Impacts of health condition on economic growth in the 1990s: an analysis for the Brazilian states[1]

Lízia de Figueiredo (Ph.D. in Economics - University of Nottingham)[*]
Kenya Valeria Noronha (Master in Economics - CEDEPLAR/UFMG)[**]
Mônica Viegas Andrade (Doctor in Economics, EPGE-Fundação Getúlio Vargas)[***]

1 – Introduction

The health condition of the Brazilian population shows a quite uneven behavior as the federative states are compared. As for the infant mortality rate for 1990-1999, a very unequal situation can be observed; e.g., while the state of Alagoas shows both the highest rate (81.76 deaths per thousand) and the highest standard deviation (11,79), at the other extreme, the state of Rio Grande do Sul presented the lowest infant mortality rate (19.26) and the lowest standard deviation in the period (2.42), a comparable rate with those for developed countries[2]. Such inequality partially reflects differences in the access and quality of health services rendered to the population and is also partially related to differences in socioeconomic conditions, habits, and living conditions, all of which are added up to other inequalities to which the Brazilian population is submitted. Thus, as health condition is an important element of the individual and social human capital, social disparity in health seems not only to contribute but also to enhance the inequality and poverty cycle existing in Brazil for several decades.

This paper aims at investigating the relation between health and economic growth in Brazil during the last decade – the states of the federation being considered as units of analysis. The discussion on economic growth was reinvigorated during the 1990s with the emergence of endogenous growth models, which assumed constant returns for reproducible factors. Such models allowed explaining one of the events stylized by Kaldor: the existence of positive growth rates of income per capita over time.

Intensifying such a debate, however, did not give rise to obsolescence of the exogenous growth models (with decreasing returns for the factor capital) but, conversely, it has encouraged the reinterpretation of the models elaborated by Solow and Cass-Koopmans, which became even more disclosed in the textbooks of economics. In such a process, the emphasis on the existence and stability of the long-run equilibrium - a characteristic of post-war discussions - was added to the discussion on the determinants of income per capita and the discussion on convergence. The relation between health and growth has been delayed – notably in

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[*] Professor at CEDEPLAR/UFMG (a graduate center for regional development and planning of the Federal University of Minas Gerais).

[**] Doctorate student in economics at CEDEPLAR/UFMG
[***] Professor at CEDEPLAR/UFMG
[2] In 2000, the average infant mortality rate in the OECD countries was 12 deaths per thousand. In the USA, this rate was equal to 7. On the other hand, in Pakistan and Madagascar, which belong to the group of countries with a low human development index, in the very year, for every thousand children about 85 died before 1 year of age. Such a figure is near to the average of infant mortality in Alagoas between 1991 and 2000 (PNUD, 2002).

empirical works – which is probably explained by a greater emphasis given to the relation between growth and education.

This paper is an attempt to investigate the relation between the provision of health care and growth rates among the Brazilian states in 1991-2000. The major results found showed that a greater health care provision – neared by infant mortality – revealed a positive and significant relation with the growth of income per capita in the federative units. Furthermore, as can be observed, the impact of heath care provision on growth mainly occurred in an indirect way through the encouragement of human capital accumulation.

This paper is divided into six sections besides this introduction. The next section shows some aspects of the economic growth theory and how such a literature relates growth to health. In section 3, we present some international and Brazilian empirical evidence. Section 4 discusses the econometric model and estimation procedures. In section 5, we present the independent variables and the dependent variable used in this work. Section 6 discusses the major results found. Section 7 is the conclusion.

2 – Theoretical Aspects

The relation between health condition and economic growth may be considered through at least two mainstreams: the relation between the average health condition in the economy and the human capital stock and the presence of externalities in health as well. In the first case, the literature is mainly concerned with Solow´s model (1956), which was amplified by Mankiw, Romer, and Weil (1992), while in the second Lucas (1988) and Romer´s (1986) models would be the sources of inspiration. Let us see both mainstreams.

Mankiw, Romer, and Weil (MRW -1992) pioneered the introduction of human capital in the literature of economic growth by reformulating the concept of capital present in Solow's model. In the latter, the output growth rate by units of labor efficiency results from two opposite forces, as follows: firstly, the greatest accumulation of physical capital – determined by the saving rate of the economy (exogenous and constant) – tends to increase the rate of growth; secondly, a portion of the increased capital stock is used to recover the physical depreciation of capital and keep capital stock constant by effective labor units.

As decreasing returns for the capital factor are assumed (besides the fulfillment of Inada's conditions), there will be a constant value for the effective labor units of capital. An initial inference can be drawn, thus: that there only exists growth of capital per capita of which output per capita is a function of technological progress considered exogenous to the model.

Three other inferences are worth noting: the differences between equilibrium income per capita among regions stem from differences between major parameters of the model – marginal propensity to save, technological level, fertility rate, and depreciation rate of physical capital stock. Secondly, the growth rate of output per capita in the transition for the stationary status is a result of the same variables determining the equilibrium output per capita (plus the exogenous rate of technological progress). Finally, if the parameters between the economies are equal, the poorest regions will increase faster towards the stationary status (absolute beta convergence). Conversely, the poorest regions will increase more rapidly in the direction of their respective stationary status (conditional beta convergence).

From the theoretical viewpoint, MRW have broadened the concept of capital used by Solow: the capital embedded in the production function does not represent physical capital alone with a participation in income of 30%, but it also reflects human capital effects. Their sum represents 75% of income generation. Human capital is basically understood by these authors as education. Differences in income per capita and transition growth rates among countries would also be explained by schooling differences. The pace of convergence would also be increased if human capital were included in the analysis.

The relation between the average health condition in the economy and the human capital stock has been the most traditional way of incorporating health condition in growth models. In this case, health condition is considered to be part of human capital stock, which directly affects the productive capacity of individuals. The individual health condition affects productive capacity through direct effects in labor productivity and reduced labor supply as well (it affects the workday supplied and the probability of labor force participation)[3]. The inferences of such models are similar to those of MRW's: countries with better health levels would show higher equilibrium income per capita and transition growth rate. Furthermore, convergence would be even faster for the stationary states. It is also worth mentioning that the concern about discussing the impact of health on labor supply enriches growth studies based on Solow's model and its modifications.

The relation between health condition and human capital stock, however, can even be analyzed by taking into account the dynamic aspect present in this relation. First of all, the depreciation rate of human capital stock would be directly associated with the health condition level of the population. That is to say, as the individuals' health stock decreases with their lifetime, such a reduction may be considered as a depreciation rate. Such a depreciation rate may be higher or lower depending on the technological level of the society which would allow the introduction of new kinds of medical assistance and medicines, access to health care services, demographic profile (age and sex distribution), living and consumption habits, among others.

Thus, the treatment given to human capital depreciation can be improved in the analysis of economic growth. In addition to the direct relation between health stock and depreciation rate of human capital, there is also a relation between this rate and net investment in human capital. Societies with higher depreciation rate, which can be included in higher mortality levels for example, tend to show a lower level of investment in education as the cost of such an investment may not be offset. That is, in the face of a lower life expectation, individuals tend to decide for a lower level of education.

Finally, it is also worth noting the relation between health and fertility. The higher the fertility level in an economy, the lower the income per capita. In this way, as health care also involves decision-making concerning family planning, higher fertility rates are likely to be observed in societies showing a lower health care level. Again, Solow's theoretical framework is further enriched.

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[3] In such growth models, health condition is usually incorporated as an additional variable determining the human capital stock in a Mincerian equation (Barro, 1996; Mayer et alli, 2000; Bloom et alli, 2001).

A second line through which health affects economic growth is associated with the presence of externalities in health. Externalities acting on the economic growth process were introduced by the endogenous growth models. In Romer's (1986), by investing, the competitive firm increases general productivity of the economy, though it does not perceive such an effect. A greater productivity resulting from learning by investing is similar to a public good which is widespread throughout the economy, offsetting the trend of the marginal product of capital to decrease. The outcome is a growth in the output per capita being determined (among other factors) by this externality.

Lucas' model (1988), however, is the most relevant one for the discussion on health condition. According to Lucas, production is accomplished by means of a combination of physical capital, human capital, and labor. Human capital not only generates domestic effects by increasing labor productivity but also externalities in production, which account for a positive growth rate of income per capita in the long run. In this model, accumulation of human capital – here again identified with education – possesses a distinct logic from that of physical capital accumulation. Human capital accumulation is a (linear) function of the number of non leisure hours dedicated to accumulation.

As for health, such externalities are present to the extent that the individual health level not only depends on one's own health condition but also the society's average health condition. These are called diffuse externalities. This is the case of contagious diseases, diseases avoidable by basic sanitation, and diseases avoidable by vaccination. Such externalities have health effects on economic growth not only through its average level, but also through health care distribution and access to health services for all population groups. This effect is more visible in less developed countries in which a close relation between health and poverty can be observed. African countries with high AIDS incidence show how the existence of externalities in health may undermine economic growth. Though indirectly, such externalities may also affect business investment decisions. Thus, health effect on growth models can also be indirectly captured through the physical capital of the economy.

All such relations mentioned above point to a negative relation between poverty and health condition and a positive relation between the output growth rate and health condition.

3 – Economic Growth and Health: empirical evidence

This section presents the major results found in the empirical literature on economics concerning the relation between economic growth and health. As mentioned before, only recently has health condition been given relevance as a possible determinant of economic growth, a reason why only a few study efforts have tested such a relation. Furthermore, an additional hindrance is related to the existence of compatible health measures among countries/economies which are able to capture the multiple health condition dimensions of the population. The majority of the empirical work in this field, prior to the 1990s, have used a microeconomic approach and have mainly investigate the relation between the individual income determination and health condition. In the macroeconomic approach, the relations between economic growth, income per capita level, and health have been under investigation mainly based on the extension of human capital, which was introduced as an argument in the aggregate production function. Whether such a broad concept of human capital affected the income per capita level and its growth rate (transition or long-run rate, according to the model adopted) was then tested.

The pioneer work accomplished in this literature was that of Knowles and Owen (1995) who extended the estimation made by Mankiw-Romer-Weil (MRW) so as to include the health capital stock in the production function. The authors used the same MRW database, except for the variable education, which has been replaced by the average number of years of study for the population aged 15-64 constructed by Barro and Lee (1993). Health capital was measured through life expectancy at birth, which is an average of health condition of the population as a whole[4]. The dependent variable is the growth rate of the gross domestic product for 1960-1985. The work showed two major results: 1) a statistically significant positive correlation between health and economic growth; 2) the variable education was no more significant when the health stock was included as one of the explaining variables, suggesting a strong correlation between health and education. This result is also revealed in other exercises, but its persistence usually relies on the proxies used for education and health respectively.

A similar analysis was accomplished by Barro (1996), which is an extension of his growth model (Barro, 1991) including a proxy variable for the initial status of health capital[5]. The author used the least squares method in three stages and estimated health condition by using three distinct measures: infant mortality rate; mortality rate for children under 5 years of age; and life expectancy at age 5. The results found evidenced a positive and significant relation between the initial health stock of the population and the rate of economic growth, irrespectively of the kind of the health stock measure used. The results also suggested a positive correlation between female education and fertility rate, and health condition. In this case, the education level of adult female population seems not to affect economic growth, and such a relation appears to occur only indirectly through the above channels. On the other hand, the education level of male population is still an important explaining variable of economic growth.

A positive correlation between health condition and growth is also shown in Bhargava *et alli* (2001) and Bloom *et alli* (2001), who used panel data for different countries. The first used virtually the same variables proposed by Barro (1991), including a proxy variable for the health capital and the survival probability at 60 years of age, provided that one is alive fifteen years after the interaction of this very probability with the output level[6]. The authors found a positive correlation between health and economic growth for countries with lower levels of income per capita in which the higher the survival probability, the higher the human capital stock in the economy. For countries with higher income level, the relation is reversed - being negative then. A possible interpretation of such a result is that with an increased survival probability, there is an increase in the elderly portion of the population which is not translated into productive human capital. The second work consists in an

[4] The authors used the functional transformation proposed by Arnand and Ravaillon (1993) which consists in a natural logarithm of the difference between 80 life expectations at birth.

[5] The author used the following as independent variables: initial output level, fertility rate, opening degree of the economy, a variable measuring the terms of trade, regional dummies, output level at the beginning of the period, average schooling at the beginning of the period, indicator of democracy degree, index measuring investment attractiveness *(rule of law index).*

[6]The estimation was accomplished for the quinquennial panel data for 1965-1990, by using two different databases for the output per capita variable: data from PENN table and data made available by the World Bank.

estimation of the traditional growth by using panel data for 1960/1990 with decennial observations for each country. The positive relation between health condition and economic growth is once more confirmed. According to the authors, a 1 year increase in life expectancy of the population bears a 4% increase in production.

In opposition to the positive relation hypothesis between the population health condition and the output growth rate, Zon & Muysken (1997) tested a proposition by Baumol. According to this author, the population health condition may have several effects on economic growth: on the one hand, it may positively affect economic growth, as it increases the society's human capital; on the other hand, as it is a nonproductive activity, it competes with productive sectors in the economy in the allocation of scarce resources which determines a negative relation with the economic growth. In order to test such a hypothesis, the authors simulated two distinct specifications by using the calibration technique: in the first, health condition is included in the model as a component of the human capital stock only, while in the second, in addition to the human capital component, health condition directly affects the individual utility. As for the second specification, the result shows a negative relation between economic growth and the health condition of population, confirming Baumol's proposition.

Notwithstanding the scarce international empirical literature, most of the works point to a positive relation between health condition and economic growth and between health and level of income per capita. However, the comparison between the coefficients obtained has not shown compatibility with each other and it seems to be sensitive to the estimation method, due to the diversity of the health measurements used. Health condition was only incorporated as a human capital stock, and it is still necessary to take into account the remaining channels through which health condition may affect economic growth.

3.1 - Empirical evidence for the Brazilian case

The relation between health condition and economic growth in Brazil was approached first in 2000 in a series of papers presented to the Pan-American Health Organization (PAHO)[7]. Although their main results pointed to a positive and significant relation, similar to those observed for the other countries, the understanding of such a relation is to be enhanced further, due to the precariousness of the controlling variables used[8].

Mora and Barona (2000) attempted to replicate Barro's model (1996) by using the least squares method in three stages for the Brazilian states and the years of life lost by premature death as a proxy for health[9]. The authors found a negative and significant coefficient, but the absence of a number of explaining variables – which are common to growth models – makes the results found feeble. Cermeno (2000), using quinquennial panel data for 1980-1995, attempted to replicate the growth model proposed by MRW for the Brazilian states. The results point towards a positive

[7] A series of papers on the relation between economic growth, health, and income disparity in Latin-American and Caribbean countries, accomplished by Mayer et alli (2000).

[8] The relation between health and income in Brazil has also been studied in a microeconomic approach by means of individual data. See: Kassouf (1999), Thomas & Strauss (1997), Alves and Andrade (2003), Alves et alli (2003).

[9] The observations are for the periods: 1965/1975, 1975-1985, 1985/1990.

relation between health – measured through life expectancy –, probability of survival within the next five years, infant mortality rate, and economic growth. Such a relation, however, is not robust enough in the set of estimations accomplished and the sign of the other control variables is not consistent with the expected behavior. Similarly to the conclusion by Mora and Barona (2000), the authors credited the fragility of the results to the difficulty in obtaining a more consistent control[10].

4 – Econometric Model and Estimation Procedures

This paper is intended to contribute towards the investigation of a possible positive relation between health, income per capita level, and (transition) growth rate for the Brazilian states. Based on the amplified Solow's model, we accepted the hypothesis that growth differentials among per capita earnings – in this case, among the Brazilian states – are explained by differences in the variables determining the equilibrium level of income per capita as well as by the distance which each state is from its own stationary status. As Brazil is not a frontier country, we believe that Solow's model is the most appropriate one for studying its economic growth rate, since endogenous growth models are associated with explaining growth for leading regions. Our study is restricted to the period from 1991 to 2000 for the reasons explained below.

Let i and t be the subscripts concerning the federative units and years respectively. Thus, the econometric model can be specified as follows:

$$\gamma_{it} = \beta_1 + \beta_2 y_{it-1} + \beta_3 \, HEALTH_{it-1} + \Sigma_t \beta_t \, year + \Sigma_s \beta_s \, Region + \Sigma_j \beta_j X_{jit-1} + \varepsilon_{it} \qquad (1)$$

in which:

γ_{it} = the growth rate of real GDP per capita;
β_k = the estimated parameters for the k variables;
β_t = the estimated parameters for the t years, with t varying from 1991 to 2000, being 1995 the reference year;
β_s = the estimated parameters for the s regions, being s equal to the North, Northeast, Southeast – except for São Paulo -, Center-West, and South regions, being São Paulo the reference region;
y_{it-1} = real GDP per capita with a one-year gap;
$HEALTH_{it-1}$ = average health condition of the population measured as the infant mortality rate;
X_{jit-1} = socioeconomic and demographic variables specified in CHART 1 below;
ε_{it} = random shocks.

Our work differs from that of Mora and Barona (2000) as it uses the panel technique and due to a change in the proxy for the health variable. It is also different

[10] The work developed by Mayer (2000), who uses the microeconomic approach to produce macroeconomic inferences, is also part of such studies. Using data from PNAD (the Brazilian national household sample surveys) for 1977-1995, the author attempted to analyze the relation between the income growth rate of each income decile in the Brazilian states and health condition. The author uses different health measures: infant mortality rate, survival probability, maternal mortality rate, mortality rate by contagious and noncontagious diseases. The health variables, however, differently from the other controlling variables, are not associated with the income deciles, but they are variables which are common to the Brazilian states. The most robust results reveal a positive correlation between the income growth rate in the superior income and the probability of female survival. \

from the study by Cermeno (2000), due to the difference in specifying independent variables and because it uses the fixed-time panel.

Our main objective is to test whether the coefficient of the HEALTH variable is statistically higher than zero, i. e.:

H_0: $\beta_3 > 0$
H_1: $\beta_3 \leq 0$

The independent variables of our model are proxies of the equilibrium determinants of income per capita. Their function – in (1) – is to control the econometric model so that the omitted variables are not allowed to bias the estimate of the HEALTH variable coefficient. Notwithstanding, the estimation procedure we are going to use will also test the hypothesis that such independent variables are equal to zero. In this way, we will be able to observe whether the inclusion of HEALTH as an explaining variable offers new information on the role of the remaining variables in determining the economic growth for our sample.

The model specified in (1) assumes that the intercept may be different for the distinct years in the sample, which would lead us to estimate the fixed-time panel for equation (1). Three different determinants led us to choose the fixed-time panel: a) using the panel increased the number of observations; b) the intent to control the model by means of economic cycle effects, which thus became filtered by the year dummies; c) the test that the time variables would be jointly significant, which led us to reject the pooling alternative.

The other independent variables of our model are proxies of the equilibrium income per capita determinants. The choice of these variables was based on the international empirical literature, constrained by data availability though. Such variables included a set of socioeconomic and demographic measures usually considered in the analysis of economic growth. CHART 1 shows each of these variables as well as their data source and description. All variables were included in the model with a one-year gap in relation to the growth rate of real GDP per capita. Additionally, we included income per capita (y) in the beginning of each period, in order to test the presence of conditional convergence (convergence β) of economic growth and a set of dummy variables for each region, the state of São Paulo, and for each year.

The relation between economic growth and health is endogenous, i. e., it is simultaneously determined by the model. Using instrumental variables, which are related to the infant mortality rate but not to the growth rate of real GDP per capita, is a way of controlling endogenicity. The variable itself – with a time lag in relation to the dependent variable – is usually the instrument used in this kind of analysis. For this reason, the infant mortality rate (the proxy for HEALTH ins this paper) was considered with a one-year gap in relation the growth rate of real GDP per capita in this model. The endogenicity issue is present for almost all independent variables in the model, for which we also used lagged variables as a way to control this problem.

Three tests were accomplished in this paper: one for the normalcy of residues, one for detecting autocorrelation, and another for the heteroscedasticity. The test for residue normality was based on a combination of the skewness and kurtosis tests. The result led us to accept the hypothesis that the residues are normally distributed at a 1% de significance.

Chart 1. Description of Independent Variables

<table>
<tr><th>Variable</th><th>Data source</th><th colspan="2">Description</th></tr>
<tr><td>Gini Coefficient</td><td rowspan="5">PNADs for 90, 92, 93, 95-99.

Census of 1991 and 2000.

PNAD was accomplished in 1994</td><td>Estimated based on household income per capita.</td><td rowspan="3">A simple interpolation was determined for 1994.

North region: PNAD does not take the urban area into account. Based on the 1991 and 2000 censuses, we estimated each variable for urban and rural areas and then the rural area only. We obtained the ratio between the variable estimated for the rural area and the variable estimated for both localities for each census year. We interpolated this ratio and applied the value found the correspondent variable estimated based on the PNADs.</td></tr>
<tr><td>Average years of study of working age population (WAP)</td><td>Full years of study</td></tr>
<tr><td>Age Structure</td><td>Proportion of WAP in relation to total population. (We also tested the dependence ratio which is the proportion of individuals under age 14 and over 64 in relation to the WAP. The results are quite similar)</td></tr>
<tr><td>Urbanization Rate</td><td>Proportion of individuals living in urban areas</td><td>North region: simple interpolation using the censuses of 1991 and 2000.</td></tr>
<tr><td>Migration rate (refers to urban residents only)</td><td>Net migration rate = migratory balance/observed population.

Migratory balance = Immigrants – Emigrants</td><td>Immigrant = individual not residing in the federation unit – FU – in the previous five years and living there in the survey year.
Emigrant = individual reporting the place of residence in the previous five years as he/she did not live in the FU on that date.
For 1994: simple interpolation</td></tr>
<tr><td>Demographic density</td><td>DATASUS</td><td colspan="2">Population divided by the FU territorial extension</td></tr>
<tr><td>Fertility rate</td><td>Sawyer et al, (1999)</td><td colspan="2">These rates were estimated for 1991, 1995, 2000, 2005, 2010, 2015, and 2020.
We used the 1991 information for 1991-1994 and the 1995 fertility rates for 1995-2000.</td></tr>
<tr><td>Physical capital stock</td><td>Statistical Yearbook (several years)</td><td colspan="2">Measured as the total electric energy consumption</td></tr>
<tr><td>Economic distance</td><td>Statistical Yearbook (2000) and regional accounts (1985-2000)</td><td colspan="2">$D_j^t = \sum_i d_{ij}^t \frac{PIB_i^t}{PIB_{total}^t}$,where d_{ij} is the distance from the capital of the state j in relation to the other state capitals. D_j is estimated for each FU for each year t.</td></tr>
<tr><td>Participation of industry in the GDP of FU</td><td colspan="3" rowspan="2">Statistical Yearbook (2000)</td></tr>
<tr><td>Participation of services in the GDP of each FU</td></tr>
</table>

In order to detect heteroscedasticity, the Cook and Weisberg test (1983) was done, the null hypothesis of which is that t=0 in the following expression for the residue variance: $Var(e)=s^2e^{Zt}$, where Z corresponds to the adjusted values. In case heteroscedasticity is present, we use the White procedure to correct it.

We tested the presence of autocorrelation, by comparing the coefficient ρ estimated by the Prais-Winsten method with the critical values from the Durbin-Watson table. The estimated coefficient was located in the indecision region. The model was corrected by the Prais-Winsten method and no significant discrepancies with the results estimated by the least squares method were found.

The estimation procedure is stepwise-typed, i. e., when estimating the model, the least statistically significant variable will be removed so that only variables whose coefficients are different from zero to at least 10% of significance can be found. This procedure does not include time dummies and dummies for the Fus (federal units) either, which are submitted to the test F for joint significance.

IV.1 – Describing variables and sample

The dependent variable of the model is the growth rate of real GDP per capita measured at market price (in thousand dollars) and at fixed dollar in1990[11]. The data source is the regional accounts accomplished by IBGE (the Brazilian census agency), which provides nominal GDP for each federation unit[12]. The analysis encompasses all the Brazilian states in 1991-2000[13]. Choosing this period was mainly due to restricted compatible and reliable data on health condition for all FUs. Only in the 1990s, with the foundation of the Datasus. Using data for previous periods with annual periodicity would not be possible. Additionally, as the decade of 1990 is a period of remarkable structural changes in the area of health and such changes are not uniformly observed for all states, using a panel for 10 years – which takes account of the existing diversity among the FUs – seems to provide a set of information useful to start understanding the relation between growth and health in Brazil.

As shown in Table 1, most states present a positive average growth rate in the period of analysis. The states whose averages are negative are: Amazonas, Roraima, Pará, Amapá, Sergipe, and São Paulo.

[11] In order to obtain the deflated GDP for each state – measured based on the 1990 dollar – , we have estimated the series of the Brazilian real GDP. Afterwards, we have multiplied the participation of nominal GDP per capita of each FU by the estimated Brazilian real GDP. Such a procedure allowed us to deflate the GDP of each state, in relation to variations in domestic prices and the (foreign) dollar inflation. The Brazilian nominal GDP in 1990, measured in dollars, and the real GDP growth rates for 1991-2000 were taken from *Conjuntura Econômica* (2000).

[12] IBGE, *Diretoria de Pesquisas, Departamento de Contas Nacionais, Contas Regionais do Brasil 1985-2000.*

[13] The Federal District was excluded as it presented a quite peculiar standard.

Table 1. Average Growth Rate of GDP from 1991 to 2000 by Federation Unit

Federation Unit	Average	Standard Deviation	Smallest Value	Highest Value	Federation Unit	Average	Standard Deviation	Smallest Value	Highest Value
Rondônia	0.0009	0.10	-0.21	0.14	***Alagoas***	0.0034	0.04	-0.06	0.06
Acre	0.0073	0.05	-0.05	0.12	***Sergipe***	-0.0001	0.05	-0.08	0.09
Amazonas	-0.0108	0.10	-0.10	0.18	***Bahia***	0.0102	0.02	-0.03	0.04
Roraima	-0.0267	0.15	-0.25	0.19	***Minas Gerais***	0.0168	0.03	-0.03	0.09
Pará	-0.0243	0.13	-0.24	0.27	***Espírito Santo***	0.0246	0.05	-0.02	0.12
Amapá	-0.0168	0.09	-0.13	0.13	***Rio de Janeiro***	0.0290	0.05	-0.03	0.11
Tocantins	0.0330	0.06	-0.12	0.12	***São Paulo***	-0.0003	0.03	-0.05	0.06
Maranhão	0.0160	0.06	-0.09	0.12	***Paraná***	0.0073	0.04	-0.07	0.07
Piauí	0.0227	0.06	-0.13	0.12	***Santa Catarina***	0.0125	0.05	-0.07	0.07
Ceará	0.0260	0.04	-0.03	0.11	***R. G. do Sul***	0.0085	0.04	-0.05	0.07
R. G. Norte	0.0262	0.07	-0.12	0.11	***Mato G. Sul***	0.0186	0.05	-0.080	0.14
Paraíba	0.0152	0.07	-0.16	0.10	***Mato Grosso***	0.03	0.06	-0.09	0.13
Pernambuco	0.01	0.05	-0.10	0.07	***Goiás***	0.01	0.06	-0.11	0.10

Source: IBGE, *Diretoria de Pesquisas, Departamento de Contas Nacionais, Contas Regionais do Brasil 1985-2000* (research director's office, department of national accounts, Brazilian regional accounts).
Elaborated by the authors.

In order to certify the relation between health condition and economic growth, we used the infant mortality rate as the proxy for health measure. Using data from IBGE (2002), such a rate was defined as the ratio between the number of deaths among children under one year of age and the number of live-born children. The relation between these two variables is expected to be negative, i. e., the lower the infant mortality rate, the healthier the population, and the higher the economic growth. This indicator is a measure of the average health level of a population that is quite sensitive to social policies. The infant mortality rate reflects both the health condition of live-born children and that of their parents. This is so because it is associated, on the one hand, with health policies designed to preventive actions for the population treatment and access to health services; and, on the other hand, also with the parental health condition (mainly as for nutrition, living habits, and information on health). The infant mortality rate provides – to a certain extent – information on the access of health services, if we have in mind that most of the deaths of children under 1 year of age result from avoidable causes that are related to socioeconomic characteristics of their environment and the consumption of preventive health care.

The infant mortality rate decreased in all states during the 1990s. Table 2 shows this rate average by FU. As can be seen, the Northeast shows the highest averages, especially for Alagoas (81.76 deaths per thousand live-born children). The ratio between the smallest value and the highest value – which correspond to the infant mortality rate in the end and the beginning of the period respectively – shows a reduction of about 33% of such an indicator from 1990 to 1999. The highest decrease occurred in Roraima (53.66%) and the smallest, in Amazonas (27.75%).

Table 2. Average Infant Mortality Rate by Federation Unit from 1990 to 1999

Federation Units	Average	Standard Deviation	Smallest Value	Highest Value	Ratio between the smallest and highest values (%)
Rondônia	32.03	4.13	26.70	38.93	-31.42
Acre	44.62	5.84	36.76	54.05	-31.99
Amazonas	36.03	3.99	30.85	42.70	-27.75
Roraima	29.19	7.78	19.80	42.73	-53.66
Pará	36.84	5.16	30.06	45.35	-33.72
Amapá	31.12	3.51	26.63	37.06	-28.14
Tocantins	39.02	6.67	30.90	50.62	-38.96
Maranhão	61.64	8.28	50.65	75.02	-32.48
Piauí	49.70	8.69	38.06	63.69	-40.24
Ceará	55.08	10.41	41.66	72.45	-42.50
R. G. Norte	58.58	9.48	46.44	74.54	-37.70
Paraíba	62.82	10.20	49.96	80.13	-37.65
Pernambuco	62.15	9.38	49.83	77.58	-35.77
Alagoas	81.76	11.79	65.36	100.05	-34.67
Sergipe	55.76	8.14	45.02	69.09	-34.84
Bahia	52.05	7.33	42.46	64.14	-33.80
Minas Gerais	29.10	4.70	23.06	37.01	-37.69
Espírito Santo	27.14	3.22	22.82	32.36	-29.48
Rio de Janeiro	25.72	3.48	21.25	31.56	-32.67
São Paulo	24.27	3.97	19.25	31.02	-37.94
Paraná	29.09	4.71	23.03	36.97	-37.71
Santa Catarina	23.13	3.53	18.66	29.11	-35.90
R. G. do Sul	19.26	2.42	16.32	23.49	-30.52
Mato G. Sul	25.61	3.90	20.73	32.29	-35.80
Mato Grosso	29.11	4.20	23.66	36.09	-34.44
Goiás	27.50	3.81	22.60	33.90	-33.33

Source: IBGE, 2002.
Prepared by the authors.

The correlation between the growth rate of real GDP per capita and the infant mortality (lagged) rate by FU and year is negative in most cases, which indicates that a precarious health condition of the population seems to be harmful to the economic growth. It should be noted, however, that such a correlation is not statistically relevant at 10% (Table 3).

Table 3. Correlation between the Growth Rate of Real GDP and Infant Mortality Rate By State and Year

Federative Unit	Correlation	Federative Unit	Correlation	Year	Correlation
Rondônia	-0.5892*	***Alagoas***	-0.1618	***1991***	0.3088
Acre	0.1473	***Sergipe***	0.2697	***1992***	-0.242
Amazonas	-0.2067	***Bahia***	-0.5881*	***1993***	-0.0278
Roraima	-0.8996*	***Minas Gerais***	0.1693	***1994***	-0.0764
Pará	-0.0391	***Espírito Santo***	-0.04	***1995***	-0.075
Amapá	0.1607	***Rio de Janeiro***	-0.0138	***1996***	0.4428*
Tocantins	0.098	***São Paulo***	-0.2407	***1997***	0.1072
Maranhão	-0.0749	***Paraná***	-0.2096	***1998***	-0.0952
Piauí	-0.1106	***Santa Catarina***	-0.2976	***1999***	-0.0482
Ceará	0.6021*	***R. G. do Sul***	0.1699	***2000***	-0.1955
R. G. Norte	-0.1949	***Mato G. Sul***	0.0328		
Paraíba	-0.3293	***Mato Grosso***	-0.0031		
Pernambuco	-0.0114	***Goiás***	0.0186		

* Significance at 10%.
Source: Prepared by the authors.

5 – Major Results

This paper has two main objectives. Firstly, we attempted to verify whether health condition directly impacted the Brazilian economic growth during the 1990s. Microeconomic studies have pointed out that a worse health condition reduces productivity and the number of work-hours supplied, provoking losses in individual earnings. We were interested in verifying whether such losses were reproduced in the macroeconomic level, as predicted by the literature. Secondly, we attempted to evaluate the indirect effect of health condition on economic growth by means of its relation with education. Improved health condition contributes to reduce the effective depreciation rate of human capital. In this way, an indirect positive effect of health condition on economic growth may occur, since a smaller depreciation rate contributes to increase investment in education and other forms of human capital, increasing, in turn, the average productivity of the population. Another indirect effect may occur through fertility determination, in which reduced mortality rates, i. e., improved health condition, implies reduced fertility rates.

In order to verify such effects, the following exercises were accomplished. Firstly, we estimated the economic growth model by including the infant mortality rate (a proxy for health condition) so as to verify the direct effect of such variable as well as whether there is any change in the education effect on economic growth. Secondly, we let the infant mortality rate, the education variable, and the fertility rate to interact so as to evaluate whether health had any indirect effect on the growth of GDP per capita. For each of such specifications, we estimated a model taking account of all the variables mentioned in section 4 and a parsimonious model including the statistically significant variables at least at 10%.

Subsection 5.1 analyzes the major results of the model taking account of the direct impact of health on economic growth. Subsection 5.2 shows the model results with the interaction terms between the proxy variable for health condition and the fertility and education rates.

The main results show that health condition contributes positively to economic growth. Decreased infant mortality rates make the growth rate of real GDP per capita to increase. This effect seems to occur mainly through investment in human capital, more specifically in education. A higher infant mortality rate, i. e., a worse health condition, tends to reduce the positive effect of education on the growth rate of GDP.

5.1 The direct effect of health condition on economic growth

Table 4 shows results for the full model, i. e., with all variables, and for the parsimonious model. The latter is obtained by means of the significance analysis of each variable[14]. We also present the results of the base model, which is obtained from the estimation of the parsimonious model without the infant mortality rate. This model allows us to verify what happens with the education effect on economic growth when the proxy variable of health condition is omitted.

The results for the two models estimated with the infant mortality rate are quite similar and, in general, they present the expected sign[15]. As for the parsimonious model, we noticed that the economy presented a conditional beta convergence. A unity reduction in the initial income per capita gave rise to an increase of 6.5% in the growth rate of GDP per capita. This means that, by controlling the steady state level, the smaller the initial output level, the higher the rate of economic growth.

The main factors explaining the state economic growth in 1990s were the human capital level (the rate of infant mortality and education), investment in physical capital (measured as the rate of electric energy variation), fertility rate, population density, industrial participation in the GDP, and economic distance.

The estimated coefficient of mortality was negative, indicating that a worse health condition is harmful to economic growth. A unity increase in this variable led to a decrease of 0.13% in the economic growth. Among the FUs in the 1990s, the infant mortality rate was reduced in approximately 36% in average (from 50.45 deaths per thousand to 32.40 in 2000), which contributed to an increase of 2.33% in the average rate of economic growth *ceteris paribus*.

The states presenting the highest decreases in mortality rate in the period were those of the Northeast region, specially Alagoas, Ceará, and Paraíba. In these states, *ceteris paribus*, improved health condition contributed to increase the rate of economic growth in 4.47%, 3.97%, and 3.89% respectively.

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[14] Each variable is excluded one by one as a base for the significance level obtained by test t. Exclusion of regional dummies is based on the result of a test of F, through which the joint significance of such variables is verified. This same test is accomplished for the year dummy variables, which were jointly significant. Thus, such variables were kept in our model, and we estimated a model for the fixed-time panel data.

[15] The full-model and the parsimonious model results are quite similar, indicating robustness of then results.

Table 4. Indirect effect of health condition on economic growth

Independent Variables	*First Specification of the Model: without interaction terms*		*Base Model: without the term health*
	All Variables	***Parsimonious Model***	
Initial GDP	-0.09696***	-0.06563***	-0.04684***
Infant Mortality Rate	-0.00126*	-0.00129***	
Variation rate of electric energy	0.04890**	0.04960***	0.04850***
Fertility rate	0.03177+	0.03049**	0.01898+
Gini coefficient	-0.11701+		
WAP proportion in relation to total population	-0.00093+		
Education	0.03410*	0.04031***	0.04137***
Urbanization rate	0.00141+		
Population density	0.00019*	0.00017**	0.00003+
Economic distance	-0.00002+	-0.00003**	-0.00003**
Migration rate (urban residents)	-0.00313*		
Industrial participation in state GDP	0.00306*	0.00200***	0.00113*
Services participation in state GDP	0.00032+		
North	-0.09814*		
South	-0.05570**		
Center-West	-0.07657**		
Northeast	-0.12669**		
Southeast (except for São Paulo)	-0.06153**		
1991	-0.03049+	-0.03053+	-0.03426+
1992	-0.05619**	-0.06222***	-0.06185***
1993	-0.00304+	0.00796+	0.01330+
1994 (reference year: 1995)	0.00751+	0.01282+	0.01919+
1996	-0.00384+	-0.00524+	-0.00474+
1997	-0.01589+	-0.01394+	-0.01188+
1998	-0.05135**	-0.05203***	-0.04835**
1999	-0.03997*	-0.03957**	-0.03436*
2000	-0.01448+	-0.01359+	-0.00511+
Constant	*0.00989+*	*-0.07943+*	
Number of observation.	*260*	*260*	*260*
F(k; n-k-1)	*4.38*	*5.57*	*5.63*
Prob>F	*0.0000*	*0.0000*	*0.0000*
R-square	*0.3488*	*0.3036*	*0.2838*
Root MSE	*0.05974*	*0.06049*	*0.06121*
Rho (dw)	*0.0376*	*0.0571*	*0.050*

Source: Prepared by the authors

+ nonsignificant, * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

The average education effect of the active age population was predictable. The higher the educational level, the higher the economic growth. An additional year in education represents a 4% increase in the growth rate. In the 1990s, the average educational gain was 1.12 year, which contributed to a 4.52% increase in the growth rate (*ceteris paribus*). In this period, the states presenting the highest gains were Acre (1.6), Tocantins (1.51), and Roraima (1.5). The effect of such gains on the rate of economic growth was around 6%. Taking the base model into account, we observed that the education effect did not change when the infant mortality was omitted. This result differs from that found by Knowles and Owen (1995), in which the education effect becomes nonsignificant with the inclusion of the health variable.

The variables with positive effect on the growth rate were population density, investment in physical capital, industrial participation in GDP, and fertility. *Ceteris paribus*, localities with higher number of people per square meter showed a higher growth rate due to that the population density coefficient was positive and significant at 1%. Such a result suggested that the agglomeration did not restrict growth. The positive sign of the population density coefficient also suggested that the frontiers – which have played an important role in diminishing regional disparities – seemed to have lost dynamism during the 1990s.

In the same way, increased investment in physical capital and industrial participation in GDP have contributed to increase the rate of economic growth. Despite the increased participation of services in GDP, mainly in the second half of the 90s, the industrial sector was still an important variable as far as per capita growth is concerned. A 1% increase in the growth rate of electric energy would bear a 5% increase in the growth rate of GDP per capita, *ceteris paribus*. Using this proxy was an attempt to estimate the effects of the level of capital per capita on the per capita growth rate. The variables industrial participation in GDP and participation of services in GDP were included aiming at testing whether the economies of scale – resulting from the forward and backward effects in these sectors – had an impact on per capita, as predicted in the literature of the new economic geography[16]. The positive and significant coefficient of industrial participation in the output suggested that, *ceteris paribus*, an increased participation of the industrial sector would bring about a 0.2% increase in GDP per capita.

A slightly intuitive result is concerned with the effect of fertility rate. According to Table 1, we observed that higher fertility rates have contributed to economic growth, as their coefficient was positive and significant at 5%. This result was opposite to that predicted by the theoretical and empirical literature.

The economic distance effect was negative and significant, indicating that the nearer the state of a richer economy, the higher the growth rate in GDP per capita. Using such a variable was an attempt to measure the transport cost effect suggested by the new economic geography. According to the latter, transport costs play a distributive role, since – at their intermediate levels – it is the developed economies that attract production. Low transport costs, in turn, would tend to disperse production. This result means that more developed economies would tend to improve their growth, reinforcing the positive effect of demographic density, which indicates a possible reconcentration of output per capita among regions in the 1990s.

5.2 – The indirect effect of health condition on economic growth

Table 5 shows results of the model in which infant mortality rate interacted with fertility rate and average schooling so that we could measure the indirect effects of health condition on economic growth. Full model 2 was obtained by including the interaction terms in the parsimonious model, analyzed in the previous subsection. Here again, the variables nonsignificant at 10% were excluded so that we could obtain the final parsimonious model 2.

Generally speaking, the effects of major variables on the rate of economic growth do not change when the interaction terms are considered in model, and the results of the full model 2 and the parsimonious model 2 are quite similar. When

[16] Ver a respeito Fujita, Krugman e Venables (1999) e Figueirêdo (2002).

analyzing the parsimonious model 2, we have noticed that the economy showed the conditional beta convergence. Moreover, the major variables affecting the rate of economic growth were average education of the population at working age, investment in physical capital, fertility rate, population density, industrial participation in GDP, and economic distance. The major change in the results in relation to the previous analysis was concerned with the effect caused by health condition.

Table 5: Indirect effect of health condition on economic growth

Second Model Specification: with interaction terms		
Independent Variables	***Full Model 2***	***Parsimonious Model 2***
Initial GDP	-0.07691***	-0.07277***
Infant mortality rate	0.00606^{+}	
Variation rate of electric energy	0.04525***	0.04662***
Fertility rate	0.07040*	0.03052*
Education	0.08183***	0.05429***
Demographic density	0.00018***	0.00019***
Economic distance	-0.00004**	-0.00003**
Industrial participation in state GDP	0.00241***	0.00228***
Education * Mortality	-0.00096*	-0.00033***
Fertility * Mortality	-0.00092^{+}	
1991	-0.02679^{+}	-0.02876^{+}
1992	-0.06275***	-0.06237***
1993	0.01010^{+}	0.00806^{+}
1994	0.01509^{+}	0.01316^{+}
1996	-0.00383^{+}	-0.00444^{+}
1997	-0.01448^{+}	-0.01418^{+}
1998	-0.05284***	-0.05240***
1999	-0.04436**	-0.04194**
2000	-0.02234^{+}	-0.01795^{+}
Constant	*-0.38470**	*-0.13384**
Number of obs.	*260*	*260*
F(k; n-k-1)	*5.14*	*5.67*
Prob>F	*0.0000*	*0.0000*
R-square	*0.3165*	*0.3109*
Root MSE	*0.06017*	*0.06017*
Rho (dw)	*0.0533*	*0.0589*

Source: Prepared by the authors

$^{+}$ nonsignificant, * Significant at 10%, ** Significant at 5%, *** Significant at 1%.

After including interaction terms, the direct effect of health became nonsignificant. A possible explanation for this would be related to the proxy of health considered in the paper. Though it is an ample measure, such a variable might not be adequately capturing the effect of health condition on productivity, and hence on the rate of economic growth, as it did not act directly on the working age population. For this reason, extensions of this paper should attempt to take account of indicators that could measure health condition of the population as a whole, specially the portion directly affecting the productivity capacity in the country. A constraint for this is the unavailability of reliable morbidity and mortality measures over time for the Brazilian states. The results suggest that health condition affects economic growth indirectly through its relation with the level of human capital investment. Table 5 shows that the net effect of education is given by:

(0.05429 - 0.00033 x infant mortality rate) x education.

This relation showed that education has affected positively the rate of growth when infant mortality rate was less than 165.64. For all the Brazilian states, this rate was lower than this value all over the 1990s. Thus, increased years of study favored the growth rate of real GDP per capita in the period. However, it is worth noting that the net effect of education was lower than its pure effect due to the infant mortality rate. The higher this rate, the lower the education effect on the economic growth. The localities presenting higher mortality rates tended to show a lower productivity due to smaller investment in education and other forms of human capital, leading to lower educational returns in those regions. It is also worth observing that this result strongly differs from that by Knowles and Owen (1995), who obtained a nonsignificant coefficient for education when they introduced the health proxy in their econometric model. Not only the education coefficient remained positive and significant when mortality rate was introduced among independent variables, as can been seen in Table 4, but also the major effect of health variable on economic growth occurred indirectly through education, as shown in Table 5. The relation between health and fertility rate, however, is nonsignificant, as indicated by the interaction variable coefficient between fertility and infant mortality, as can be also seen in Table 5.

6. Final Remarks

This paper aimed at estimating the impact of health condition on the growth of income per capita among the Brazilian states during the 1990s. The major results found show that health affects positively economic growth, mainly through its interaction with education. The localities with higher infant mortality rates presented lower labor productivity and high human capital depreciation. Such a result indicated that regions with lower health care provision tended to show a lower level of income per capita in the long run, as compared to those presenting better health condition, which contributed to enhance interregional inequality in the country. However, the relation between health and fertility rate was nonsignificant.

An extension of this paper would be to estimate the impact of health, by using measures other than the infant mortality rate, which would allow to test the robustness of such results and to capture other dimensions of the population health condition as well. Though it is an ample measure, the infant mortality rate does not act directly on the working population. Furthermore, other lines of work would lead to investigate more extended time periods and distinct econometric models that would permit to measure the impact of health condition externalities on economic growth.

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