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On the Role of Health in the Economic and Demographic Dynamics of Brazil, 1980–1995[†]

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Abstract

We conduct an integral study of the effects of health on the economic and demographic dynamics of Brazil. Using probability of survival by age and gender groups as health indicator, we find a complex mosaic for the interaction of health with each of the principal aspects of the transition – namely income, net fertility, education, and female economic participation. The strongest effects of health on income occur through increased education, followed by increased productivity and finally by increased female participation. We also find that health slows the decrease of net fertility, except for high income groups, engendering a developmental vicious circle.

JEL Classification

I10, O11, O47, O54

Key words

Brazil, health, development, economic growth, demographic transition.

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Introduction

How much and by what channels does health affect development dynamics? This is an important policy issue presently under discussion at the Pan American and World Health Organizations (1999a), which may result in a reevaluation of the priorities guiding resource allocation for health. For example, investing in the health of the poor may provide a policy tool to alleviate persistent poverty. Amongst the first studies on the relation between health and development is the Nobel prize winning series of works by Fogel (1991, 1994[a], 1994[b]), who states that about a third of the economic growth in England over the last 200 years is due to improvements in nutrition and health. More recent macroeconomic studies on economic growth have also shown the importance of health. Barro (1996) finds that life expectancy has a significant positive coefficient in growth regressions. Knowles and Owen (1995, 1997) include health capital in Mankiw, Romer and Weil's (1992) augmented Solow economic growth model, obtaining more significant results than for education. Jamison and Wang (1998) also find that survival rates contribute to growth more than education, but less than decreases in fertility. Gallup and Sachs (1998) find that regions more prone to malaria grow less. Conducting a Levine-Renelt test of the impact of health on economic growth in Latin America, Mora and Barona (1999) find that years lost to premature death is on occasion one of the few robust predictors of economic growth. In studies combining the methodology of estimating economic growth and Granger causality, Mayer (1999a, 1999b) finds evidence of strong causal links from adult health to economic growth over 25 to 30 year horizons for Mexico and Latin America.

The links which have been detected between health and economic growth at the macroeconomic level need to be investigated in more detail at the microeconomic level, to determine what the channels of interaction between health and income are. The first obvious and important question that has been asked is to what extent health has an impact on productivity. Recent microeconomic research studies the role of health as human capital investment, applying integrated models of returns which include education, nutrition, health, and migration to identify the independent impact of each on wages. As part of the identification strategy, the models consider the inputs and policies that most effectively lead to the accumulation of each factor (Schultz, 1992, 1997; Thomas and Strauss, 1997; Strauss and Thomas, 1998, amongst many others). Some of these studies find that investments in health are positively but maybe somewhat weakly reflected in wages (Knaul, 1999; Murrugarra and Valdivia, 1999; Parker, 1999; Ribero and Nuñez, 1999, a set of recent interrelated studies carried out by the IDB).

However, in addition to its direct impact on productivity, health has other effects on both economic development and the demographic transition. Good infant health and nutrition directly increase the benefits of education (World Bank, 1993; World Health Organization, 1999b). In addition, Barro (1996), for example, theorizes that, by increasing longevity, health reduces the depreciation rate of human capital, making investments in education more attractive. More generally, the burden of disease curtails the generation of income itself, rather than productivity (ibid.), for example through removing obstacles to female participation. Ehrlich and Lui (1991) examine the impact of longevity on economic growth through intergenerational economic exchange. Theoretical considerations support the idea that expectation of a longer and healthier life may affect the intertemporal discount rate and therefore saving (Mayer, 1999c). Finally, each of the mechanisms affected by health may have an impact on income distribution dynamics, which may itself affect income growth (Birdsall and Londoño, 1997).

These possible interactions point out that health may affect income through a variety of pathways in addition to direct productivity increases. From the point of view of policy, what needs to be known is what effects present changes in health have on future levels of various economic (including educational) and demographic indicators. The integral study of the effects of health on development, however, encounters difficulties from the point of view of the data. Health indicators have been systematically included in economic surveys only exceptionally or recently. In this article, we take an empirical point of view and examine directly the impact of health on future levels of the main variables of the economic and demographic transition in Brazil. We use health data mainly obtained from death certificates including mortality by causes and by age and gender groups, for the states of Brazil in five-year periods between 1980 and 1995. This data has been worked into life expectancy by ages. We found it much better to use the probability of survival into the next age group, a concept that in itself is an excellent health indicator, with which obtained excellent results. Unfortunately this data is not available in combination with economic and demographic information. However, a good source for the later exists in the PNAD household surveys. We construct a database holding economic and demographic information for each Brazilian State by deciles, and examine the impact on the rates of change of these indicators that the state level health indicators have, taken as contextual variables. The increased number of observations implied by structuring the information by deciles allows us to conduct macroeconomic-like estimations in which these techniques work well. Complementarily, the availability of health indicators by causes and by age and gender groups allows us to systematically compare the results and thus raise their level of confidence.

Our results give further evidence of the complex array of interactions which exists between health and the dynamics of each of the main indicators of the socioeconomic transition in Brazil, namely income, education, net fertility (defined herein as the percentage of the population under one year of age), female participation, employment and wages. These effects are significantly different for different income levels. Our estimates allow us, in particular, to set the results on the impact of health on productivity in context, with important implications. We find that the strongest effects of health on income occur through increased education, followed by productivity and finally by female participation. This implies strongly that policy decisions related to the role of health in generating income must carefully assess the full array of contributions of health to income, especially since related studies (Mayer 1999a, 1999b) show that income increments take time –30 years or even longer– to come fully into effect. We also find that health slows the decrease of net fertility, except for the high-income groups, confirming in our data set a well-known vicious circle in the process of development.

The rest of the paper is organized as follows. In section 2 we describe our data. In section 3 we set out our econometric method. In section 4 we describe and analyze the results and in section 5 we give our conclusions.

The Database

We consolidated the information from the eight PNAD surveys (1977 to 1995), summarizing them at 10 income levels (that is, by deciles) for each Brazilian state.[1] Along with other types of data, these surveys include information on the size and composition of households, on schooling and school attendance, on the economic participation and employment of men and women, on household income, and on the percentage of urban population. The advantages of this portion of the database include the fact that all of the information is tied to income distribution, and that the number of condensed observations (24 states $\times$ 10 deciles $\times$ 4 time periods) is relatively large for a macroeconomic-style study.

The health data obtained from death certificates include mortality and years lost to premature death classified by cause and by age and gender groups, and life expectancy for five-year periods between 1980 and 1995. All this data is included for each state in Brazil.[2]

In order to harmonize the two sources of information, it was necessary to extrapolate the years 1980 (based on 1979 and 1981) and 1985 (based on 1983 and 1986) from the PNAD.

From a descriptive standpoint, the indicators reveal a major economic and demographic transition. Low-income households have more children, a less economically active population (especially in the case of women), greater unemployment, and less education. They are also less urban. These differences decline considerably over time, although inequality in income distribution does not.

Used in conjunction, the databases allow us to examine how the contextual variables of health by age and gender groups correlate with the growth or decline in income, net fertility, education, and the economic participation of each decile of the population.

Econometric Estimation

In order to examine the role of health in Brazil's economic and demographic transition, we estimate a series of growth regressions, similar to those used by Barro (1996), for several important indicators. This means that we examine how health and certain other economic indicators intervene in the explanation of changes, that is, in the dynamics, of the principal indicators of Brazil's economic development and demographic transition. In other words, the *variables to explain* (left-hand side) are the *growth rates of:*

- *Per capita* income.
- Percentage of the population under one year of age (which we refer to as net fertility).
- Schooling and the percentage of children aged 7, 10, and 15 who attend school.
- Economic participation, unemployment, and wages for men and women.

These variables describe the major aspects of the economic and demographic transition. As *explanatory variables*, we use (right-hand side, logarithms):

[1] This work was carried out by Dr. Suzanne Duryeau at the IDB.

[2] This work was carried out by Dr. María Helena Prado de Mello Jorge, Department of Epidemiology, University of São Paulo, Brazil.

1) *Economic and demographic variables* (logarithms):

- The initial level of the variable whose growth rate is being studied.
- *Per capita* household income and its square (to obtain a flexible functional form).
- Schooling of the household head and its square (similarly).
- Average schooling in the household.
- Male and female economically active population.
- Percentage of urban population.
- Population growth rate.
- Percentage of the population under 1 or 6 years of age.

These variables include the main indicators that describe (in averages) the economic situation of the households for each decile in each state. They are: income, schooling of the household head, average schooling of the household as a whole, economic participation, the percentage of urban population, and the percentage of newborns and young children in the household. The population growth rate is included to take into account the distributive effects implicit in using *per capita* indicators from the left-hand side. However, it was not very significant, since population growth is taken into account by the percentage of the population under 1 year of age. The initial level of the variable to explain makes it possible to take into account convergence-type effects, in which the growth rate of a variable depends on its initial level. The squares of income and schooling of the household head are included as explanatory variables to give the estimator, which simultaneously adjusts to the behavior of households with different levels of income, functional flexibility.

2) *Health variables* for ages 0, 1, 5, 10,..., 70, or 75 and for men and women (logarithms):

- Life expectancy.
- Probability of survival to next age group, p_t^{t+a}.
- Maternal mortality, mortality from communicable diseases and from noncommunicable diseases.

Of these, we used mainly the probability of survival. The other variables were used mostly for comparative purposes. The probability of survival, a concept that in itself is an excellent health indicator, was defined in a manner consistent with the mathematical concept of life expectancy. That is, in time t, the probability p_t^{t+a} of surviving a years satisfies the following equation:

$$(1) \qquad EV_t = p_t^{t+a} EV_{t+a} + \frac{1}{2}(1 - p_t^{t+a})a \,,$$

where EV_t is life expectancy at age t (if the subject does not survive, a life expectancy of half the period is assumed). Excellent results were obtained with this indicator.

Finally, we state the system of equations that describes the estimation carried out for each dependent variable. Since information on health is not available by deciles, we estimated panel-type growth equations such as the following:

(2) $$\frac{y_{sd\,(t+5)} - y_{sdt}}{5} = \boldsymbol{a} y_{sdt} + \sum_i \hat{a}_i X^{\,i}_{sdt} + \boldsymbol{g}_d S_{st} + c_d\, \boldsymbol{c}_d + \boldsymbol{q}_{85} \boldsymbol{c}_{85} + \boldsymbol{q}_{90} \boldsymbol{c}_{90} + \boldsymbol{e}_{sdt}\,.$$

In this equation, states, deciles, and years are represented by the indices $1 \le s \le 24$, $1 \le d \le 10$, and t = 1980, 1985, and 1990, respectively. Each of the variables to explain takes the place of y. The independent economic and demographic variables are X^i. The health variable is S. The right-hand side also includes *dummy variables* by decile $\boldsymbol{c}_d$, and by date $\boldsymbol{c}_{85}$, $\boldsymbol{c}_{90}$, in order to control for the respective fixed effects. One time period is lost to obtain a growth rate on the left-hand side. In effect, $y_{sd(t+5)}$ is estimated in terms of variables at time t, much reducing the problems of simultaneity. The estimates include 24 Brazilian states.

The interpretation of results must take into account the fact that the health indicators are *state level* indicators. These differ from the remaining data, which refer to both *states* and to *income levels*. Thus, the regressions answer the following question:

What is the correlation between the *state* health indicators S (for a certain age and gender group) and the growth rate of the economic indicator *y of each income decile*, once the variables X^i and the initial level of y have been taken into account?

The health indicators thus play the role of contextual variables, necessitating correction for a possible covariance structure in the errors (see for example Rice and Jones, 1997). Thus we estimate the regressions by generalized least squares, correcting for heteroskedasticity and correlation in the errors between deciles and states.[3]

We estimate these regressions by sets in which the health indicator covers the population's classification by age and gender. For each regression, a coefficient $\boldsymbol{g}_d$ is obtained for each income decile d, which estimates the correlation for each decile between the state health indicator and the growth rate of the variable to be explained. We examine these coefficients in three dimensional graphs in order to observe, for each gender, the pattern they follow with respect to age group and income decile (Graphs 1 to 4). In these graphs non-significant coefficients are set at zero so as to also observe significance.

In order to complete our analysis, in a different estimate we also included the following as a variable to be explained: *improvements in the probability of survival for men and women*. In this case, we use the equation

(3) $$\frac{S_{s(t+5)} - S_{st}}{5} e_d = \boldsymbol{a} S_{st} e_d + \sum_i \hat{a}_i X^{\,i}_{sdt} + c + \boldsymbol{q}_{85} \boldsymbol{c}_{85} + \boldsymbol{q}_{90} \boldsymbol{c}_{90} + \boldsymbol{e}_{sdt}\,,$$

where e_d =1. Here, the relationship between the change in the health variable and the economic and demographic explanatory variables by deciles is estimated uniformly for the different income levels, but with the functional flexibility provided by the squares of income and education.

Analysis and Results

A very considerable number of the health indicator coefficients were significant in many of the regressions. In certain cases, the graphs of these coefficients of correlation between health indicators

[3] The size of our sample allows the use of this more general method, rather than more efficient but restricted methods developed specifically for contextual variables.

and the growth rates of the main variables of the economic and demographic transition show a high degree of regularity and consistency. These allow us to draw a series of conclusions. In other cases the graphs show diverse behaviors that raise more questions than they answer. Although we discuss the overall results, here we will only show the numerical results of some of the groups of regressions. These correspond to cases in which the dependent variables are the growth rates of income, female economic participation, the percentage of the population under 1 year of age, and schooling. In general, the female health indicators yield higher and more significant coefficients than their male counterparts. Accordingly, here we will show only the graphs of the coefficients obtained by female health indicators for this set of variables. Table 1 contains a summary of the coefficients obtained for the economic and demographic explanatory variables in the regression sets mentioned above, while Graphs 1 through 4 show the coefficients for the health variables. All of the coefficients are comparable, since they represent elasticities.[4]

Relationship between Health and Growth of Per Capita Income

We begin, for purposes of comparison, by using two indicators of health, life expectancy and the probability of survival, to study the growth of income *per capita*. With the second indicator, p_t^{t+a} (see Graph 1), we obtain much more precise results, since it correctly separates the effects by age group, while life expectancy at age t is a weighted composite of health for age groups t and thereafter. Thus for the remainder of this study probability of survival was used rather than life expectancy.

Graph 1 shows that the probability of survival for females aged 5 to 45 is positively correlated with income growth, except for the sectors of the population with very high or very low income levels. In these cases the correlation is negative. In the case of high income, there appears to be a wealth effect on health in which women stop working and become involved in some other activity. The main such activity may be motherhood, when women choose to remain at home. This hypothesis is strengthened by the results obtained when we take as the variable to be explained the growth rate of the economic participation of women, especially young women (Graph 4). In upper income levels, health correlates negatively with future female participation. This effect is also corroborated when unemployment is used instead of participation. We will deal with the results for the lower income deciles in the section on participation and employment.[5]

We consider it important to estimate the order of magnitude of the positive correlations between health and the growth of income and economic participation. For this, we used as a reference the average increases that occurred in the probability of survival p_t^{t+a} for women between 1985 and 1995. These estimates were hindered by the fact that in this period there was a decline in the health indicators for some age groups. Therefore, we estimated only the ranges in which the coefficients were observed. The maximum range for the *direct* effect on income of the average 1980 to 1995 health increase is 0.19% per year. The average of the maximum range of the effect on female participation of p_t^{t+a} for women aged 15 to 35 is 0.39% per year. Since

[4] The elasticity of a dependent variable y with respect to an independent variable x is $\partial \log(y)/\partial \log(x)$. This represents the percentage change in y when x changes by 1%.

[5] To ensure that the negative health coefficients found for deciles 1 and 10 in the equation for income growth are not due to the limited (quadratic) non-linearity allowed for household income in equation (2), we re-estimated the equation adding a separate income variable for deciles 1 and 10, thus allowing unlimited non-linearity for income effects at these levels. The resulting health coefficients were very similar, preserving all signs. If anything, the negative coefficients were slightly reduced in magnitude and the positive were slightly larger and smoother.

female participation is about 50% of male participation, and male participation is practically 100%, this increase in participation translates into an income growth of about 0.13% annually.

Regarding these magnitude estimates, it should be mentioned that long-term studies on the effect of health on income for Mexico and Latin America (Mayer, 1999a, 1999b) find that permanent health increments lead to permanent income increments which come into full effect over a prolonged time period of 30 years or even longer. In any case, the effects of health on income that can be measured over a five-year period in all likelihood represent only a part of the full effects that may be expected to occur over time. The above-mentioned Latin American study also uses probability of survival as a health indicator, obtaining a very similar coefficient pattern (a spike peaking at young age groups) to the one found here for the middle 80% of the population (Graph 1). In that study, however, once the actual long-term increments in survival probability are taken into account, it is found that adult and old-age health improvements, which are greater, have had the largest effects on income.

As for the other explanatory variables for income growth, the results are consistent with economic theory and appear in the first column of Table 1. There is income convergence, which is somewhat greater for low incomes than for high incomes. The schooling of the household head contributes positively to growth, while schooling involving young people correlates negatively in that it represents an investment (in regressions not reported here). The appropriate indicator would be an intermediate one. The percentage of the urban population contributes positively to growth. The percentage of the population less than one year of age contributes negatively, as is consistent with the impact on *per capita* income arising from a higher population. On the other hand, a larger percentage of children under age six contributes positively, possibly indicating that households with young children seek higher incomes.

Relationship between Health and net Fertility

In order to study the interaction between health and changes in net fertility, we take as the dependent variable the growth rate in the percentage of children under one year in the household, a PNAD indicator found by income levels.

The results show that health has a considerable impact on the demographic transition. Improvements in health are associated with *higher* rates of net fertility in deciles 1 to 8, and *lower* rates in deciles 9 and 10 (Graph 2). The difference among the coefficients is significant at the 0.0001 confidence level, according to a Wald test.

Average increases in the probability of female survival during the period 1985–1995 correlate with an increase of approximately 1% per year in the percentage of children under age one, for low income levels, and with a reduction on the same order in the upper income levels. As before, these effects may well be greater over longer periods of time.

Concerning the other explanatory variables (Table 1, second column), the results indicate that for the lower deciles an increase in income correlates with an increase in net fertility, while in decile 10 the relationship is the reverse. This change in sign has been widely observed and has been modeled in economic theory (see, for example, Becker et al., 1990, Dahan and Tsiddon, 1998). Schooling of the household head contributes positively to net fertility in all deciles, increasingly with wealth. However, average schooling contributes negatively, i.e. in the new generations education reduces net fertility. In addition, there is a declining trend in net fertility over time.

Relationship between Health and Education

In order to study the interaction between health and changes in education we estimated regressions for the growth rates of schooling and of school attendance at ages 7, 10, and 15.

In the case of schooling (Graph 3), as well as attendance, the results show effects of mixed signs. The following are some of our hypotheses concerning these results. Health, both for children (who study) and adults (who support them so they can attend school), has a positive impact on education indicators. However, with regard to negative effects, on observing the corresponding regions in the graphs on economic participation, it appears that healthier children may join the work force. This effect may also be correlated with higher net fertility and female unemployment. Thus it may be that a greater burden of young children in the home (correlated by higher health) reduces the level of schooling of older children. Other explanations could be that there are conflicts in the allocation of public resources between health and education or that there is some association with phenomena of adolescence, including drug addiction, in which healthier adolescents more frequently drop out of school. Using the variable of violent deaths in men between the ages of 10 and 20 as a proxy for some juvenile problems, we obtain a decrease in the magnitude of the coefficients in the negative area, but not their disappearance. This study cannot distinguish between these and other hypotheses. What the magnitude and confidence levels of the coefficients do show is that the relationship between health and education is complex.[6]

Again, using the increase in health from 1980–1995 as a reference, we estimate the magnitude of health's contribution to schooling, when this is positive. The maximum range is 0.29%. An estimate of the returns of years of schooling for the household head yields a coefficient of 0.90.[7] This implies, if the returns remain constant, that the contribution of health to economic growth through education has a maximum range of about 0.35% annually. As before, these effects may be greater over the longer term.

Concerning the other variables, in the case of schooling (Table 1, third column), income levels lead to convergence, while schooling of the household head leads to divergence. Both processes are more intense at lower income levels. The percentage of children aged 1 to 6 leads to growth in schooling as expected. As for school attendance at 7, 10, and 15 years of age, the results yield a mosaic that is difficult to interpret. Some of the complexity may be due to stratification of the educational phenomena, for example urban-rural or through the schooling of household heads. There is a positive correlation between female economic participation and increases in school attendance. The percentage of urban population has a positive effect on school attendance. Furthermore, there is a convergence effect on the initial level of each education variable analyzed.

Relationship between Health and Economic Participation, Unemployment, and Wages

The correlation between increases in health and female economic participation was mentioned in the section on income. In the case of males, there are increases in

[6] The negative effect found for the health of certain age and gender groups on schooling could be related to the negative partial correlation found between schooling and income growth in Latin America by several other authors, for example Barro (1996), who also offers no explanation for this unexpected sign.

[7] We control for participation and male and female employment, the population under age 1 and 6 and temporal fixed effects. We use generalized least squares and correct for heteroskedasticity and correlation in the errors between deciles and states.

participation and decreases in unemployment.[8] These are especially sharp in the lowest decile and for the health indicators of young men and women. For corresponding regions of the graphs, we find that a higher participation decreases wages in a market effect with a very high implicit elasticity of approximately −6. These factors help to explain the reduction in income found for the poorest decile when health indicators rise (Graph 1). Increases in health increase participation and employment in this decile (which is the one most vulnerable to unemployment, as can be observed in the database) and the increased supply leads to a reduction in real wages and income.

With regard to the other explanatory variables (Table 1, fourth column), the results are consistent. Income correlates positively with an increase in male participation and negatively with female participation, as is consistent with increased net fertility. Schooling of the household head correlates with an increase in female participation and the wages of both genders. This decreases a little with income. The percentage of the urban population reduces participation and increases unemployment and wages. The percentage of the population less than one year increases female unemployment. The percentage of the population under six increases male participation and the wages of both genders. Furthermore, there is convergence on the initial levels of each variable analyzed.

Relationship between Health, Epidemiology, and Income Distribution

When we examine the correlation of income growth with the health variables maternal mortality, mortality from communicable diseases, and mortality from noncommunicable diseases, we find a surprisingly similar pattern. The correlation between increases in health (reduced mortality) and changes in income is positive for a broad segment of the intermediate deciles, following an inverted U shape as in Graph 1. However, it is negative for the very high or very low deciles. We have shown that in the high deciles, lower female participation reduces income, while in the lower deciles it is higher participation and employment that reduces wages and income. Our previous explanations have assumed that state health indicators correlate with the health of every decile in every state, and have been based mainly on the resulting sign (and thus not on the strength of the correlation). In fact, this assumption is confirmed by the existence of significant, differentiated, and consistent results for each decile. However, because the indicators are by state rather than by decile, the intensity of the correlation of the state indicator with the health of each decile may be different. The inverted U shape of the correlation between health indicators and economic growth is evidence of such differences and is consistent with other work indicating that demographic segmentation of the health systems reinforces the existing inequities (Londoño and Frenk, 1997, González Block et al., 1997, Frenk, 1994). This implies the following: from its maximum on, which lies between deciles 4 and 6, state increases in health foster income convergence. For the lower deciles, in contrast, income divergence is fostered, i.e. less growth or even marginalization. The lower deciles receive fewer benefits from the health systems and must compete with deciles receiving better benefits. Additional evidence that health-related phenomena lead income to divergence is that when health indicators are included in the regressions, the coefficients indicating convergence become more significant.

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[8] The distinction between employment and participation is somewhat blurred in the results, probably because when taking surveys the questions and answers can be ambiguous on this point or understood differently by different population sectors.

Summarizing, we find evidence that increases in the state health indicators represent increases in health that are unevenly distributed among the population. Below decile 4, this inequality leads to divergence in income growth, while above decile 6 it leads to convergence. In contrast, we find little difference in the pattern of income change due to different epidemiologies such as mortality from causes linked with maternity, communicable diseases, and noncommunicable diseases.[9]

Relationship between Income and Improvements in the Probability of Survival, p_t^{t+a}

The results of these regressions show a pattern in which health is increasingly sensitive to income with increasing age, especially for the older age groups, for men and, slightly, for the lower income deciles.

Conclusions

Our results highlight the complex mosaic of interaction that exists between health processes and the economic and demographic transition of Brazil. The use of the probability of survival by age and gender groups as a contextual health indicator yields excellent results. Our set of estimates shows a high degree of consistency. The levels of health are found to affect future levels of each of the principal aspects of the transition – namely income, net fertility, education, and female economic participation. The later is in itself important for economic development (Galor and Weyl, 1993), as are the effects of the demographic transition on economic growth (e.g. Bloom and Williamson, 1998). The signs of the coefficients of other variables such as income, education, proportion of urban population and proportion of the population younger than one or six years of age are the expected signs in almost every case, strengthening the confidence of our results.

According to our estimates, health increases income growth through three main channels: increases in educational levels, direct productivity effects, and increases in female participation. As may be expected these phenomena are intimately related with the household's productivity. In making comparison to other studies in other contexts, it must be taken into account that the period examined (1980-1995) is characterized by low or negative economic growth, which could mean that the economic potential of health might not have been fully realized in this period. There are even some decreases in health status occurring for some age and gender groups. This makes it difficult to measure the magnitude of the economic impact of health. The upper levels observed for the effects of improvements in health for the period are 0.35, 0.19 and 0.13 percentage points annually for the income growth rates due to increases in educational levels, direct productivity effects, and increases in female participation respectively, adding up to 0.67% annually. These magnitudes approximately coincide with those obtained by the IDB studies mentioned in the introduction, which are also based on recent data corresponding to a low growth period, and which are also mostly framed in the short term. In long-term studies on Mexico and Latin America (Mayer, 1999a, 1999b), permanent health increments are found to lead to permanent income increments which come into full effect over a prolonged time period of

[9] This finding in the relationship between causes of mortality and rates of income growth does not imply that the effect by income group of such causes of mortality is of similar level.

30 years or even longer. In these studies, only about 0.66% of the effects of health on income has occurred after 5 years. Accordingly, the full long-term income effects of health improvements in Brazil could lead to income increments of approximately 1% annually. This is the approximate magnitude for the contribution of health to income found in the study on Latin America mentioned above. The study on Mexico finds even larger productive effects, possibly because it covers a period with higher economic growth.

Health also affects the distribution of income. In principle increases in health can reduce inequality, since their effects are greater when the deficiency is greater. For example, higher health leads to increases in male and female participation especially in the low and middle-income sectors. However, the evidence shows that the distribution of health improvements is inequitable, and in fact leads to divergence in incomes among the lowest 40% of the population. In addition, the lowest 10%, who are most vulnerable to unemployment, see their income reduced due to increases in their economic participation that reduce their wages. No really strong differences were detected in the patterns of the effects on income growth levels of mortality from causes related to maternity, communicable diseases, or non-communicable diseases.

Health diminishes the decline of net fertility at all income levels except for the highest, where it reduces net fertility – a phenomenon consistent with the economic theory of endogenous fertility pioneered by Becker. The 2% magnitude of these differences in net fertility between upper and lower deciles may be even larger over the long term. However, education reduces net fertility in the new generations, and net fertility shows a tendency to decline over time.

In a possible connection with maternity, the economic participation of women in decile 10 decreases with increased health, reducing income through what cannot necessarily be viewed as a negative effect since it is a result of the household's choice.

The Brazilian database that we have studied has enough indicators of the necessary quality to bring out some of the complex interactions of health with the economic and demographic transition, which include considerable effects on income. These effects are intimately related to the role of health in household productivity. For this study we have availed ourselves of health variables as contextual indicators. Deeper studies delving into some of the issues and magnitudes arising here may depend on using household surveys jointly collecting economic and health data. However, for some time to come, only exceptionally will these surveys span a long enough time period to account for the effects of health on income.

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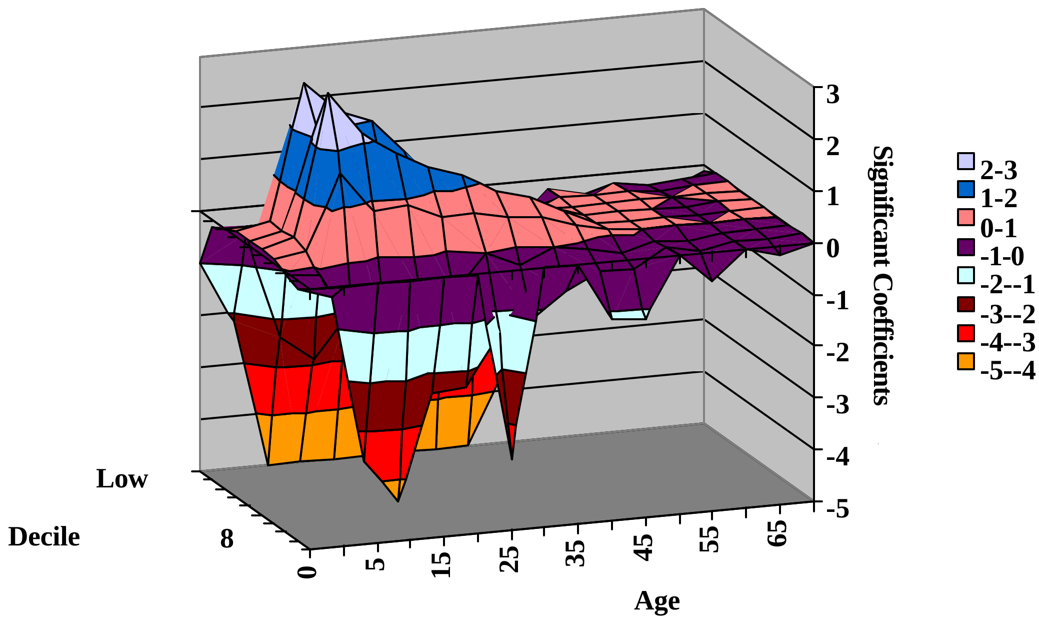
Table 1
Average Coefficients in Main Groups of Regressions
Health Variable: Probability of Survival
(GLS, CSW, White)
(711 observations in the periods 1980, 1985, 1990)

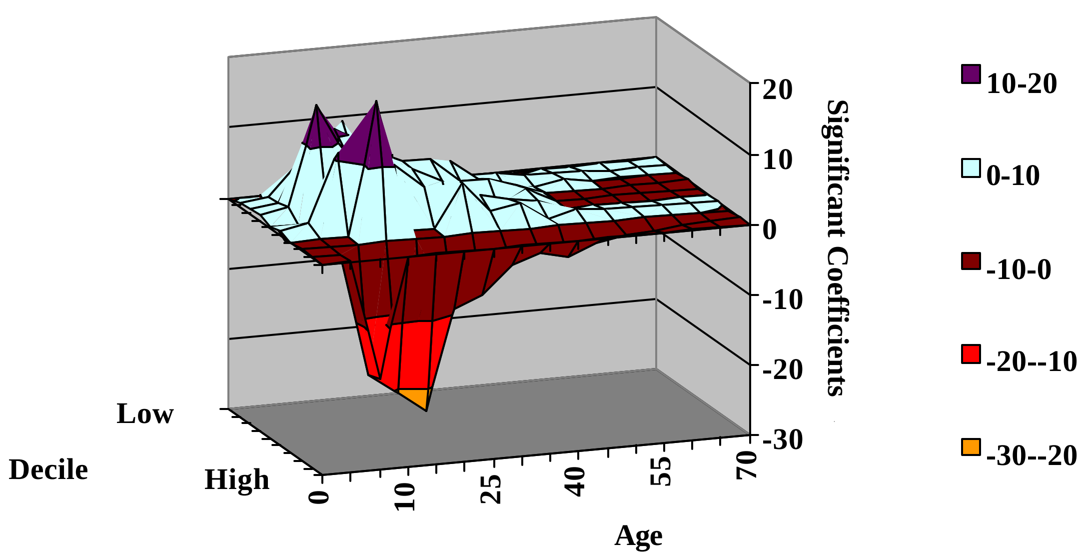
Dependent Variable	**Income Growth**	**Growth of % of Pop. under 1 Year of Age (Net Fertility)**	**Growth of Schooling**	**Growth of Female Economic Participation**
Number of regressions	32	32	32	17
Health indicators	Both genders	Both genders	Both genders	Female
Average of decile fixed Effects	**1.532** **(16.06)**	**-0.575** **(-9.82)**	**0.289** **(2.72)**	**0.33** **(3.36)**
Income	**-0.4544** **(-14.48)**	**0.096** **(3.04)**	-0.0455 (-0.06)	**-0.1377** **(-4.75)**
Income squared	**0.0263** **(8.3)**	**-0.0188** **(-4.41)**	0.00122	**0.00924** **(4.75)**
Schooling of the household head	0.0065 (0.5)	0.0115 (1.23)	**0.0852** **(5.76)**	**0.0266** **(3.36)**
Schooling of the household head, squared	-0.0012	**0.0199** **(6.35)**	-0.0095 (-1.5)	-0.0061 (-1.27)
Average schooling	-	**-0.0237** (-1.15)	**-0.1767** **(-31.74)**	-
Economically active Female population	-0.0002	0.0075 (0.21)	**0.0114** **(4.57)**	**-0.1129** **(-28.96)**
Economically active male population	0.0101 (0.38)	-0.0674 (-1.62)	**-0.0794** **(-3.67)**	0.0016
Percentage urban population	0.0023 (0.61)	-0.0022 (-0.01)	0.004	**-0.0214** **(-6.83)**
Population growth	-7.15E-09	4.17E-08 (0.6)	**-9.12E-08** **(-6.48)**	**-8.27E-08** **(-5.25)**
Percentage of population under 1 year of age	**-0.0018** **(-3.96)**	**-0.1894** **(-26.23)**	**0.0055** **(2.82)**	0.0034 (0.88)
Percentage of population under 6 years of age	0.0003	**0.082** **(7.97)**	**-0.0213** **(-6.57)**	-0.0072 (-0.78)
Dummy 85	**-0.0277** **(-9.87)**	**-0.0406** **(-8.87)**	**0.0306** **(16.46)**	**0.0255** **(16.61)**
Dummy 90	**-0.052** **(-71.78)**	**-0.0509** **(-12.66)**	**0.0203** **(15.23)**	**0.0248** **(21.28)**
R^2 (minimum) (maximum)	0.960 0.988	0.605 0.731	0.885 0.929	0.706 0.803
Adjusted R^2 (min) (maximum)	0.958 0.988	0.586 0.718	0.88 0.926	0.692 0.794
Durbin-Watson (min) (maximum)	1.935 2.386	2.189 2.285	1.965 2.055	2.156 2.251
F statistic (minimum) (maximum)	528.01 1823.91	32 57	163.06 277.97	52.54 89.33

Minimum *t* statistic in parentheses, if the signs coincide in all regressions.

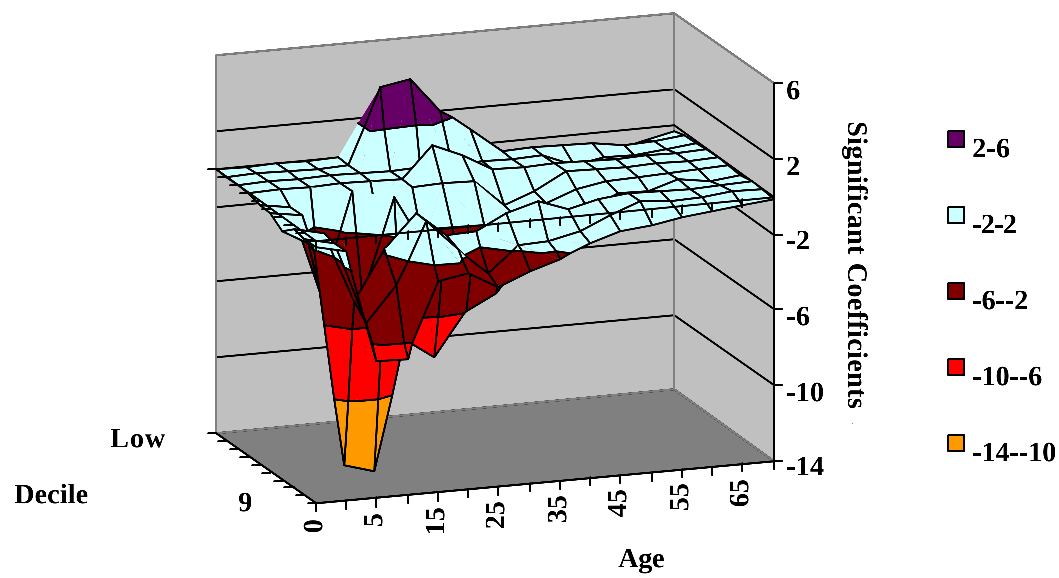
Income Growth Rate
(GLS, CSW, White)
Graph 1
Significant Coefficients (2.5%) of the Probability of Survival for Women



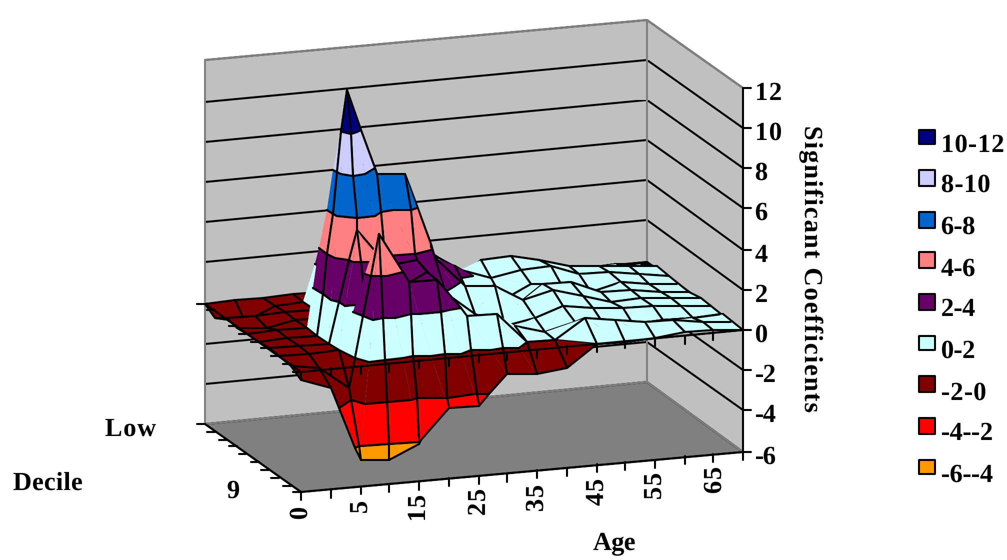
Growth Rate of the Percentage of the Population under 1 Year of Age (Net Fertility)
(GLS, CSW, White)
Graph 2
Significant Coefficients (2.5%) of the Probability of Survival for Women



Growth Rate of Schooling
(GLS, CSW, White)
Graph 3
Significant Coefficients (2.5%) of the Probability of Survival for Women



Growth Rate of Female Economic Participation
(GLS, CSW, White)
Graph 4
Significant Coefficients (2.5%) of the Probability of Survival for Women



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