F	0.1848	0.9041	0.4919	0.1582
R squared	0.0752	0.0006	0.0208	0.0271
Adj. R squared	0.0349	-0.0428	-0.0218	0.0138

Note: t-statistics in parentheses.

Although the results are far from what could be considered a good adjustment, the coefficients obtained for Y_0K_0 in Model 1 for the decades of 1970, 1980, and 1990 show an expected positive signal, and one of them (for 1980) is significant at 95% confidence. The dummy for the incentives presents an expected positive signal as well, and is significant for the 1980s. However, the low values obtained for R2 in all regressions clearly indicates that the models explain just a reduced part of the capital movements among Brazilian states. In short, although these two variables are far from being the only factors behind the capital movements among Brazilian states in the period, both the differences in rates of return in the beginning of the period and the fiscal incentives given during the period did have a positive impact in the inter-regional movements of capital among Brazilian states between 1970 and 2000.

Labor Stock

Econometric tests were performed to check if labor movements responded to differences in initial levels of marginal product of labor among Brazilian states during the period. The econometric equation tested is based upon equation (29), as shown below:

$$grL = a_0 + a_1\tilde{y} + \varepsilon \tag{36}$$

The results of the regressions for each decade and for the entire period are presented in table 6.

The results reported in table 6 clearly show that the initial levels of marginal product of labor among Brazilian states do not explain labor movements in the country during the period. These results show that the assumptions behind equation (29) might not have fit data in Brazilian states. This might be a consequence of the unrealistic assumption of the same natural rate of growth of the population in all regions. As fertility tends to be higher in poorer states, a model based upon this assumption could hardly fit the data. In fact, according to data of the Brazilian Health Ministry, in 2000, the average number of children per woman per year in the poor Northern and Northeastern regions of the country was 3.09 and 2.64, respectively, while the same average was only 2.08 and 2.09 in the richer Southeastern and Southern regions[15]. These differences tended to be even higher in the past. Besides, the proxy used for wage differentials in the model might not capture the forces behind migration movements in Brazil. In fact, although states with higher levels of output per capita tend to attract migration movements, wage differentials and employment opportunities are not fully captured by the differentials in output per capita, especially if qualifications requirements are taken into account.

Conclusions

In this paper, a neoclassical model of regional growth for Brazilian states was tested using recently published data on the states' GDP and residential capital stock for the period between 1970 and 2000. The use of a proxy for the capital stock allowed the production function, along with the capital mobility among Brazilian states, to be econometrically tested. It was shown that the rates of growth of the capital stock have a positive and significant impact on the rates of growth of the output per capita. On the other hand, the regressions were inconclusive about the impact of human capital on economic growth. The rates of accumulation of human capital did not present significant impact on the rates of growth of the output per capita, and the initial levels of education sometimes presented an unexpected significant negative coefficient when regressed against the subsequent rates of growth of the output per capita. As the levels of education and output per capita are positively correlated in Brazilian states, the negative signal obtained seems to be an indication of the convergence process that took place in the country during the period as whole. The ambiguous results obtained for the impact of human capital on the rates of growth of the output per capita in the Brazilian states suggest the necessity of further studies focusing on the human capital mobility among regions, and the proxy used for this variable. Consistently with other previous works, a convergence process was

[15] All data are available on http://www.datasus.gov.br

identified for the entire period. The convergence movement was especially strong during the 1980s and seems to have ceased in the 1990s.

In the model, capital was supposed to move inter-regionally as a result of (i) differences in rates of return on capital in the beginning of each decade and (ii) the availability of fiscal incentives at the federal level during each decade. Although these two variables are far from being the only ones behind the capital movements among Brazilian states in the period, they both had an expected, positive, and sometimes significant impact on these movements. These results suggest that the absence of a national policy of regional development during the 1990s might be behind the interruption of the convergence process observed in that decade. On the other hand, the model does not satisfactorily explain labor movements among Brazilian states during the period. This might be a consequence of the unrealistic assumption of the same natural rate of growth of the population in all regions considered in the model. Besides, wage differentials and employment opportunities are not fully captured by the differentials in output per capita, as supposed in the model, especially if qualification requirements are taken into account.

Although additional research is required to explore the factors that impacted economic growth of Brazilian states during the period between 1970 and 2000, the use of a proxy for the capital stock allowed the model to be econometrically tested. The availability of this proxy, in addition, creates considerable possibilities of testing the impacts of factors extensively used in the traditional cross-country regressions in further studies about regional growth in Brazil. Further research may also include a closer look on the role of education levels on the rates of growth of the output per capita in Brazilian states and the use of some additional methodological approaches, like weighted regressions by the initial economic size of the states (to avoid the excessive influence of some very small states in the results) and fixed effects regressions for the panel data.

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