

Christofoletti, Maria Alice Móz; Spolador, Humberto Francisco Silva

**Conference Paper**

## Income convergence among Brazilian states after the economic openness

50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden

**Provided in Cooperation with:**

European Regional Science Association (ERSA)

*Suggested Citation:* Christofoletti, Maria Alice Móz; Spolador, Humberto Francisco Silva (2010) : Income convergence among Brazilian states after the economic openness, 50th Congress of the European Regional Science Association: "Sustainable Regional Growth and Development in the Creative Knowledge Economy", 19-23 August 2010, Jönköping, Sweden, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/118805>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

**Paper to be presented in the 50th European Regional Science  
Association Meeting (ERSA  
2010) to be held at Jönköping, Sweden, August 19<sup>th</sup> to 23<sup>rd</sup>, 2010.**

## **Income convergence among Brazilian states after the economic openness**

*Maria Alice Moz Christofolletti*

Graduated student of Economics at “Luiz de Queiroz” College of Agriculture, University of Sao Paulo, Brazil

Address: Avenida Padua Dias, 11 caixa postal 09  
13418-900 – Piracicaba, Estado de São Paulo – Brazil  
Phone: 55 19 3429 4464 Fax 55 19 3422 9082  
E-mail: [mamchristofolletti@yahoo.com.br](mailto:mamchristofolletti@yahoo.com.br)

*Humberto F. S. Spolador*

Professor of Economics at “Luiz de Queiroz” College of Agriculture – University of São Paulo – Brazil.

Address: Avenida Padua Dias, 11 caixa postal 09  
13418-900 – Piracicaba, Estado de São Paulo – Brazil  
Phone: 55 19 3429 4444 Fax 55 19 3434 5186  
E-mail: [hfsspola@esalq.usp.br](mailto:hfsspola@esalq.usp.br)

**Abstract:** This paper expands the analysis developed by Ellery Jr. (1994), who estimated the income convergence among Brazilian states from 1970 to 1990. The methodology is based on the convergence model proposed by Barro and Sala-i-Martin (1992) and is applied to test both the beta-convergence and the sigma-convergence. For the period after 1990, and sub-periods, (the) effects of educational level (used as a proxy for human capital), and international trade on the increase of income states were estimated. The preliminary results show that even after the economic openness in 1990s, the income convergence process has not changed compared to the first period previously analyzed (1970-1990) among the 27 Brazilian states and this process has been still ongoing (0.79% *per year*) to the recent years.

**Key Words:** convergence, GDP *per capita*, Brazilian states.

### **1. Introduction**

Importance of sustained growth in *per capita* income can be represented in a simple example, as shown by Gondim and Barreto (2004): a real growth of 2% per year over a period of 20 years, increase *per capita* income by 50%. If this growth rate is maintained for a period of 35 years, it could double the initial *per capita* income. Jones (2000) shows some stylized

facts of economic growth: i) there is a significant variation between *per capita* incomes, ii) growth rates are not uniform across countries, iii) growth rates are not constant over time.

In the 1950s and 1960s neoclassical models of growth were developed based on works of Solow (1956 and 1957), Cass (1965) and Koopmans (1965). According to neoclassical models, different levels of GDP *per capita* of countries should converge in the long run. The phenomenon of income convergence is related to the fundamental hypothesis of the neoclassical model of decreasing returns of capital, so countries with a lower initial *per capita* income and capital would have higher rates of investment and, consequently, higher rates of economic growth. However, income convergence among countries or regions is not always observed, which is only found under special conditions. As noted by Dowrick (1992), between 1960 and 1988, however, wealthier countries grew faster than poorer ones in *per capita* terms.

Barro and Sala-i-Martin (1992) published an important work on income convergence, which showed empirical studies on convergence among states in the U.S.A. The authors suggest two measures of income convergence: (1)  $\beta$ -convergence, which is related to the concept of faster economic growth of poorer economies in relation to more developed economies, (2)  $\sigma$ -convergence, which involves the decline of cross-sectional dispersion of *per capita* income, or product, over time.

Thus, in the research line on economic growth, measuring convergence speed of *per capita* incomes among regions within a country is important to analyze the economic growth process, ensuring if *per capita* income gap among countries or regions is decreasing over time. Moreover, as indicated by Gondim and Barreto (2004), lack of convergence or existence of conditional convergence only when submitted by a particular factor (e.g. level of education, trade exchange ...) would guide policy makers to correct paths aiming to reduce such inequalities.

According to Cravo e Soukiazis (2006), most empirical studies show that the convergence process is conditional and not absolute. So, convergence is related to the argument of endogenous growth theory with increasing returns of scale (mainly due to human capital and technology), rather than constant returns (or decreases) of scale.

However, finding conditioning factors that better explain the convergence process among different economies has become a major problem in the growth theory. Among a variety of studies, the approach of endogenous growth theory argues that one of the factors that leads to economic growth is human capital. According to Cangussu et al. (2008), theoretically, human capital is important in determining income convergence directly and

indirectly. Direct effects of human capital affect income through improved labor productivity, even keeping all other factors constant (capital and technology), by improving workers' skills to perform their tasks. It is represented by the introduction of human capital directly to the production function. As indirect effects, we mention those concerning the amount of technology available for production process. So, these factors influence the creation and diffusion of technology. Barro and Sala-i-Martin (1992) suggest that, among other factors, trade liberalization could accelerate the process of income convergence among countries. Regarding income convergence among Brazilian states, and Focchezatto and Stülp (2005) show that trade liberalization has forced the economy to undergo structural adjustments, to modernize technology and to improve productivity. Once regions have different productive structures, sectorial changes, on the other hand, influenced the spatial configuration of production and income. Regions that had productive structures mostly composed of sectors affected by the trade opening, mainly by imports liberalization, had their small scale compared to that of other regions.

## **2 Literature Review**

From the 1940s, models of Keynesian inspiration, such as the Harrod model (1939), Domar (1946) and Robinson (1956), who sought to determine susceptible growth rate to ensure growth with full employment, considering the level of investment as the key factor in the economy. In models of Keynesian inspiration, prominently the Harrod-Domar model, both the income growth rate and investment growth rate depend directly on the propensity of saving and, depend conversely on a constant product capital ratio.

The neoclassical growth model, based on works of Solow (1956 and 1957), Cass (1965) and Koopmans (1965), shows that GDP level *per capita* of different countries should converge in the long run. The phenomenon of convergence is related to the fundamental hypothesis of the neoclassical model of diminishing returns of capital, so countries with lower *per capita* income, and scarce capital, would have higher rates of investment and thus, higher rates of economic growth. Assumptions and Solow transition dynamics imply that developing economies, with low levels of *per capita* income and capital, should have higher growth rates. This result, in the absence of any restriction or control of particular characteristics of each economy, leads to the hypothesis of absolute income convergence among different economies.

During the 1980s, several studies tested the hypothesis of income convergence among countries. Baumol (1986) states that there is convergence between groups of similar economies, but when the model of countries is increased and includes distinct economies, the convergence hypothesis was not found. Barro and Sala-i-Martin (1992) tested the convergence hypothesis among states in the U.S.A. and found the absolute convergence of regional economies, identifying the states later takes about 35 years to halve the income gap for richer states.

De Long (1988) disputed results of Baumol (1986) on the convergence of industrialized countries in the twentieth century, and highlighted that the result could have been influenced by the process of selecting countries, once it had been included only countries with high *per capita* incomes at the end of the period (1980s), which caused spurious results.

In the 1980s and 1990s, human capital, as well as research and development (R & D), was introduced in the new models of economic growth, which influenced works carried out by Robert Lucas (1988) and Paul Romer (1986). In the theory of human capital, individual productivity in the future is affected by their decision on which activity they allocate their time to in this period. Lucas (1988) underscores that policies encouraging increases of time that individuals spend on qualification generate a permanent increase output per worker. Thus, the author concludes that an economy with low initial levels of human capital and physical capital will remain with lower *per capita* income comparing to other developed economies. Sachs and Warner (1997) also argue that human capital accumulation is a nonlinear function of the level of human capital: when the initial level of human capital is low, the accumulation of human capital is also low; when human capital is at an intermediate level, then the accumulation of human capital reaches the highest speed. When the level of human capital is already very high, so once again the accumulation of human capital is low. This means that growth tends to be higher in economies with an intermediate level of human capital.

In the model proposed by Romer (1986), it is assumed that the generation of ideas is an input in the productive function, which, given the characteristic of non-rivalry of ideas, leads to a productive function with increasing returns<sup>1</sup>. Garcia (2006) examines that faster growth of developed countries is highly correlated with their augmentation of R&D (Figure 1), which could accelerate the rate of technological change and hence economic growth.

---

<sup>1</sup> By doubling the inputs of production, including the stock of ideas, we can get more than the double of products.

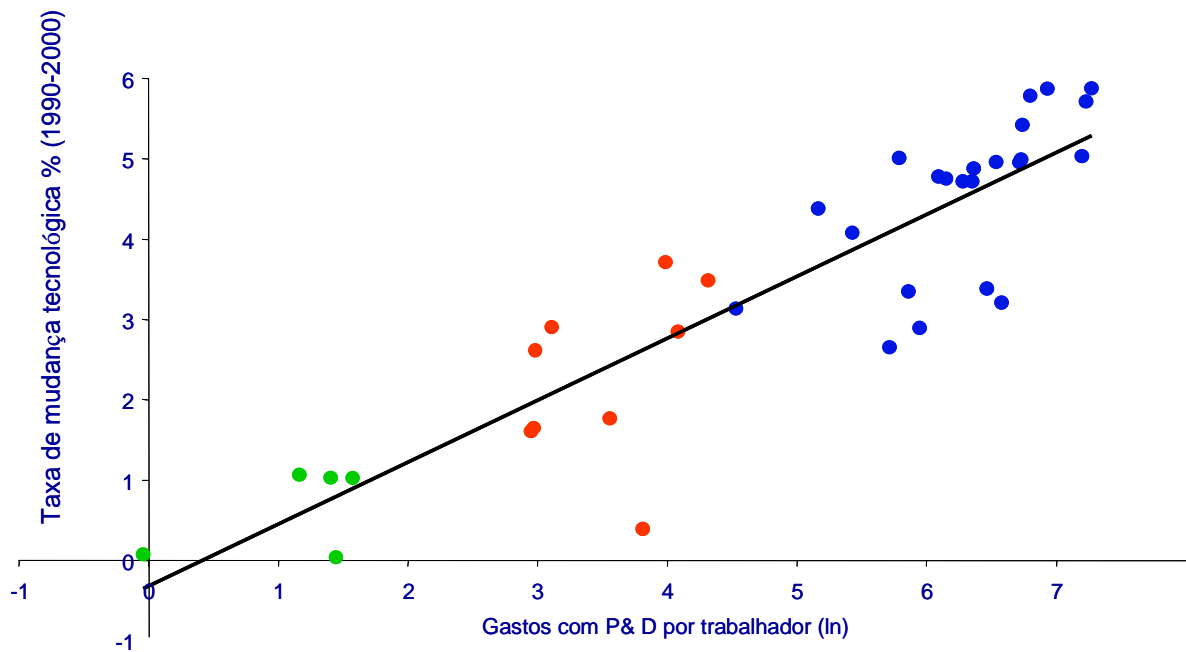


Figure 1 - Investment on research and development per employee and the rate of technological change (%) by groups of countries - from 1970 to 2000

Source: Garcia (2006).

Abramovitz (1986) points out that qualitative and institutional variables would be equally or more important than the access of poorer countries to technology developed by richer countries. Abramovitz (1986) argues that there is an interaction between social capacity and technological opportunity, being that the education level and institutions of the economy may limit the adoption of new technology, while technological innovations would press for changes, especially in the institutional framework.

Among the factors that facilitate the absorption of new technologies by developing economies, Abramovitz (1986) highlights three, namely:

1. Facilities to disseminate knowledge, such as channels of international communication, multinational corporations, interaction with international markets and direct foreign investment;
2. Conditions of labor supply, like a surplus of labor force in agriculture and control internal and external migration, and;
3. Macroeconomic conditions that encourage investment.

Stern (1991) criticizes the theories of growth developed so far, which deal primarily with capital accumulation, human capital, technology and population growth to determine the growth process of a region or country. The author suggests the inclusion of other variables to

study the growth, which involve, basically, determinants of institutional and organizational economics.

Barro and Sala-i-Martin (1992), based on conceptual framework developed by Solow (1956), investigated the existence of absolute convergence among states in the U.S.A. over the period between 1840 and 1988. According to the authors, poorer states tend to have a growth rate of *per capita* income higher than that of richer states, indicating a clear convergence of *per capita* income inter-regional in the United States at a yearly rate of about 2%. Considering the same process with 98 countries between the years 1960 and 1985, the authors found that there was conditional convergence, in other words, there was convergence after performing a control on the steady state of each economy. Those countries do not necessarily converge to the same point of steady state, but to their own steady state. Subsequently, Sala-i-Martin (1996) conducted a study on 110 countries that were randomly chosen and stressed that, because of differences in economic, social and structural policies, he could not verify occurrence of absolute convergence and dispersion of *per capita* income level was actually increasing. Countries that started the period with higher *per capita* income grew more than those countries with lower *per capita* income. Moreover, dispersion of *per capita* income level increased. When countries and regions with similar characteristics – Japanese prefectures, states, countries of the Organization for Economic Cooperation and Development - OECD and European regions – are analyzed, it is observed both the convergence and sigma beta.

Dunford and Smith (2000) emphasized that recent research on income convergence is mainly the results of neoclassical models of regional economic development. An example of research on regional convergence is the work of Serra et al. (2006), which presents a model of convergence between regions in the following countries: Argentina, Brazil, Chile, Colombia, Mexico and Peru. In some cases, results suggest the existence of convergence among "clubs of regions" (or homogeneous regions within countries). Serra et al. (2006) suggests that regional disparities, curiously increased, in the countries studied, after the implementation of structural reforms and trade liberalization in the 1990s.

Shankar and Shah (2001) assessed the impact of policies to reduce regional income inequality in the process of income convergence among 21 countries with several degrees of regional income inequality, during the 1990s. Results show that countries like Thailand, Chile, Pakistan, the United States and Uzbekistan have submitted their respective convergence to regional incomes, resulting from the implementation of common policies to promote an economic union by removing barriers to facilitate mobility and ensure minimum

standards of basic services for the entire nation. Specifically in the Chilean case, the convergence of regional incomes is partly explained by economic liberalization, which eliminates distortions in the economy and led each region to discover its best comparative advantage. However, countries such as Brazil, Indonesia, Russia and India have shown a process of regional income divergence, resulting from applications of regional interventionism. Thus, the authors concluded that, paradoxically, to disadvantaged areas, it is advisable to create equitable conditions, instead of implementing policies of paternalism and protectionism.

Dobson and Ramlogan (2002) analyzed income convergence in Latin America between 1960 and 1990. According to the authors, in this period, there is evidence of  $\beta$ -convergence, in other words, countries were converging at a low speed to the same level of *per capita* income. However, in this period, there is no evidence of  $\sigma$ -convergence. Moreover, rates of *per capita* income convergence were higher during the 1970s and early 1980s, decreasing considerably in the second half of this decade. This is because, during the 1970s, industrialization programs introduced by developing countries (including modernization of the agricultural sector) and availability of external financing to support the productive sector, were key factors for strengthening the process of income convergence in these countries. However, during the second half of the 1980s, the economic crisis led to a change in the speed of convergence and even the subsequent recovery of economies in the 1990s was not enough for countries to return to a pattern of convergence.

## **2.1 Studies on income convergence in Brazil**

Regarding Brazilian studies on economic growth and income convergence, Ellery Jr. (1994), using the neoclassical model proposed by Barro and Sala-i-Martin (1992) tested the existence of income convergence of GDP *per capita* among Brazilian states from 1970 to 1990. Estimates of  $\beta$ -convergence confirmed the existence of a convergence process among Brazilian states at a rate of approximately 1.3% per year. For American states, Barro and Sala-i-Martin (1992) found a value of  $\beta$ -convergence between 1.75% and 2.5% per year, considerably higher than what was found by Ellery Jr. (1994). Concerning dispersion of GDP *per capita* of the states ( $\sigma$ -convergence), estimates show a variance of steady-state below the initial variance, indicating that there is indeed a process of income convergence in Brazil.

Azzoni (2001) indicates that from 1939 to 1995, there was absolute income convergence among Brazilian regions. However, the author found out that there were cycles of convergence and divergence through time, which can be explained by periods of economic



expansion showing higher economic growth in more developed regions, while in periods of economic slowdown, these same regions were directly affected, with further negative impact in poorer regions. Maciel, Andrade and Teles (2005) performed a dynamic analysis of five Brazilian regions, and proved a convergence of *per capita* income in the southern, midwestern and southeastern regions for the period from 1985 to 2005.

Chein et al. (2007) also analyze the convergence among Brazilian regions, from 1970 to 2000, but noted lack of convergence in this period, stressing differences among regions regarding attributes associated with development patterns and their respective administrative territorial divisions. At this point, we can mention the northeast, a region that since the 1970s has not been homogeneous, once the state of Bahia has shown a higher level of development comparatively to its neighbors.

Other studies have evaluated the convergence process regarding states - Ferreira and Diniz (1995) and Azzoni (1997). The importance of human capital in the convergence process of GDP *per capita* among states is presented in Brazilian studies like Barros et al. (2001), Cravo and Soukiazis (2006), Cangussu et al. (2008) and Barreto and Almeida (2008) that focused on the analysis of convergence specifically for the state of Ceara. Azzoni et al. (2000) analyze human capital and explain the importance of geographical variables and institutional constraints to determine the income difference among Brazilian regions, which influence the convergence of *per capita* income in the states.

Chagas and Toneto (2003), and Fochezatto Stülp (2005), Uchôa and Martins (2007) investigated determinants of growth of Brazilian cities in the states of Rio Grande do Sul and Bahia, respectively. For convergence clubs, Magalhães (2001), Laurini et al. (2003), Gondim and Barreto (2004), Magalhães and Miranda (2005) and Trompieri-Neto et al. (2008), assuming that, although there is no strong evidence of global convergence, some states are approaching each other in terms of *per capita* income. Then, these states would form groups or clubs of convergence. Most of these studies found evidence of convergence clubs formed primarily by two groups: one for states in the North and Northeast and other states in the South and Southeast.

### **3. Methodology**

The concept of convergence is present in neoclassical models of economic growth, and implies that developing economies tend to grow faster than more developed economies, mainly due to reduction of capital returns. Nowadays, however, income convergence involves return of capital, in a broad sense, that includes expansion of human capital and technological

knowledge asset. When the economy is below its steady-state point, it will grow faster than when it is operating above that point.

Barro & Sala-I-Martin (1992) carried out empirical studies on income convergence among states in the U.S.A. The authors proposed two types of convergence: (1) the beta-convergence concept, which is related to faster economic growth of poorer economies in relation to developed economies; and (2) the sigma-convergence, which involves the decline over time of income dispersion (sectional), or the GDP *per capita* among the states.

### 3.1 Convergence Theoretical Model

The analytical model proposed in this work was developed by Barro & Sala-i-Martin (1992). In this model, , production function, in per capita terms, is:  $\hat{y} = f(\hat{k}) = A \cdot \hat{k}^\alpha$ ,  $\hat{y}$  and  $\hat{k}$  are the product and the capital per unit of effective labor, respectively.

Barro & Sala-i-Martin (1992) developed a model aiming to find an equation that relates the rate of economic growth with its initial income, and to estimate the speed of convergence of the economy to its steady-state point.

Families maximize, in an infinite horizon of time, consumption of utilities (c):

$$\begin{aligned} \text{Max} \int_0^{\infty} \frac{c^{1-\theta} - 1}{1-\theta} \cdot e^{-(\rho-n)t} dt \\ \text{s.a. } \dot{\hat{k}} = f(\hat{k}) - \hat{c} - (\delta + x + n)\hat{k} \end{aligned} \quad (1)$$

Where,

$\theta$  = marginal utility elasticity with respect to c;

$\rho$  = rate of time preference;

$n$  = growth rate of labor force;

$x$  = growth rate of labor productivity;

$\delta$  = rate of depreciation.

The first order condition of maximization of utilities is:

$$\frac{\dot{c}}{c} = \frac{1}{\theta} \cdot [f'(\hat{k}) - \delta - \rho] \quad (2)$$

Barro & Sala-i-Martin (1992) showed that transitional dynamics can be quantified through a log-linearization of equations (1) and (2) around the steady-state point. The solution for  $\log[\hat{y}(t)]$  in log-linearized approximation, as in Barro & Sala-i-Martin (1992), is:

$$\log[\hat{y}(t)] = \log[\hat{y}(0)] \cdot e^{-\beta t} + \log(\hat{y}^*) \cdot (1 - e^{-\beta t}) \quad (3)$$

Beta ( $\beta$ ) parameter represents the adjustment speed to steady-state point. The authors also showed that average growth rate of  $y$  (product *per capita*) ranging between 0 and  $T$  is:

$$\frac{1}{T} \cdot \log\left[\frac{y(T)}{y(0)}\right] = x + \frac{1 - e^{-\beta T}}{T} \cdot \log\left[\frac{\hat{y}^*}{\hat{y}(0)}\right] \quad (4)$$

In expression (4), Barro & Sala-i-Martin (1992) wrote that: “the higher the beta, the greater the responsiveness of average growth rate to the gap between  $\log(\hat{y}^*)$  and  $\log[\hat{y}(0)]$ , that is, the faster the convergence to the steady state.” (p.226)

From the equation (4), the econometric model to estimate the beta-convergence, is:

$$\frac{1}{T} \cdot \log\left(\frac{y_{i,t}}{y_{i,t-1}}\right) = B - \left(\frac{1 - e^{-\beta T}}{T}\right) \cdot \log(y_{i,t-1}) + u_{i,t_0,t_0+T} \quad (5)$$

$$\text{Where, } B = x + \left[\frac{(1 - e^{-\beta T})}{T}\right] \cdot [\log(\hat{y}^*) + xt_0].$$

The relationship expressed in equation (5), when beta parameter is positive, implies that countries with lower *per capita* product in the initial period will have a growth rate of *per capita* product increased over time (beta-convergence).

### 3.1.1 Concept of sigma-convergence

When there is, over time, a reduction of deviation standard *per capita* product in countries, it means that there is sigma-convergence. Serra et al (2006) argue that dispersion of the level of *per capita* product is reduced only when poorer countries grow faster than richer ones (sigma-convergence). Beta-convergence is a necessary condition, but not enough for convergence.

From the expression (5), Ellery Jr. (1994) shows that, assuming that the random term has zero mean and constant variance, it is possible to obtain:

$$\sigma_t^2 = e^{-2\beta} \sigma_{t-1}^2 + \sigma_\varepsilon^2 \quad (6)$$

In the steady state, according to Ellery Jr. (1994), the solution for equation (6) is:

$$\sigma^2 = \frac{\sigma_\varepsilon^2}{1 - e^{-2\beta}} \quad (7)$$

The condition to occur sigma-convergence is:  $\sigma_0^2 > \sigma^2$ .

#### 4. Database

We used in this study interpretative analysis of secondary data, organized in tables and charts, from time series of annual regional GDP *per capita*. These data were collected from IBGE (Brazilian Institute of Geographic and Statistics) from 1985 to 2004.

The Ministry of Development, Industry and Commerce (MDIC) is the source for data on Brazilian imports and exports. These data formed the basis to calculate the volume of international trade. The National Institute of Educational Studies and Research (INEP) provides annual data on education in different Brazilian states and regions, for example, total number of students enrolled in primary, middle and high school.

To estimate the econometric models, we used the statistical software EViews, version 4.1.

#### 5. Results

This section analyzes results of estimated econometric models. Three different models were estimated: i) the traditional model (as represented by equation 5), using only the GDPs *per capita* of the 27 Brazilian states, covering period from 1990 to 2004, and its sub-periods from 1990 to 1995; from 1995 to 2000 and from 2000 to 2004; ii) the alternative model, which incorporates the variable “education”, covering the years from 1995 to 2000, and iii) the alternative model that incorporates both variables "education" and “trade volume”, estimated in the period from 2000 to 2004. The variable "trade volume", which was obtained through the sum of imports and exports of the respective states and regions, was preferred over the variable "economic opening" due to lack of data availability in this time series, which does not change the final outcome of the study aiming to measure convergence speed, over time, among the Brazilian states.

Results of regressions are presented in table 1.

Table 1 - Results for  $\beta$ -convergence in traditional and alternative models

Period	Parameter <sup>3</sup>	$\beta$ (%)	R <sup>2</sup>
1990 to 2004 <sup>t</sup>	-0.007908 (-1.805732)	0.8418	0.1154
1990 to 1995 <sup>t</sup>	-0.005245 (-0.582208)	0.5329	0.0134
1995 to 2000 <sup>t</sup>	-0.003905 (-0.654512)	0.3951	0.1684
2000 to 2004 <sup>t</sup>	-0.014256 (-2.251990)	1.4790	0.1701
1995 to 2000 <sup>1</sup>	-0.002345 (-0.359380)	0.2362	0.0329
2000 to 2004 <sup>2</sup>	-0.009749 (-1.380878)	0.9995	0.2341

Source: Authors.

Notes: (t) traditional model defined as equation (5);

<sup>1</sup> alternative model, incorporating the variable 'education'.

<sup>2</sup> alternative model that incorporates both the variable "education" and "trade volume".

$$^3 \text{ parameter} = - \left( \frac{1 - e^{-\beta \cdot T}}{T} \right)$$

Standard error in brackets.

In all results estimated, we confirmed the existence of absolute convergence among Brazilian states, since values for parameter  $\beta$  are positive and significant. In the traditional model, value of  $\beta$  for all period (1990-2004) was 0.84% per year.

In the case of sub-periods, the rate of *per capita* income convergence of Brazilian states is greater in sub-period from 2000 to 2004, 1.47% per year, followed by sub-period from 1990 to 1995 (0.53% per year). For the period from 1995 to 2000, we found convergence speed of 0.39% per year. Results show that the speed of absolute convergence, that is, speed at which poorer states reduce the gap in *per capita* income toward richer states, was more evident between 2000 and 2004. However, this process occurred at a lower rate than that observed by Barro and Sala-i-Martin (1992) between 1840 and 1988 for states in the U.S.A. (2% per year). For Brazil, results of Ellery Jr. (1994) show a convergence rate among the Brazilian states of about 1.3% per year between 1970 and 1990, higher than the rate estimated in this paper for the period between 1990 and 2004. Azzoni (2001) calculated a rate

of convergence among the Brazilian states, from 1948 to 1995, of 0.68% per year, a similar rate found for the period 1990-2004 in this study.

The alternative model that includes the variable “education”, represented by total number of students enrolled in elementary school, also provided evidence of conditional convergence, at a speed of convergence rate of 0.23% per year for the period between 1995 and 2000; below the level estimated for the same period using the traditional model. This result is in agreement with those presented by Cravo and Soukiazis (2006) for 1980-2000, in which the estimated convergence rate was approximately 0.26% per year for the country as a whole.

The third model estimated, which incorporates the variables "education" and "trade volume" in the five-year period from 2000 to 2004, the convergence rate found was approximately 1% per year, which is below the rate calculated for the traditional model. The inclusion of both variables increased the explanatory power of the model ( $R^2$ ) in comparison to other models previously estimated.

In order to analyze and measure differences in the income convergence process among Brazilian regions, we estimated the same models using *dummy* variables (Table 2), which increased considerably the models explanatory power. Following a procedure previously adopted by Ferreira and Ellery (1996), we included in the original model a *dummy* variable for each region of the country. *Dummy* variables not statistically significant were excluded.

For all period, from 1990 to 2004, the incorporating of *dummy* variables to regions decreased the convergence speed previously estimated to 0.79% per year. Important to note that results of the model for the sub-period from 1990 to 1995, which included *dummy* variables for the Northern and Northeastern regions, improved the explanatory power of the model (41%), and increased estimated convergence speed to 1.43% per year.

Table 2. Results for  $\beta$ -convergence in traditional and alternative models with variables dummies.

Period	Beta (%)	DN	DNE	DSE	DS	EDUCA	CORRC	R <sup>2</sup>
1990 to 2004 <sup>t</sup>	0.79692 (0.0043)	-0.01226 (0.00221)	-0.00698 (0.00232)	-0.00634 (0.00280)	-0.00652 (0.00304)	-	-	0.62767
1990 to 1995 <sup>t</sup>	1.435 (0.0091)	-0.01782 (0.00453)	-0.00867 (0.00524)	-	-	-	-	0.41007
1995 to 2000 <sup>1</sup>	0.16442 (0.0061)	-0.00658 (0.00342)	-	-	-	-1.39E-09 (0.003422)	-	0.16691
2000 to 2004 <sup>2</sup>	0.99947 (0.0067)	-	-	-	-	-1.33E-09 (1.15E-09)	-3.40E-05 (4.62E-05)	0.23406

Source: Authors.

Notes: (t) traditional model:  $\log 1 = c + b \cdot \log 2$

<sup>1</sup> alternative model, incorporating the variable 'education'.

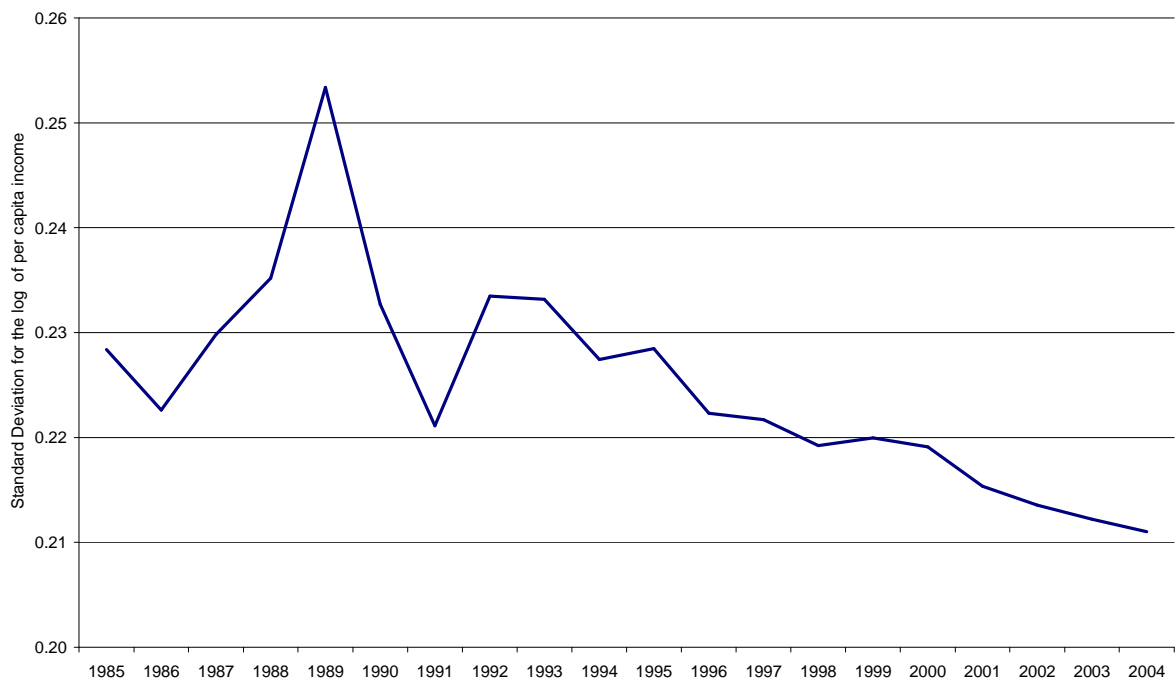
<sup>2</sup> alternative model that incorporates both the variable "education" and "trade volume".

<sup>3</sup> DN = *dummy* for North region, DNE = *dummy* for Northeast region, SDR = *dummy* for Southeast region, DS = *dummy* for the South region.

\* Standard error in brackets.

In order to examine whether there is or not convergence, we checked the dispersion of GDP *per capita* logarithm of Brazilian states and regions (Figure 2), a criterion known in the literature as  $\sigma$ -convergence. Thus, the existence of convergence will depend on whether or not there is decrease of dispersion.

Considering a larger period beginning in 1985, we can observe that the reduction was more significant from 1993/1994, period marked by the implementing of the economic plan "Plano Real" and the consequent monetary stabilization. Important to highlight that in the period 1999/2004, which coincides with macroeconomic reforms, such as the adoption of floating exchange rate, expansion of social programs and income distribution, adoption of system for inflations targets and law of fiscal responsibility, there was considerable decline in the dispersion of GDP *per capita* logarithm. We can also observe a period of income divergence between 1986 and 1990, which coincides with hyperinflation period and macroeconomic instability.



**Figure 2** – Dispersion for the log of *per capita* income across Brazilian States - 1985 to 2004  
Source: Authors.

## 6 CONCLUSIONS

Positive values found for  $\beta$ -convergence and the condition in which standard deviation of GDP *per capita* in the initial period is higher than the standard deviation of the GDP *per capita* logarithm in the final period ( $\sigma_0 > \sigma_f$ ) confirms the income convergence process among Brazilian states and regions in the years analyzed. Therefore, this study showed that the *per capita* income convergence among Brazilian states, as observed in periods prior to the 1990s, continued throughout that decade, and remained in the 2000s. Alternating periods of higher or lower rates of *per capita* income convergence among the states, relevant fact is that the difference between the *per capita* income of richer states, and *per capita* income of poorer states, has declined over this period.

Barro and Sala-i-Martin (2004) argued that differences concerning technology, economic and political institutions tend to slow down the convergence process. In this context, it is important to note that in the 1990s, the consolidation of political institutions, monetary stability, economic opening and sustainable economic growth were the key elements for the continuous process of income convergence among Brazilian states.

According to Pires and Garcia (2004), economic liberalization during the period analyzed in this work was still small in Brazil, educational deficiencies still remain at



significant levels, the size of the public sector continues to grow, and investments in science and technology are below those observed in countries with similar income levels. Results suggest that although there has been progress in these indicators, there is still a long way for Brazil and, consequently, for all twenty-seven Brazilian states to pass through to finally reach a meaningful pattern of economic growth. Public policies of income transfers have multiplied the effect on incomes of regional and national economies, which can be evidenced by higher reduction of dispersion of GDP *per capita* in the 2000s.

We also emphasizes the disparity of results found in this and other relevant studies compared with results reported by Chein et al. (2007), who found no evidence of absolute convergence for Brazilian regions between 1970 and 2000. For future research, we suggest an analysis of the impact of other variables on income convergence among Brazilian states and regions, such as investments in research and development, and migration, under the assumption of free mobility of factors among economies. Another suggestion is to investigate the effects of transaction costs on the return of public investment to determine economic growth dynamics and income of Brazilian regional economies.

## REFERENCES

- ABRAMOVITZ, M. Catching Up, Forging Ahead, and Falling Behind. **The Journal of Economic History**, vol. 46, n. 2, The Tasks of Economic History. p. 385-406. Jun.1986.
- AZZONI, C. R. Economic growth and regional income inequality in Brazil. **The Annals of Regional Science**, 35(1). p. 133–152, 2001.
- AZZONI C.; MENEZES-FILHO N.; MENEZES T.; SILVEIRA NETO R. **Geografia e convergência da renda entre os estados brasileiros**. In: Henriques R, organizer. Desigualdade e pobreza no Brasil. Brasília: Instituto de Pesquisa Econômica Aplicada – IPEA, p. 299-343, 2000.
- BARRETO, R. C. S.; ALMEIDA, E. S. A contribuição do capital humano para o crescimento econômico e convergência espacial do PIB *per capita* no Ceará. In: FÓRUM BNB DE DESENVOLVIMENTO, Fortaleza, Ceará. **Annals...** Fortaleza: Banco do Nordeste. 17 p. 2008
- BARRO, R.; SALA-I-MARTIN, X. Convergence. **Journal of Political Economy**, v. 100, n. 2, p. 223-251, Apr. 1992.
- BARRO, R.; SALA-I-MARTIN, X. Economic Growth. 2nd edition. The MIT Press. 2004.
- BARROS, M. A. B. et al. Regional Economic Growth in Brazil: Education as a factor of Convergence/1970-1996. **Social Science Research Network**. 2001. Available at: <papers.ssrn.com/sol3/papers.cfm?abstract\_id=273851>

BAUMOL, W. J. Productivity growth, convergence and welfare: what the log-run data show. **American Economic Review**, v. 76, n.5, p. 1072-1085, 1986.

CANGUSSU, R. C. et al. Uma análise do capital humano sobre o nível de renda dos estados brasileiros: MRW versus MINCER. In: FÓRUM BNB DE DESENVOLVIMENTO, Fortaleza, Ceará. **Annals...** Fortaleza: Banco do Nordeste, 2008. Available at: <[http://www.bnb.gov.br/content/aplicacao/eventos/forumbnb2008/docs/uma\\_analise\\_do\\_capital.pdf](http://www.bnb.gov.br/content/aplicacao/eventos/forumbnb2008/docs/uma_analise_do_capital.pdf)>. Accessed in: 23 dez 2008.

CASS, D. Optimum growth in an aggregative model of capital accumulation. **Review of Economic Studies**, v. 32, n. 91, p. 233-240, jul. 1965.

CHAGAS, A. L. S.; TONETO, R. J. Fatores determinantes do crescimento local - evidências a partir de dados dos municípios brasileiros para o período 1980-1991. **Pesquisa e Planejamento Econômico**, v. 33, n. 2, 2003

CHEIN, F., LEMOS, M., ASSUNÇÃO, J. Desenvolvimento desigual: evidências para o Brasil. **Revista Brasileira de Economia**, v. 61 n. 3 / p. 301–330, Jul-Set 2007

CRAVO, T.; SOUKIAZIS, E. O Capital Humano como fator condicionante para o processo de convergência entre os estados do Brasil. In: FÓRUM BNB DE DESENVOLVIMENTO, Fortaleza, Ceará. **Annals...** Fortaleza: Banco do Nordeste, 2006.

DE LONG, J. B. **Have productivity levels converged?: productivity growth, convergence, and welfare in the very long run**. February, 1988. Available at: <[http://econ161.berkeley.edu/pdf\\_files/Baumol\\_Convergence.pdf](http://econ161.berkeley.edu/pdf_files/Baumol_Convergence.pdf)> Accessed in: 02/27/09.

DINIZ, C. C. **A dinâmica regional recente da economia brasileira e suas perspectivas**. Brasília, IPEA, 1995.

DOBSON, S.; RAMLOGAN, C. Economic growth and convergence in Latin America. **Journal of Development Studies** 38: 83–104. Aug, 2002.

DOMAR, E. Capital expansion, rate of growth and employment. **Econometrica**, nº14, p.137-47, 1946.

DOWRICK, S. Technological catch up and diverging incomes: patterns of economic growth 1960-88. **The Economic Journal**, v. 102, n. 412, p. 600-610, May 1992.

DUNFORD, M.; SMITH, A. Catching up or falling behind? Economic performance and regional trajectories in the “New Europe”. **Economic Geography**, Vol. 76, n. 2, p. 169-195, Apr, 2000.

ELLERY-JUNIOR, R. G. **Crescimento e convergência de renda entre os estados brasileiros**. Fundação Getúlio Vargas, Dissertação de Mestrado, 57 p., Rio de Janeiro, Dez. 1994.

FERREIRA, A. Convergence in Brazil: Recent trends and long-run prospects. **Applied Economics**, 32, 479-489 p. 2000.

FERREIRA, A. H. B.; DINIZ, C.C. **Convergência entre as rendas *per capita* estaduais no Brasil** Texto para Discussão, n. 79. Belo Horizonte: CEDEPLAR, 1994.

FERREIRA, P. C.; ELLERY JUNIOR, R. G. Convergência entre a renda *per capita* dos estados brasileiros. **Revista de Econometria**, v.16, n. 1, p. 83-103, 1996.

FOCHEZATTO, A.; STÜLP, V. J. **Análise da convergência da renda *per capita* entre os municípios do Rio Grande do Sul, 1985-1998**. Fundação de Economia e Estatística, Secretaria do Planejamento e Gestão, Governo do Estado do Rio Grande do Sul. Porto Alegre, RS. 18p, 2005.

GARCIA, F. **The Role of Productivity on Growth and Inequality Empirical Evidence**. Fundação Getúlio Vargas, São Paulo, 2006.

GONDIM, J. L. B.; BARRETO, F. A. **O Uso do Núcleo Estocástico para Identificação de Clubes de Convergência entre Estados e Municípios Brasileiros**. Fortaleza: UFC/CAEN. 32p. 2004.

HARROD, R. An essay in dynamic theory. **Economic Journal**, n. 49, p.14-33, 1939.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – **IBGE**. Contas Regionais, 2009. Available at: < <http://www.ibge.gov.br/>>. Accessed in: 07/12/2009.

INSTITUTO NACIONAL DE ESTUDOS E PESQUISAS EDUCACIONAIS ANÍSIO TEIXEIRA – **INEP**. Sinopses Estatísticas da Educação Básica, 2005. Available at: < <http://www.inep.gov.br/basica/censo/Escolar/Sinopse/sinopse.asp>.

KOOPMANS, T. C. **On the concept of optimal economic growth**. Pontificacia Academia Scientiarum. The econometric approach to development planning. Amsterdam: North-Holland,. p. 225-287,1965

LAURINI, M. P. et al. Clubes de convergência de renda para os municípios brasileiros: uma análise não-paramétrica. In: XXXI ENCONTRO NACIONAL DE ECONOMIA, Porto Seguro, Bahia. **Annals...**Porto Seguro, 2003.

LUCAS, Jr., R. E. On the mechanics of economic development. **Journal of Monetary Economics**, n. 22, p. 3-32, jan. 1988.

MACIEL, P. J.; ANDRADE, J.; TELES V. Convergência regional revisitada: uma análise de equilíbrio geral para o Brasil. In: XXXIII ENCONTRO NACIONAL DE ECONOMIA – ANPEC, Natal, Rio Grande do Norte. **Annals...**Natal, 2005

MAGALHÃES, A. Clubes de convergência no Brasil: Uma abordagem com correção espacial. In: XXIX ENCONTRO NACIONAL DE ECONOMIA - ANPEC, Salvador, Bahia. **Anais...**Salvador, 2001.

MAGALHÃES, J. C. R.; MIRANDA, R. B. **Dinâmica da renda, longevidade e educação nos municípios Brasileiros**. IPEA Texto de Discussão. Brasília: Julho. 2005.

MINISTÉRIO DO DESENVOLVIMENTO, INDÚSTRIA E COMÉRCIO EXTERIOR – **MDIC**. Estatísticas de Comércio Exterior , 2009. Available at: <<http://www.desenvolvimento.gov.br/sitio/interna/index.php?area=5>>. Accessed in: 03/12/2009.

PIRES, J.O.; GARCIA, F. Productivity of Nations: a stochastic frontier approach to TFP decomposition. Texto para Discussão 143. Escola de Economia de São Paulo - Fundação Getúlio Vargas, 2004.

ROBINSON, J. **The accumulation of capital**. London: Macmillan, 1956.

ROMER, P. Increasing returns and long run growth. **Journal of Political Economy**, v. 94, October, 1986.

SACHS, J.; WARNER, A. Fundamental Sources of Long Run Growth. **American Economic Review**, 87, 2, 184-188 p. 1997.

SALA-I-MARTIN, X. The Classical Approach to Convergence Analysis. **The Economic Journal**. 106, p. 1019-1036, 1996.

SERRA, M. I. et al. **Regional convergence in Latin America**. IMF Working Paper, WP/06/125, International Monetary Fund, May 2006.

SHANKAR, R.; SHAH, A. **Bridging the Economic Divide within Nations: A Scorecard on the Performance of Regional Development Policies in Reducing Regional Income Disparities**. The World Bank. Country Evaluation and Regional Relations Division. Nov. 2001.

SOLOW, R. M. A contribution to the theory of economic growth. **Quarterly Journal of Economics**, v. 70, n. 1, p. 65-94, Feb. 1956.

STERN, N. The determinants of economic growth, **Economic Journal**. n. 101, p. 122–133, 1991.

TROMPIERI-NETO, N. et al. **Convergência de Renda dos Estados Brasileiros: Uma Abordagem de Paineis Dinâmicos com Efeito *Threshold***. 2008

UCHÔA, C. F. A.; MARTINS, M. F. L. **Crescimento econômico e convergência dos municípios baianos entre 1999 e 2004**. Universidade Federal da Bahia. 2007.