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Health, Growth and Income Distribution in Latin America and the Caribbean:

A Study of Determinants and Regional and Local Behavior

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The Regional Research Competitions are calls of a regional nature for presenting research proposals on themes relevant to the public health of the Latin American and Caribbean countries. The competitions take place on an annual basis, with the researchers applying in accordance with specific terms of reference and requirements particular to every individual competition.

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Introduction

David Mayer
Humberto Mora
Rodolfo Cermeño

In recent years, the countries of Latin America and the Caribbean have undergone a process of economic rationalization in an attempt to achieve high levels of sustainable growth. Under these circumstances, important long-term policy decisions arise in the area of health investment. Although much attention is given to the problems of health-sector restructuring and efficiency, it is essential to determine how health affects economic growth, income distribution dynamics, and education. It is also necessary to establish the best health indicators and to identify possible policy proposals. The general questions we raise are the following.

- What is the importance of health in economic growth, as an input for production?
- What is the importance of the distribution of health in terms of the distribution of income and economic growth?
- To what extent is health involved in the formation of educational capital resources in the different sectors of the population?
- What is the causal relationship between economic growth and health?
- What is the importance of the quality of health indicators in measuring the effects indicated above?

To answer these questions, we use several analytical frameworks developed in the field of economics. Our research ranges from studying the most aggregate relationships between the socioeconomic and demographic variables at the country level, to more disaggregated approaches to these relationships for specific population groups in a given country. We analyze the relationship between health and economic development, as well as income distribution and the demographic transition, in five studies with complementary analytical contexts.[1]

The quality of the data is fundamental to these studies. In particular, the health indicators were prepared specifically for this project and are of very high quality. We also assembled the more detailed information required for the more disaggregate analysis of specific aspects of the relationship between economic growth and health. We constructed four databases of economic and health indicators, one by country for Latin America and the Caribbean, and the other three by states (or department) for Mexico, Brazil, and Colombia.[2] In the case of Brazil, the economic database is organized by income deciles.

In the first study, the econometric framework uses functional specifications of the economic growth equations, such as those used by Barro (1996) and others[3], which incorporate few constraints derived from economic theory. These functional specifications include health in an extensive list of other socioeconomic, demographic, and institutional variables that, in theory, may be associated with economic growth. We apply the Levine Renelt methodology (1992) to test for the robustness of these results. The second section of this paper, after this introduction, contains the results of this analysis for the four databases.

In the second study (third section), the relationship between economic growth and human capital is evaluated in an analytical framework including far more restrictive constraints in the functional specification. These correspond to the augmented Solow model as developed by Mankiw, Romer, and Weil (1992), and applied by Islam (1995). In our specification, human capital is determined not only by education, as in the model used by these authors, but by health as well. This analysis is applied to the four databases.

In the third study (fourth section) we analyze the long-term relationship between health and income for the case of Mexico, taking advantage of the length of the time period covered by the database. The analytical framework is similar to the one used by Barro (1996). However, it focuses on the causal relationship between health and income, using Granger's causality methodology to analyze the determinants of income growth and health improvement.

In the fourth study (fifth section), we study the role of health in the economic and demographic dynamics of Brazil. In this case we take the different income levels into account, exploiting this aspect of the information contained in the Brazilian database. In particular, we examine the simultaneous relationship between economic growth, health, education, participation in the workforce, and fertility for the different income groups of Brazil.

In the fifth study (sixth section), which is similar to the one carried out for Mexico, we analyze the long-term effects of health on income growth for Latin America. This study also shares characteristics with the Brazilian study, in terms of the health indicators employed. The consistency of its results with those of these other two studies strengthens the hypothesis that the phenomena observed in Mexico and Brazil occur for the other Latin American countries as well.

Conclusions and policy recommendations can be found in the last section.

Health in the Economic Growth of Latin America

Humberto Mora
Ana Beatriz Barona

This component of the study conducts an empirical analysis of the impact of health capital on economic growth in the countries of Latin America and the Caribbean. Our point of departure is the verification of Barro's results (1996) for the worldwide sample of countries. Our objectives will be addressed through three methodological approaches.

The first approach seeks to identify the existing correlation between alternative measures of health and economic growth, for which we empirically evaluate statistical models for growth similar to those formulated by Barro (1996). The measures of health used correspond to those available for a broad sample of Latin American countries. This is done so as to be able to compare the results from Barro's global sample of countries (1996) with the results obtained for Latin America.

To supplement the above, the second approach seeks to carry out an analysis of extreme limits of the type applied by Levine and Renelt (1992) in order to assess through econometric methods the strength of the results obtained from the Barro-type specifications. Specifically, an analysis was done of the strength of the correlation between the variables of health capital and economic growth.

Third, an effort was made to include in the analyses health measurements that are much more precise than those available for a broad sample of countries. These more precise measurements correspond to mortality by cause and/or years of life lost due to premature death (YLPD). To this end, the analysis described was carried out at two geographical levels. This was first done for a group of Latin American countries in order to observe the performance of the Region in general and the impact of health capital on the economic performance of these countries in particular, using the available health indicators. Traditionally, intercountry analyses have used the variables of life expectancy at birth and infant mortality as health measures; these variables represent a highly aggregate measure. The second geographical level corresponds to a significantly more limited subset of countries in the Region—specifically, Brazil, Colombia, and Mexico—where the most precise health indicators are available. In these cases, the analysis is performed by departments or states within each country.

CORRELATION BETWEEN ECONOMIC GROWTH AND HEALTH

Health is a very important element in the formation of human capital. As Barro states (1996), it is to be expected that its effect on economic growth is produced through the direct impact on human capital stock and a reduction in the rate of depreciation.

This section presents a summary of the principal results obtained from the evaluation of this relationship at the different geographical levels mentioned above, using functional specifications similar to those of Barro (1996).

When the geographical area changes, the available data changes as well, particularly the data on health. Thus, it is not always possible to compare the effect of a single measurement of health on growth among the different geographical areas. In addition, there are variables for which information cannot be obtained by department or state for a particular country.

Table 1 shows the main results of estimating growth models by three-stage least squares. As a point of departure in this research, an attempt was made to reproduce the results found by Barro (1996), as recorded in the first column of Table 1. That study, using a sample of 138 countries worldwide, found that economic growth, calculated for three periods (1965–1975, 1975–1985, 1985–1990) correlates positively with schooling for males, the terms of trade, and variables that measure the level of democracy and the rule of law in countries. Moreover, health capital, represented by the variable of life expectancy at birth, shows a positive correlation with economic growth.

The second column shows the results of reestimating that model. It can be seen that although Barro's results (1996) are not exactly reproducible, with the data used the majority of the variables included by Barro are indeed significant. However, there may be room to improve the quality of the sample and thus eliminate possible problems of bias in the estimations. Specifically, the rate of inflation did not turn out to be significant and the significance of the other variables proved to be less than Barro's model found.

The third column shows the results of estimating Barro's model for the sample of countries in Latin America and the Caribbean. It can be seen that several of the correlations found in the sample of countries worldwide persist. Nonetheless, there are several variables, such as schooling, that have traditionally been identified as being closely linked to growth but that do not turn out to be significant. The index of democracy and inflation also turn out to be insignificant.

In addition, the fourth column shows the result of considering male life expectancy, with a lag of 15 years, for the Latin American and Caribbean countries. It can be seen that the correlation of that variable with growth is quite high. The study sought to establish the lagged effect of health on growth over time. Unfortunately, information was not available for previous periods that would allow us to study this relationship to obtain more precise measurements of health. The sample of Latin American and Caribbean countries is the only sample where that analysis could be carried out, although highly aggregate health indicators were used, as shown in the corresponding column of Table 1. These results are consistent with those on causality shown in the chapter on the reciprocal impact of health and growth in Mexico (Mayer, present paper).

Table 1: Contribution to Economic Growth

Dependent Variable: Growth of *per capita* GDP Method of Estimation: Three-stage least squares							
	Coefficients and *t* Statistics (in parentheses)						
Explanatory Variable	Barro World	Reg 4 World	Reg 5 Latin America & Caribbean	Reg 13 Latin America & Caribbean	Reg 2 Brazil	Reg 4 Colombia	Reg 8 Mexico
Log (GDP)	-0.0254 (-8.193)	-0.032 (-7.778)	-0.0396 (-6.089)	-0.0434 (-6.08)	-0.043 (-7.09)	-0.032 (-4.62)	-0.076 (-7.85)
Male (secondary and higher schooling)	0.0118 (4.720)	0.0080 (2.747)				0.049 (4.99)	0.020 (5.89)
Log (life expectancy at birth)	0.0423 (3.087)	0.060 (3.285)	0.0554 (2.655)				
Log (GDP) * male schooling	-0.0062 (-3.647)	-0.0033 (-1.702)	-0.0236 (-2.344)	-0.0384 (-3.44)			
Log (fertility rate)	-0.0161 (-3.037)	-0.0130 (-1.786)					
Government consumption ratio	-0.136 (-5.230)	-0.1657 (-5.734)	-0.0817 (-1.766)				
Rule-of-law index	0.0293 (5.425)	0.038 (5.520)	0.0459 (4.733)	0.04169 (4.67)			
Terms-of-trade change	0.137 (4.566)	0.2182 (4.062)	0.2415 (4.480)	0.1291 (2.26)			
Democracy index	0.090 (3.333)	0.0487 (1.702)					
Democracy index squared	-0.088 (-3.666)	-0.047 (-1.872)					
Inflation rate	-0.043 (-5.375)	-0.0427 (-1.220)					
Life expectancy 15-year lag (men)				0.0606 (3.40)			
Percentage of population with sewerage connection					0.028 (2.113)		
Years lost to premature death (male population)						-0.365 (-2.65)	
Years lost to premature death (total)					-0.289 (-3.44)		
Mortality from communicable disease (men)							-0.0123 (-5.43)
Participation of tertiary sector							0.042 (5.61)
Adjusted R^2 (Per. 1)	0.58	0.3795	0.1138	0.2418			
Adjusted R^2 (Per. 2)	0.52	0.3883	0.3793	0.3110			
Adjusted R^2 (Per. 3)	0.42	0.1562	0.2793	0.0934			

As already mentioned, the most precise indicators of health are those available for the departments or states of a subgroup of Latin American countries, i.e., Brazil, Colombia, and Mexico. Unfortunately, the price of having greater precision in the measurement of health is not having information on other variables identified as being associated with growth at the country level. This is the main reason why several of the variables included in the growth equation for the sample of countries worldwide, or for Latin America and the Caribbean, are not included in the results appearing in columns five through seven of Table 1.

In the case of Brazil and Colombia, information could be obtained on YLPD by cause of death. It can be seen that this variable, as well as the variable of schooling, are closely linked with growth. In the case of Mexico, information could only be obtained on mortality by cause; this is also highly correlated with growth, as shown in the last column of Table 1. The extended report shows the correlation between economic growth and other health variables, by age groups and causes of death or causes of YLPD.

The results above indicate that, regardless of the sample of countries used, both health and education are variables closely linked with the growth of national or local economies, at least in the functional specifications of Barro-type models (1996). Policies aimed at achieving greater economic growth must necessarily affect the channels that influence the formation of greater human capital through health and education.

Analysis of Extremes

The analyses of extreme limits developed by Levine and Renelt (1992) evaluates the validity of the empirical results obtained from a given specification of the growth equation, when the conditional set of data in that equation is modified.

Levine and Renelt applied this analysis in order to evaluate the soundness of a large number of results obtained in various studies on the significance of the correlation between economic growth and different groups of explanatory variables. Many of those results showed a very close correlation between economic growth and a subgroup of explanatory variables selected in each study. However, when all the remaining variables that were predetermined in the equation were modified, the apparent soundness of the results broke down.

In order to carry out the analysis, Levine and Renelt begin by identifying a set of variables that are always or almost always included as explanatory variables in the different analyses and generally show high statistical significance in the analyses. In Equation (1) these variables are included in Matrix I and correspond to the initial level of *per capita* GDP, to the rate of schooling, to the average annual level of population growth,[4] and to the intercept.

(1) $$Y = Ib_I + b_M M + Zb_Z + u$$

The other variables that enter equation (1) are the M variable, whose soundness is being tested, and the Z variables, corresponding to the remaining explanatory variables included in the economic growth regression. Levine and Renelt include three type-Z variables in each regression, taken from all the possible combinations of three variables. Thus, the full number of variables in each regression adds up to seven.

This methodology was applied to confirm the soundness of each and every one of the explanatory variables that proved to be significant in the analyses for the global sample of countries; for Latin America and the Caribbean, and for Brazil, Colombia, and Mexico (see Table 1). Table 2 shows a summary of the results of the analysis of extremes.

Once the results were obtained for all the regressions for each M variable, the specification with the highest coefficient for the variable M was identified, with its respective *t* statistic. Table 2 records the *t* statistic for that specification that yielded the highest coefficient value and is denoted as the upper limit. Similarly, Table 2 records the *t* statistic for the specification that yielded the lowest coefficient value and is denoted as the lower limit. Finally, for each M variable, the *t* statistic is reported in the case of the base regression. The base regression includes no Z variable, but only the M variable and the I variables as indicated above.

It is said that a variable is solid in the growth equation if its statistical significance is high at the upper and lower limit, as well as in the base regression, and also if the sign of its coefficient does not change.

It can be seen that for the worldwide sample, only the democracy index passes the extreme limits test. The rate of inflation is highly significant at the upper and lower limit, as well as in the base regression. However, the sign of the coefficient is contrary to expectations from the standpoint of economic theory. Life expectancy at birth is highly significant at the upper limit and in the base regression, but it shows the opposite sign and low significance at the lower limit. Of the variables that are almost always associated with growth, only the population growth rate proved to be solid.

In the sample for Latin America and the Caribbean, none of the variables is robust from the standpoint of this methodology.

In the case of Brazil, YLPD for different causes and age groups are solid, with high statistical significance, as is initial GDP. This is not true for mortality by cause. Unfortunately, the results are less robust than in the other samples, since the set of variables included in the regressions is much smaller, owing to data constraints.

Table 2: Analysis of Extreme Limits (three-stage least squares)

Variables	Limit	*t* Statistics				
		World	Latin America	Brazil	Colombia	Mexico
Democracy index	High Base Low	5.8671 2.5028 4.2793				
Democracy index squared	High Base Low	5.9793 2.8543 2.8001				
Government consumption	High Base Low	-0.7619 -4.6745 -3.2659	1.1543 -1.1374 -3.7064			
Inflation rate	High Base Low	4.5826 3.8661 2.1432				
Fertility rate	High Base Low	0.6791 -1.2572 -2.8967				
Life expectancy at birth	High Base Low	1.9275 2.4184 –02495	1.3590 -1.7554 -0.2826			
Rule of law	High Base Low	5.7535 1.7828 2.3475	3.5913 3.8391 1.4312			
Terms of trade	High Base Low	3.4482 3.5080 -0.3299	3.7037 3.0044 1.0989			
Exports/ GDP	High Base Low	1.3201 0.8349 -0.8731	0.6360 -2.0063 -2.3757		0.1017 -0.0366 -0.1440	
Mortality (working-age population)	High Base Low		0.8733 -3.5828 -1.5684			
Schooling*Initial GDP	High Base Low		-0.3264 -1.7570 -2.1139			
Years lost to premature death *per capita* (total population aged 15–69)	High Base Low			-84.7880 -125.4382 -186.3458	4.8124 -18.7039 -9.5464	
Years lost to premature death *per capita* (total population aged 0 - 4)	High Base Low			-6.8175 -8.0448 -8.5256	39.3687 -14.1027 -8.3922	
Years lost to premature death *per capita* (male population)	High Base Low			-35.3517 -48.1392 -50.0437	32.3526 -40.0092 -21.4957	

Variables	Limit	*t* Statistics				
		World	Latin America	Brazil	Colombia	Mexico
Years lost to premature death *per capita* (total population)	High Base Low			-38.5673 -51.1588 -51.4556	43.6136 -23.8608 -14.9298	
Logarithm of mortality from noncommunicable diseases (x10000)	High Base Low			-0.9008 -1.0364 -1.2954	0.3772 -0.3792 -0.1933	0.8041 -0.8693 -0.9608
Logarithm of mortality from communicable diseases (x10000)	High Base Low			-1.0681 -1.3454 -1.6802	0.9303 -2.7687 -2.9900	-1.0886 -1.6044 -1.4322
Logarithm of mortality from injuries	High Base Low			-0.7144 -0.8606 -1.0762	0.4246 -1.1276 -1.1694	0.1532 -1.5007 -2.6513
Years lost to premature death between the ages of 0 and 15 (male population)	High Base Low				4.8124 -18.7039 -9.5464	
Years lost to premature death between the ages of 0 and 4 (male population)	High Base Low				20.6086 -6.6622 -3.4322	
Years lost to premature death between the ages of 15 and 69 (male population)	High Base Low				135.0077 -367.8901 -244.1799	
Years lost to premature death (female population)	High Base Low				57.4533 -5.4407 -8.3278	
Logarithm of mortality from noncommunicable diseases (male population)	High Base Low				2.0075 -1.3149 -1.8058	-0.9047 -0.9718 -1.0414
Logarithm of mortality from noncommunicable diseases (female population)	High Base Low				2.5587 -1.8752 -1.9934	-1.0999 -1.1677 -1.2564
Logarithm of mortality from communicable diseases (male population)	High Base Low				1.9225 -1.3565 -1.2269	-0.9726 -1.3259 -1.0607
Logarithm of mortality from communicable diseases (female population)	High Base Low				1.9442 -1.4287 -1.0681	
Logarithm of mortality from injuries (male population)	High Base Low				4.3987 -1.2479 -1.3237	-0.7545 -0.9553 -0.9719
Logarithm of mortality from injuries (female population)	High Base Low				2.4126 -0.7455 -0.4179	-1.2167 -1.8477 -1.5486

Variables	Limit	*t* Statistics				
		World	Latin America	Brazil	Colombia	Mexico
Annual average number of governors	High				2.3372	
	Base				-1.5808	
	Low				-2.5003	
Number of votes in presidential elections as a percentage of registered voters	High				-0.4788	
	Base				-3.6634	
	Low				-3.7870	
Standard deviation of average schooling by standard deviation of average *per capita* GDP.	High				3.2466	1.6355
	Base				0.8159	0.7906
	Low				-4.7469	0.1390
Gini coefficient at departmental level	High				-0.6550	
	Base				-8.9784	
	Low				-8.3073	
Per capita total public spending (departmental administration)	High				0.3822	
	Base				0.2676	
	Low				-0.0362	
Logarithm of life expectancy for men	High					1.0091
	Base					-0.2119
	Low					-1.5721
Logarithm of life expectancy for women	High					0.1532
	Base					-1.5007
	Low					-2.6513
Logarithm of fertility rate with 20-year lag	High					1.0823
	Base					-2.2920-
	Low					2.5069
Logarithm of fertility rate with 5-year lag	High					1.9570
	Base					2.1743
	Low					-0.0762
Logarithm of infant mortality rate with 20-year lag	High					1.3067
	Base					0.3123
	Low					-0.6646
Logarithm of infant mortality rate with 5-year lag	High					1.4166
	Base					1.4615
	Low					0.2151
Logarithm between ratio of government spending and GDP	High					-0.4595
	Base					-2.3720
	Low					-2.1061

In the case of Colombia, YLPD is highly significant in the base regression and at the lower limit. However, the sign of the coefficient changes at the upper limit. This is why it does not pass the extreme limits test. This also occurs with mortality by cause and by age group, although in this case the significance is less than for YLPD. The same situation occurs in the case of the Gini coefficient of income distribution.

In the case of Mexico, none of the explanatory variables is solid. Mortality by cause shows some significance.

In summary, the extreme limits test is rarely passed by any of the specifications in the growth equations and in the different samples. In only two samples were there variables that passed the test. One of these variables is the democracy index in the global country sample; the other variable is YLPD in the case of Brazil.

It is not superfluous to point out that similar tests are rarely applied in other areas of economic research. Their use in the case of economic growth is justified due to the broad range of statistical models that obtain correlation results between the growth of countries and the many variables of interest to particular researchers. In areas where the functional specification of the equation to be empirically estimated is clearly derived from economic theory, the application of this type of analysis is rare. Thus, from the standpoint of expanding knowledge of the correlation between economic growth and the formation of human capital, it seems more relevant to delve further into the channels through which health or education of specific groups in society affects the population's sociodemographic dynamics, and into the relationships between these variables and growth. This type of analysis is performed in other sections of the project. Before that, the next section presents the results of estimating functional specifications derived directly from the economic theory of growth, with health as one of the determinants of human capital.

Education, Health, and Growth: Panel Regressions for Latin America, Brazil, Colombia, and Mexico

Rodolfo Cermeño*

The objective of this work is to empirically evaluate the correlation between the level of production per person, and education and health considered as components of human capital. This study is conducted for the countries of Latin America (1960–1990) and the respective states or departments of Brazil (1980–1995), Colombia (1980–1990), and Mexico (1970–1995). We use panel information in five-year periods.

The analysis is based on a Solow-type growth model augmented by human capital, as formulated in Mankiw, Romer, and Weil (1992) or Islam (1995). However, it should be pointed out, in reference to the aforementioned works, that this work considers health as a component of 'human capital'. Thus, production per person will depend on education and health levels as well as on such classical determinants as savings rates and population growth rates.

According to the specified models, it is expected that the level of production per person will bear a positive relationship with the savings rate (investment) and education levels and a negative relationship to the population growth rates. In the case of Colombia it is expected that the coefficient of the illiteracy rate be negative. With regard to the variable 'health', economic growth is expected to be positively correlated to life expectancy and the probability of surviving the next five years, and negatively to mortality. All the estimated regressions include individual effects (to control for factors specific to each country, state or department) and temporal effects (to control for factors common to all the economies that change over time). Both effects are modeled using fictitious or "dummy" variables.

Four different specifications of the model are considered in the study, depending on the treatment given to the dynamics of the product per person and to the Solow model restriction that the coefficients of the saving rate and of the sum of the growth rates of population and technology, and depreciation, be equal but of opposite sign (positive and negative respectively). These specifications and their estimation are described in detail in the full report.

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It is important to mention that in the cases of Latin America, Brazil and Colombia information was available on health indicators by groups of age and gender, which were included one by one in each regression originating a large number of results. For this reason the study concentrates on two important aspects: (i) evaluating to what point the expected relations hold for the health indicators, independently of the results obtained for the remaining variables in the model, (ii) identifying the most consistent results of the model as a whole.

Table 3 reports the total number of estimated regressions and the number for which health variables gave significant results at the 1%, 5%, 10% and 20% levels in the cases of Latin America, Brazil and Colombia. It must be stressed that the statistical significance of the individual parameters is evaluated using two-tailed *t* tests, which is quite demanding, and errors robust to problems of heteroskedasticity.

The proportion of regressions for which the health indicator coefficients are positive and significant at the 20% level or better is approximately one third of all estimated regressions. Results have also been obtained for which, against what is expected, the health indicator coefficients are negative and significant. However, these cases only represent 5% of the total. It must be noted that the greatest proportion of positive significant results is obtained in the case of Latin America.

Table 3
Number of Regressions Estimated and Significance of the Health Indicator Coefficients

	Positive Effects				Negative Effects				Total
	1%	5%	10%	20%	1%	5%	10%	20%	
Latin America									
Total LE	20	31	7	7	0	0	0	0	136
Total PS	14	10	6	7	0	3	0	5	128
Total Latin America	34	41	13	14	0	3	0	5	264
Brazil									
Total LE	5	6	9	12	0	0	0	0	128
Total PS	10	1	4	1	8	4	5	5	120
Total Brazil	15	7	13	13	8	4	5	5	248
Colombia									
Total LE	0	14	8	16	2	0	1	8	128
Total PS	16	4	9	14	0	0	0	1	128
Total Colombia	16	18	17	30	2	0	1	9	256

The case of Mexico differs from the other three in that the health indicators are not available by age groups. For this reason it is not included in Table 3. The results of models 3 and 4, which explore purely contemporary relations between production and its factors are better than those for the dynamic models 1 and 2 (see the full report). The best results are obtained in the case of the unrestricted model. These are very significant and have the expected signs when the education indicators are illiteracy, schooling and complete primary, and somewhat less significant when 'one year of university' is used. In the other cases the coefficients tend to have the expected sign and to be at least somewhat significant.

It is important to point out that the cases for which the expected relations for the health indicators are most significant do not necessarily correspond with those cases for which the results for the remaining variables in the specified models are consistent. The full report presents some regressions selected according to their consistency with the expected results for the cases of Latin America, Brazil and Colombia. In Table 4 we present the ones corresponding to the less restricted specification of the model (Model 1).

This specification includes, besides the variables saving, population growth, health and education, the lagged dependent variable (lagged *per capita* product). It is important to mention that in the case of Mexico the states of Campeche and Tabasco are excluded, since their petroleum production, registered as income, distorts the results. Similarly, in the case of Colombia the crime rate by department is included as an additional control variable.

The results presented in Table 4, show a high goodness of fit in every case, as measured by the adjusted R squared. Additionally, the F test supports the joint significance of the explanatory variables in the reported regressions. However, it must be mentioned that these results are consistent with only some of the aspects of the model. In most cases, the expected signs are obtained for the coefficients of the explanatory variables, although in the case of Colombia, where there are few observations, acceptable levels of significance are not obtained. Possibly the weak consistency of the results are due to the fact that, in the case of Brazil, and partially in the Mexican and Latin American cases, the periods under study are periods of economic adjustment rather than growth, which weakens the application of the Solow model.

The traditional factors (rate of investment in physical capital and population growth) are related to the level of production per person in the manner that would be expected a priori. In particular, production *per capita* shows a positive correlation with the rate of investment (savings rate) and a negative correlation with the population growth rate. In the case of Brazil, we see that both factors show a positive correlation, although the investment rate is not statistically significant. In the case of Mexico, the population growth rate has a positive but insignificant correlation with *per capita* production.

Education, considered in this work as a component of 'human capital', relates negatively to the level of production per person in the case of Latin America, inconsistently with a priori expectations. This occurs also in other studies, such as Barro (1996), without there being a clear explanation. In the case of Mexico there is also a negative relationship, which however is not significant. The presence of information limitations must be taken into account, as in the case of Colombia, for which the illiteracy rate is used as education indicator. In this case the expected (negative) sign is obtained, although it is not statistically significant. In the case of

Brazil, there is evidence of a significant positive correlation between production per person and education.

Finally, it should also be mentioned that the study finds evidence that the *per capita* product of groups of countries or states (according to the data base used), tend to grow at the same rate but maintaining differences in their levels ("conditional convergence"). In practically every case the parameter corresponding to lagged *per capita* income has a positive sign, is less than unity, and is statistically significant, consistently with this type of dynamics. Also, except for the case of Colombia, the technological tendency obtained, modeled as a temporal tendency, is negative. These results can be found in the complete report.

CONCLUSIONS

In general terms, in this study some evidence is found in favor of a positive relation between health and *per capita* product. On the other hand, in general the results obtained are consistent with certain aspects of the model but not with the model as a whole. This could be de to the fact that the samples include periods of economic adjustment rather than growth.

Regarding the relation between health and *per capita* product, in the Latin American case, and also somewhat in the Colombian case, a relatively important number of results (not the majority) are positive and significant at the 10% level. However, these results are not necessarily accompanied by consistent results for the remaining variables of the growth model used for the analysis. Therefore, these results can be considered as some evidence in favor of a positive relation between health and economic growth (not necessarily causal) although not in favor of the model as a whole.

On the other hand, for those results which are as consistent as possible with the model as a whole, the health indicators correspond in general to age and gender groups at the extremes, and not necessarily the most statistically significant. These results constitute partial evidence in favor of the models used although it must be recognized that these are obtained in few cases.

It is possible that the inconclusive results of this study follow from information limitations, the possible omission of additional control variables and statistical problems of simultaneity between the studied variables.

Table 4
Growth regressions for Latin America, Brazil, Colombia and México (unrestricted model)

Sample (period)	Savings Rate	Population Growth	Health	Education	Adj. R-2.	F-Test	N of objects
Latin America (1960–1990)							
(1)	0.157	-0.276	0.747	-0.217	0.992	1485.8	85
	(3.431)°	(-3.511)°	(2.272)*	(-2.340)*			
(2)	0.219	-0.339	11.487	-0.157	0.993	1127.8	62
	(3.787)°	(-3.032)°	(3.358)°	(-2.263)*			
Brazil (1980–1995)							
(3)	0.0108	0.168	0.163	0.812	0.995	3013.8	74
	(0.049)	(4.071)°	(2.883)^	(4.214)°			
(4)	0.098	0.224	62.331	0.649	0.996	2757.3	73
	(0.498)	(5.736)°	(5.171)°	(4.031)°			
Colombia (1980–1990)							
(5)	0.028	-0.113	0.469	-0.002	0.975	298.7	46
	(1.362)	(-1.488)	(1.830)^	(-1.084)			
(6)	0.037	-0.024	6.568	-0.000	0.979	307.2	46
	(1.636)	(-0.266)	(1.196)	(-0.023)			
Mexico (1970–1995)							
(7)	0.005	0.002	0.011	-0.011	0.950	401.0	150
	(2.735)°	(1.107)	(1.759)^	(-1.383)			
(8)	0.005	0.002	0.006	-0.009	0.950	400.2	150
	(2.710)°	(1.055)	(1.401)	(-1.254)			
(9)	0.006	0.002	-0.014	-0.014	0.950	402.8	150
	(2.674)°	(1.311)	(-1.519)	(-1.406)			

Note: The dependent variable is the level of production per person. All the regressions are panel regressions and include the lagged dependent variable and individual dummy and time variables. When the health indicator is 'probability of surviving the next five years', the regression also includes the total rate of perinatal deaths. In the case of Colombia, the regressions also include the crime rate by department. Due to lack of space, the results for these additional variables are not reported. The health variables are not the same for all the regressions. Regressions (1), (3), and (5) use life expectancy for men at 5, 75 and 5 years of age, respectively. Regressions (2), (4), and (6) use 'probability of surviving the next five years' for men at the ages of 5, 5 and 15, respectively. Regressions (7), (8), and (9) use life expectancy at birth for men and women and the infant mortality rate, respectively. In the case of Brazil, the health indicators are lagged one period. Values in parentheses are *t* statistics, estimated with errors robust to problems of heteroskedasticity. The symbols °, *, and ^ indicate significance levels of 1%, 5%, and 10%, respectively.

Long-term Reciprocal Impact of Health and Growth in Mexico

David Mayer

Fogel's study on the historical association between nutrition, longevity, and economic growth is a source of motivation for the contemporary study of the interaction between health and the economy. One the most interesting findings of Fogel's research is the persistence of improvements in health. When health improves during the initial years of life, it improves in all subsequent stages, and life expectancy increases. This leads to the hypothesis that increases in health can have a long-term impact on income. The database on the Mexican states offers an opportunity to examine whether this type of correlation exists between health and future income, since it includes the following five-year health indicators:

- Life expectancy for men and women, fertility, and infant mortality for the years 1955–1995.
- Mortality by age group and sex for the years 1950–1995.

It also contains five-year economic and educational indicators for the period 1970-1995. The time series of health indicators, which is much longer than that of the economic indicators, makes it possible to analyze the interaction between health and growth over a relatively long period within the context of growth studies for developing countries. We estimate economic growth regressions in which we examine the role of health indicators with lags of up to 15 and 20 years. We also examine the symmetrical equivalent, that is, regressions of growth (improvement) in health, specifically in life expectancy for men and women, which turned out to be the most significant health indicator in this database. The results yield evidence of long-term two-way causality. In particular, the magnitude of the coefficients indicates a significant channel of causality from health to income.

For economic growth regressions, we also disaggregated the results of long-term interaction by age group and sex, using the respective mortality indicators. We found a pattern of lags similar to that for life expectancy, associated with both the more economically active age groups and maternity.

ECONOMETRIC APPROACH

The technique we use is similar to that of Barro in *Health and Economic Growth* (1996). We estimate economic growth as a function of a series of explanatory variables. We perform these estimations not only for the log of income y_t but also for life expectancy for men and women EV_t[5]. Upon completion, we will have estimated equations such as the following:[6]

$$(1) \qquad (y_{t+T} - y_t)/T = \alpha_0 y_t + \alpha_p EV_{t-pT} + \beta_1 X_1 + ... + \beta_r X_r + u_t,$$

$$(2) \qquad (EV_{t+T} - EV_t)/T = \gamma_0 EV_t + \gamma_q y_{t-qT} + \delta_1 Z_1 + ... + \delta_s Z_s + v_t.$$

In these equations, T is the period of growth, t the initial period, α_0 and γ_0 coefficients with negative signs expected in the case of convergence, α_p the coefficient of life expectancy with a lag of pT years, γ_q the coefficient of *per capita* income with a lag of qT years. Finally, $X_1,..., X_r$, $Z_1,...,$ and Z_s represent additional explanatory variables, *dummy* variables for each time period in the case of equation (1) and the constant term for equation (2).

Economic growth:

- The initial value of *per capita* income.
- Some health indicator (life expectancy, fertility, infant mortality or mortality by age group and sex)
- Percentage of the population speaking an indigenous language.
- Public spending (ln).
- Percentage of the population up to four years old.
- Fixed temporal effects.
- Educational indicators.

It would be desirable for the database to contain better indicators of savings, as well as public and private investment in health. Those obtained were acquisition of banking resources, construction, public spending on education and health, and the population eligible to use the public health services. However, these were not very significant; neither was an indicator for migration.

When the rate of improvement in life expectancy is estimated, the initial value is that of life expectancy itself, and a lagged GDP is used as an explanatory variable.

Equations (1) and (2) constitute a Granger causality test between y_t and EV_t, except for the presence of the additional explanatory variables, and the use of a pattern of lags constrained by the available information. Thus, it is a *conditional* Granger causality test that studies causality once the effects of the additional variables have been controlled.

A significant coefficient for a lagged variable indicates that the hypothesis that the correlation indicates causality cannot be rejected. The magnitude of the coefficients establishes the magnitude of the causal relationship suggested by the regression.

The results indicate that, in economic growth regressions, the coefficients of life expectancy and their significance reach their maximums for lags of 15 or 20 years. In the opposite direction, for which the horizon is shorter, the coefficients and their significance reach their maximums for lags of 10 years. The magnitude of the coefficients indicates that the first Granger causality relationship is considerable, whereas the second relationship is smaller. This second result inclines us to believe that the income *per capita* of the Mexican states may not be a good indicator of actions, including the channeling of resources, that improve health.

We also broke down the effect of life expectancy on economic growth by using indicators of mortality according to age and sex. This confirmed the results of lagged impact that we have mentioned, and we found that the results cluster around the health of the economically active population and possibly maternal health.

RESULTS: INCOME GROWTH AND HEALTH

Here we summarize the results of the income growth regressions.

Life Expectancy, Fertility, and Mortality

Life expectancy for men and women shows a significant positive correlation with growth of *per capita* income for time lags ranging from 0 to 15 years after the initial period, with the maximum at 15 years. The coefficients have the expected sign, are highly significant, and tend to increase as the lag increases from 0 to 15 years. The first four columns of Table 5 show these coefficients for 0 and 15 years. The results are not significant when fertility is used, while infant mortality has a significant coefficient with only 0 years of lag time.

Table 5
Economic Growth Regressions:
Comparison of the Impact of Several Health Indicators[7]
(main coefficients)

	Life expectancy for men	**Life expectancy for men**	**Life expectancy for women**	**Life expectancy for women**	**Fertility**	**Infant mortality**
Lag	**0**	**15**	**0**	**15**	**0**	**0**
Health indicator	**0.118** **(3.569)**	**0.153** **(3.356)**	**0.085** **(3.631)**	**0.114** **(2.887)**	-0.057 (-1.58)	***-0.046*** ***(-2.041)***

Mortality by Age and Sex

We sought to identify the age groups and sex for which health has a lagged impact on income growth. In Tables 6 and 7, we show for each age group and sex the coefficients of the regression that yields the most significant coefficient, for time lags of 15 or 20 years. Except for the group aged 30 to 49 years, the results are more significant for women, for whom significant coefficients in the group aged 5 to 14 and 15 to 29 years are obtained. The coefficients are even higher for men between 30 and 49 years of age. In the case of women, the age groups point to maternity and economic participation as relevant to causality, given the characteristics of women's participation in the workforce. In the case of men, the economically active ages are the most important. Concerning maternal mortality, it is noteworthy that this is an indicator of the availability of technologically feasible health services, and thus shows the importance of broad coverage of health services.

Tables 8 and 9 are similar to the previous tables but deal with the lag of 0 years, where the causal relationship is less clear. These results are significant for women from the age of 15 on, while they are not significant for men. Several phenomena are present here. With respect to older women, their greater vulnerability compared to men is evident. For younger women, the phenomenon may be related to maternity and other health conditions that receive less care when economic resources decline.

Summarizing, there is strong evidence of causality from life expectancy of men and women to economic growth occurring in the five-year period beginning 0 to 15 years later; both the coefficients and their confidence level grow during this time. When we employ the mortality indicators by age groups and sex, we find that this causal relationship has greater significance for men aged 30 to 49 and for females aged 5 to 14 and 15 to 29. Thus, the causal relationship detected is associated with the more economically active groups and with maternity.

In addition, the strongest correlations in the case of the 0-year lag, in which causality is less clear, are found only for women, with two peaks, one for the age groups in the childbearing years and the other for the elderly.

Education

The education variables show colinearity with the health indicators. While they may be significant in the absence of the health variables, their confidence levels decline when these latter are included. This may indicate that part of the effect of health on future growth may occur through education, as is found in the study on Brazil. It may also be a reflection of poor quality of the indicators.

Table 6
Impact of Male Mortality by Age on Economic Growth Regressions: 15 or 20- Year Lag with the Most Significant Coefficient for Each Age Group[7]
(main coefficients)

Age group	**0 to 4**	**5 to 14**	**15 to 29**	**30 to 49**	**50 to 69**	**70+**
Lag	**15**	**20**	**15**	**20**	**20**	**20**
Health indicator	-0.002 (-0.21)	-0.007 (-1.124)	-0.005 (-0.603)	***-0.018*** ***(-2.095)***	-0.019 (-1.214)	-0.008 (-0.59)

Table 7
Impact of Female Mortality by Age on Economic Growth Regressions: 15 or 20- Year Lag with the Most Significant Coefficient for Each Age Group[7]
(main coefficients)

Age group	0 to 4	5 to 14	15 to 29	30 to 49	50 to 69	70+
Lag	**15**	**15**	**15**	**15**	**15**	**15**
Health indicator	-0.009 (-1.337)	*-0.011* *(-1.909)*	***-0.015*** ***(-2.078)***	-0.016 (-1.568)	-0.011 (-1.148)	-0.018 (-1.77)

Table 8
Coefficient of Male Mortality by Age in Economic Growth Regression: 0-Year Lag[7]
(main coefficients)

Age group	0 to 4	5 to 14	15 to 29	30 to 49	50 to 69	70+
Health indicator	0.001 (0.147)	0.001 (0.101)	-0.007 (-0.772)	-0.008 (-0.842)	-0.014 (-1.079)	-0.007 (-0.462)

Table 9
Coefficient of Female Mortality by Age in Economic Growth Regression: 0-Year Lag[7]
(main coefficients)

Age group	0 to 4	5 to 14	15 to 29	30 to 49	50 to 69	70+
Health indicator	0 (-0,068)	0 (-0,002)	***-0.022*** ***(-2.655)***	*-0.019* *(-1,664)*	***-0.025*** ***(-2,094)***	**-0.043** **(-3,526)**

Table 10
Life Expectancy Growth Regression
with Several *per capita* Income Lags[7]
(main coefficients)

Income Lag	Men				Women			
	0 years	**5 years**	**10 years**	**15 years**	**0 years**	**5 years**	**10 years**	**15 years**
Initial life expectancy	**0.026**	0.008	*-0.023*	-0.02	**0.02**	-0.004	**-0.036**	**-0.042**
	(2.773)	(0.709)	*(-1,673)*	(-0,908)	**(3.117)**	(-0,508)	**(-4,413)**	**(-3,327)**
Per capita income (ln)	0.006	**0.011**	**0.019**	*0.016*	**0.016**	**0.021**	**0.03**	**0.033**
	(1.646)	**(2.771)**	**(3.919)**	*(1.771)*	**(3.849)**	**(4.614)**	**(6.308)**	**(4.202)**
Observations	155	124	93	62	155	124	93	62

Table 11
Life Expectancy Growth Regression with Several
Educational Indicators
(main coefficients; 93 observations)[7]

Educational indicator	Men				Women			
	Literacy	Primary Complete	Degree started	Schooling	Literacy	Primary complete	Degree started	Schooling
Initial life expectancy	***-0.029***	***-0.033***	*-0.024*	*-0.046*	**-0.041**	**-0.040**	**-0.039**	**-0.068**
	(-2.030)	***(-2.355)***	*(-1.749)*	***(-2.246)***	**(-5.451)**	**(-5.067)**	**(-4.908)**	**(-6.309)**
Per capita income with a lag of 10 years	**0.015**	**0.020**	**0.017**	**0.015**	**0.019**	**0.029**	**0.023**	**0.018**
	(2.848)	**(4.169)**	**(3.224)**	**(2.787)**	**(3.955)**	**(6.576)**	**(4.550)**	**(3.529)**
Education	*0.001*	***0.001***	0.008	0.007	**0.001**	**0.001**	**0.032**	**0.016**
	(1.713)	***(2.575)***	(0.819)	(1.503)	**(4.733)**	**(3.081)**	**(3.238)**	**(4.125)**

RESULTS: GROWTH IN LIFE EXPECTANCY

In the life-expectancy growth regressions, the dependent variable is the rate of growth in life expectancy for men or women (i.e. its rate of improvement).[8] Tables 10 and 11 show the main results.

For both sexes, the “income” variable is notably more significant when the lag is 10 years from the initial period and with the expected positive sign. However, in the case of women, the coefficient for 15 years is somewhat higher. Note that the number of available observations declines with the lags. For the 10- and 15-year lags, the coefficient of initial life expectancy is negative, which indicates convergence. This sign is lost for the lag of 0 years. This may be the result of not having enough explanatory variables.

Education

Using *per capita* income with a 10-year lag, we now introduce the education variables (Table 11). The results are much more significant for females than for males. For males, literacy and primary education prove to be significant, while for females all the education variables are significant. The most significant variable for men is primary education, while for women it is literacy. The negative life expectancy coefficient represents convergence in life expectancy.

MAGNITUDE OF THE COEFFICIENTS

We read the magnitude of the coefficients of the interplay between life expectancy and income in the best regressions for each causal direction. We find that for every permanent one-year increase in life expectancy, there is a 0.8% increase in the growth rate of *per capita* income in the five-year period beginning 15 years later. In Mexico during the period in question, the five-year increases in life expectancy have values of 2.34 years for men and 2.77 for women. This means that the contribution to income growth is on the order of 2% per year. The increases in life expectancy continue to be approximately two years per five-year period in 1990.

In the opposite direction, the magnitude is the following. If income with a 10-year lag is doubled, life expectancy increases by approximately 70 days. However, the R^2 of the regressions is smaller, indicating that the variables of the regression are not sufficiently explanatory with respect to improvements in health.

CONCLUSIONS

The results strongly indicate that health is correlated with future economic growth—that is, that it causes economic growth in the long term in the conditional Granger sense. When we examine the impact of mortality by age group and sex, we see that this causality is associated with maternity and with the most economically active age groups. We also detect causality in the opposite direction, but find only a small magnitude. This may be because the income *per capita* of the Mexican states is not a good indicator of actions that improve health, including public spending on health. It may also be because a significant portion of health improvements occur for reasons other than income, such as technological and cultural change. Growth regressions, as Solow notes, do not take account of such changes, which appear in the residual. Particularly in the case of the life expectancy growth regression, we should consider that the residual, which is higher, includes not only technology, but also preferences—especially when considering fertility, which in turn interacts strongly with other health indicators. This means that changes in health are highly dependent on technology advances, public policy, and behavioral patterns.

The 15- or 20-year lags between health and growth surely result from the persistence of health improvements in health and the intergenerational nature of the formation of educational and health capital. Investment in bringing up children involves lags of this length and depends on the wealth of the parents.

In this study, we found that improvements in health indicators are correlated with future economic growth over long periods of time that do not exhaust the horizon of available information. The magnitude of the correlation indicates the possibility that the contribution of improvements in health to growth during this period of Mexican development may be as significant as 2% annually.

Health in the Economic and Demographic Transition of Brazil, 1980–1995

David Mayer

Amongst the main objectives of studies on the economic impact of health is the identification of the main channels of interaction. In addition to its direct impact on productivity, health has other effects on both economic development and the demographic transition. Barro (1996), for example, states that health reduces the depreciation rate of human capital, making investments in education more attractive. In fact, good infant health and nutrition directly increase the benefits of education (World Health Organization, 1999; World Bank, 1993). Ehrlich and Lui (1991) examine the impact of longevity on economic growth through intergenerational economic exchange. Health can facilitate the economic participation of women. This in itself is important for economic development (Galor and Weyl, 1993). Health is a factor of fertility, itself a pivotal phenomenon of the demographic transition, which in turn has been studied extensively from the economic standpoint. Finally, it is important to study the impact of each of these mechanisms on income distribution dynamics and on the different sectors of the population.

Together, these interactions paint a complex picture. Their simultaneous presence poses considerable difficulties to their study and to the empirical detection of the diverse processes. In the case of Brazil, an excellent database was compiled from PNAD household surveys and from the classification of mortality by causes as obtained from death certificates. The quality of this database allows us to pursue the detection of complex phenomena related to the role of health in changes in income, education, economic participation, employment, and fertility. From this analysis emerges a picture that consistently shows that health has important economic, demographic, and distributive interactions that can be influenced by public policy.

DATABASE

We consolidated the information from the eight PNAD surveys (1977 to 1995), summarizing the data at 10 income levels (i.e., by deciles) for each Brazilian state.[9] 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 the information is tied to income distribution, and that the number of observations is large.

The health data obtained from death certificates include mortality and years lost to premature death classified by cause and by age group, sex, and life expectancy for five-year periods between 1980 and 1995. All this data is included for each state in Brazil.[10]

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 health variables by age group and sex correlate with the growth or decline in income, 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 (1991, 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 (a proxy for 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) *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.
- 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 principal indicators that describe (in averages) the economic situation of the households of 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 the variables income and schooling of the household head are included to give the estimator, which simultaneously adjusts to the behavior of households with different levels of income, functional flexibility. They are also included as explanatory variables.

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 subject does not survive, 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:

$$\frac{y_{sd(t+5)} - y_{sdt}}{5} = a y_{sdt} + \sum_i \hat{a}_i X^{i}_{sdt} + g_d S_{st} + c_d c_d + q_{85} c_{85} + q_{90} c_{90} + e_{sdt} \,.$$

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 c_d, and by date c_{85}, c_{90}, in order to control for the respective fixed effects.

The estimates include 24 Brazilian states. The regressions were estimated by generalized least squares, correcting for heteroskedasticity and correlation in the errors between deciles and 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 group and sex) 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?

We estimate these regressions by sets in which the health indicator covers the population's classification by age and sex. For each regression, a coefficient 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 graph these coefficients in three dimensions in order to observe the pattern they follow with respect to age group, sex and income decile (non-significant coefficients are graphed at zero).

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

$$(2) \qquad \frac{S_{s(t+5)} - S_{st}}{5} e_d = aS_{st}e_d + \sum_i \hat{a}_i X^i_{sdt} + c + q_{85}c_{85} + q_{90}c_{90} + e_{sdt},$$

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 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 the following variables: 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. Accordingly, here we will show only the graphs of the coefficients obtained by female health indicators for this set of variables. Table 12 contains a summary of the coefficients obtained for economic and demographic explanatory variables in the regression groups mentioned, while Figures 1 through 4 show the coefficients of the health variables. The coefficients are comparable, since they represent elasticities.[11]

Relationship between Health and Growth of *per Capita* Income

We begin 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 Figure 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 mean of health for age groups t and thereafter.

Figure 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 is 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 (Figure 2). In upper income levels, health correlates negatively with future female participation. This effect is 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.

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 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. It should be recalled that since the increments in health are persistent, these effects are probably greater over longer periods of time, as indicated by the causality studies for Mexico and Latin America.

As for the other explanatory variables for income growth, the results are consistent with economic theory and appear in Table 12. 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 under one year of age contributes negatively, and this 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.

Table 12
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 Economic Participation	Growth of the Percentage of the Population under 1 Year of Age	Growth of Schooling
Number of regressions	32	17	32	32
Health indicators	Both sexes	Female	Both sexes	Both sexes
Average of fixed effects of the deciles	**1.532** **(16.06)**	**0.33** **(3.36)**	**-0.575** **(-9.82)**	**0.289** **(2.72)**
Income	**-0.4544** **(-14.48)**	**-0.1377** **(-4.75)**	**0.096** **(3.04)**	-0.0455 (-0.06)
Income^2	**0.0263** **(8.3)**	**0.00924** **(4.75)**	**-0.0188** **(-4.41)**	0.00122
Schooling of the household head	0.0065 (0.5)	**0.0266** **(3.36)**	0.0115 (1.23)	**0.0852** **(5.76)**
Schooling of the household head, squared	-0.0012	-0.0061 (-1.27)	**0.0199** **(6.35)**	-0.0095 (-1.5)
Average schooling	-	-	**-0.0237** (-1.15)	**-0.1767** **(-31.74)**
Economically active female population	-0.0002	**-0.1129** **(-28.96)**	0.0075 (0.21)	**0.0114** **(4.57)**
Economically active male population	0.0101 (0.38)	0.0016	-0.0674 (-1.62)	**-0.0794** **(-3.67)**
Percentage urban population	0.0023 (0.61)	**-0.0214** **(-6.83)**	-0.0022 (-0.01)	0.004
Population growth	-7.15E-09	**-8.27E-08** **(-5.25)**	4.17E-08 (0.6)	**-9.12E-08** **(-6.48)**
Percentage of the population under 1 year of age	**-0.0018** **(-3.96)**	0.0034 (0.88)	**-0.1894** **(-26.23)**	**0.0055** **(2.82)**
Percentage of the population under 6 years of age	0.0003	-0.0072 (-0.78)	**0.082** **(7.97)**	**-0.0213** **(-6.57)**
Dummy 85	**-0.0277** **(-9.87)**	**0.0255** **(16.61)**	**-0.0406** **(-8.87)**	**0.0306** **(16.46)**
Dummy 90	**-0.052** **(-71.78)**	**0.0248** **(21.28)**	**-0.0509** **(-12.66)**	**0.0203** **(15.23)**
R^2 (minimum) (maximum)	0.96 0.988	0.706 0.803	0.605 0.731	0.885 0.929
Adjusted R^2 (min) (maximum)	0.958 0.988	0.692 0.794	0.586 0.718	0.88 0.926
Durbin-Watson (min) (maximum)	1.935 2.386	2.156 2.251	2.189 2.285	1.965 2.055
F statistic (minimum) (maximum)	528.01 1823.91	52.54 89.33	32 57	163.06 277.97

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

With respect to the other explanatory variables for income growth, the results are consistent with economic theory (see Table 11). There is income convergence, a little more for low-income than for high-income groups. The schooling of the household head contributes positively to growth, while the average schooling, which refers more to that of young people, contributes negatively (in regressions not reported here), since it represents an investment. The ideal indicator would be something in between. The percentage of urban population contributes positively to growth. The percentage of the population under one year of age contributes negatively, which is consistent with the impact on *per capita* income generated by a larger population.

Relationship between Health and Fertility

In order to study the interaction between health and changes in 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 fertility in deciles 1 to 8, and *lower* rates in deciles 9 and 10 (Figure 3). 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. These effects can be greater over longer periods of time.

Concerning the other explanatory variables (Table 12), the results indicate that for the lower deciles an increase in income correlates with an increase in fertility, while in decile 10 the relationship is the reverse. This change in sign is consistent with economic theory. Schooling of the household head contributes positively to fertility in all deciles, increasingly with wealth. However, average schooling contributes negatively, i.e. in the new generations education reduces fertility. In addition, there is a declining trend in 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 (Figure 5), 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 join the work force. This effect may also be correlated with higher fertility and female unemployment. Thus it may be that a greater burden of young children in the home 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.

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 education for the household head yields a coefficient of 0.90.[12] 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 greater over the longer term.

Concerning the other variables, in the case of schooling (Table 11), 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 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 participation and decreases in unemployment.[13] 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 a decrease in wages, with a very high implicit elasticity of approximately -6. These factors help to explain the reduction in income that occurs in the poorest decile when health indicators rise (Figure 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 11), the picture is consistent. Income correlates positively with an increase in male participation and negatively with female participation, consistently with increased fertility. Schooling of the household head correlates with an increase in female participation and the wages of both sexes. This decreases a little with income. The percentage of the urban population reduces participation and increases unemployment and wages. The percentage of the population under one year increases female unemployment. The percentage of the population under six increases male participation and the wages of both sexes. 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. 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. 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 to divergence is that when health indicators are included in the regressions, the coefficients indicating convergence become more significant.

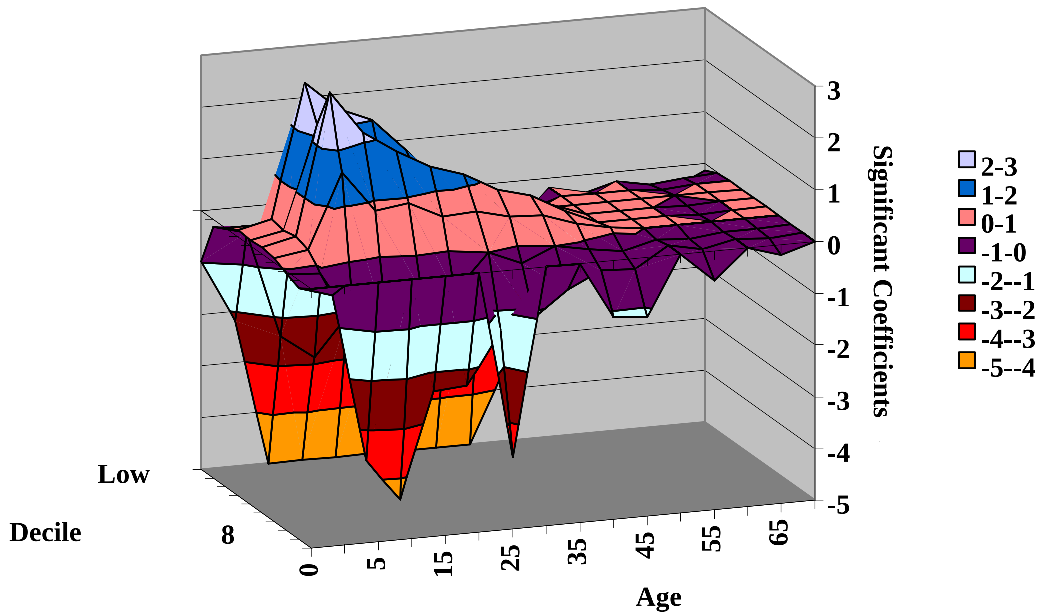
Summarizing, we find evidence that increases in the state health indicators represent increases in health that are unevenly distributed among the population. Below decile 4, this inequality leads to divergence in income growth, while above decile 6 it leads to convergence. In contrast, we find little difference in the pattern of income change due to different epidemiologies such as mortality from causes linked with maternity, communicable diseases, and noncommunicable diseases.[14]

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, showing a larger magnitude for men and, slightly, for the lower income deciles.

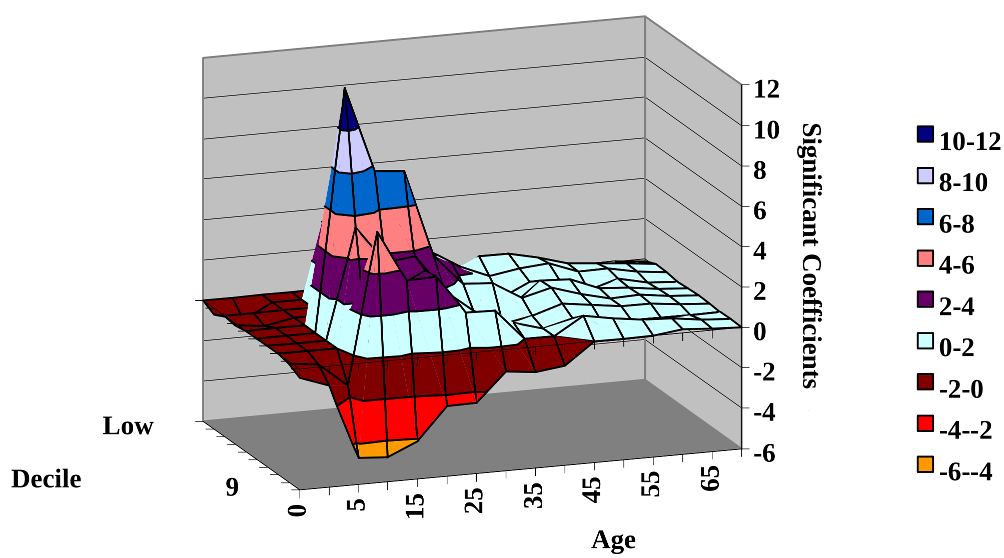
Income Growth Rate
(GLS, CSW, White)

Figure 1
Significant Coefficients (2.5%) of the Probability of Survival for Women



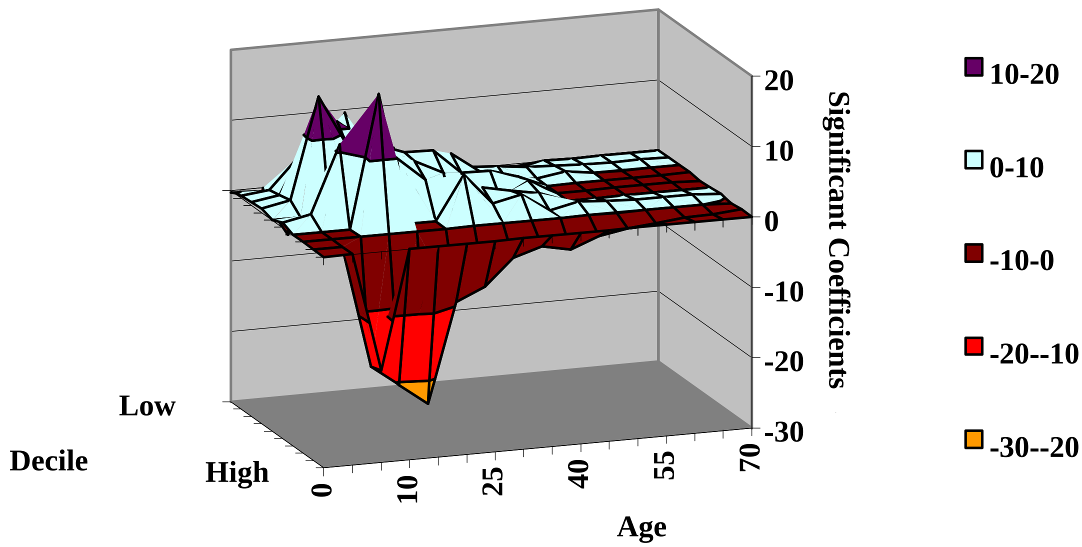
Growth Rate of Female Economic Participation
(GLS, CSW, White)

Figure 2
Significant Coefficients (2.5%) of the Probability of Survival for Women



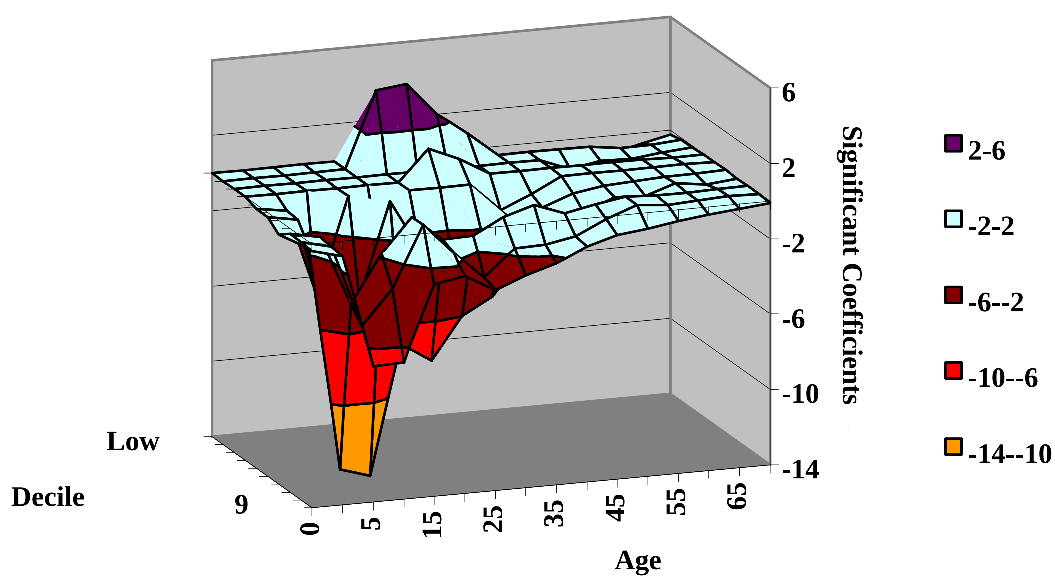
Growth Rate of the Percentage of the Population under 1 Year of Age
(GLS, CSW, White)

Figure 3
Significant Coefficients (2.5%) of the Probability of Survival for Women



Growth Rate of Schooling
(GLS, CSW, White)

Figure 4
Significant Coefficients (2.5%) of the Probability of Survival for Women



CONCLUSIONS

Our results clearly indicate that health processes are part of Brazil’s economic and demographic transition. The levels of health affect each of the principal aspects of the transition —namely income, fertility, education, and economic participation.

According to our estimates, health increases income growth through three main channels: increases in educational levels, direct productivity effects and increases in female participation. 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. It is also a period of small increases in health status (see Figures 7 and 8 of the study on Latin America). In the case of Brazil, there are even some decreases in health status 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 increases in educational levels, direct productivity effects and increases in female participation respectively. Evidence from the long-term studies for Mexico and Latin America indicates makes it likely that these effects are greater in the long run.

Health increases fertility (or limits its decline) at all income levels except for the highest, where it reduces fertility—a phenomenon consistent with the economic theory of endogenous fertility pioneered by Becker (see, for example, Becker et al., 1990, Dahan and Tsiddon, 1998). The 2% magnitude of these differences in fertility between upper and lower deciles could be even larger in the long term. However, education reduces fertility in the new generations, and fertility has a tendency to decline over time.

The health of both students and their parents increases schooling and school attendance. However, there are also negative correlations when minors apparently choose or are sent to work. This may be a secondary effect of greater fertility, in which homes with more children may provide less support from adults for school attendance. Both this effect and women’s choice of working or remaining at home during motherhood are not adequately studied in economic theory. The reduction in schooling or school attendance may also be the result of budgetary conflicts between health and education. In addition, there may be choices linked to adolescence that result in a reduction in human-capital formation.

When the effects of income on the probability of survival are studied, we confirm the conclusion arrived at in the study on the reciprocal impact of growth and health in Mexico (fourth section), in the sense that the causal relationship from health to income growth is much stronger than its inverse.

With regard to the distribution of income, in principle increases in health can reduce inequality, since their effects are greater when the deficiency is greater. For example, increases in male and female participation occur 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. 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 noncommunicable diseases.

The results of the estimates show a high degree of consistency. The signs of the coefficients of 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. The Brazilian database which we have studied has enough indicators of the necessary quality to establish that health has complex interactions in the economic and demographic transition. Health manifests both positive and negative correlations with the trends of change of the main economic indicators. It increases income growth by fostering education, productivity, and economic participation. However, it also increases fertility at low and average incomes. This induces vicious circles in both income and schooling that only revert for high-income levels. Due to maternity, the economic participation of women in decile 10 decreases, reducing income through what cannot be viewed as a negative effect since it is a result of the household's choice. Health also affects the distribution of income. Probably due to its poor distribution, it originates lower income growth in the lower 40% of the population. Finally, the lowest 10%, who are most vulnerable to unemployment, see their income reduced due to increases in their economic participation that reduce their wages.

The Long-Term Impact of Health on Economic Growth in Latin America

David Mayer

In this study we analyze the long-term impact between health and economic growth in Latin America. Our motivation is the same as in the section on the long-term reciprocal impact of health and growth in Mexico, and we follow the conditional Granger causality methodology explained in that section. This analysis is possible since life tables are available at five-yearly intervals since 1950 for a good number of Latin American countries. Besides establishing a strong long-term relationship between health and economic growth, the results are interesting because they are directly comparable with both the above-mentioned study for Mexico and the study on the role of health on the economic and demographic transition of Brazil. The first of these studies uses life expectancy and mortality by age group and sex for a good number of five-year periods, but not the full life tables, while the second only uses contemporary life tables.

THE STUDY

The economic growth regressions we run are the following:

$$\frac{y_{s(t+5)} - y_{st}}{5} = a y_{st} + \sum_i b_i X_{st}^i + g S_{s(t-l)} + \sum_i c_i c_i + e_{st} .$$

Times t take the values 1975, 1980 and 1985. The variables are the following. y_{st} is the logarithm of income *per capita*. Variables X_{st}^i are the logarithm of: average number of years of primary schooling of the population over 25 years of age; real investment as a proportion of product; real "consumption" expenditure of the government as a proportion of product and total fertility (children per woman)[15]. These include indicators for the basic explanatory variables of economic growth, namely education, saving and population growth. Variables c_i are temporal "dummies" for the years 1975, 1980, 1985, which take into account temporal effects common to the countries in the sample, such as macroeconomic and technological shocks, etc. Subindex i runs through the following 18 countries: Argentina, Bolivia, Brazil, Costa Rica, Chile, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, the Dominican Republic, Uruguay and Venezuela. During these years the average growth rates of these countries for the five-year periods 1960–1965 to 1985–1990 were 2.2%, 2.4%, 3%, 2.1%, -2.2% and –0.6% respectively.

Results for 204 Economic Growth Regressions for 18 Latin American Countries (GLS, CSW, White)

Table 13
Coefficients and Their Significance

	Coefficient			Probability		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Initial Income	-9.17E-06	-7.26E-06	-1.82E-06	**6.20E-12**	**2.63E-03**	1.21E-01
Primary	-1.68E-02	-9.90E-03	-3.35E-03	**9.98E-18**	**1.22E-04**	**9.13E-03**
Investment	1.67E-02	1.27E-01	1.66E-01	**2.19E-11**	**1.30E-02**	5.22E-01
Government Consumption	-1.18E-02	1.96E-02	6.47E-02	**8.29E-02**	6.80E-01	9.98E-01
Fertility	-6.87E-03	-3.57E-03	3.10E-03	**3.40E-06**	3.30E-01	9.96E-01
Dummy75	-3.30E+00	-8.47E-01	8.65E-02	**8.93E-06**	**6.59E-02**	9.81E-01
Dummy80	-3.34E+00	-9.01E-01	4.22E-02	**1.18E-06**	**3.88E-02**	8.83E-01
Dumy85	-3.33E+00	-8.81E-01	6.17E-02	**2.98E-06**	**4.54E-02**	9.74E-01

(Bold types indicate a confidence level better than 1%.)

Table 14
Global Statistics

	Minimum	Average	Maximum
R-squared	0.86	0.92	0.97
Adjusted R- squared	0.83	0.91	0.97
F statistic	32.19	71.15	179.25
Log probability	0.00000	0.00000	0.00000
Durbin-Watson	1.88	2.08	2.37
Number of observations	52	52	52

The health variable S_{it} used was the probability of survival to the next age group obtained from life expectancy by age groups and sex as described in the previous section. The age groups are 0-1, 1-5, 5-10, ..., 75-80 years. The health variable was used with lags l of between 0 and 5 five-year periods. This means that the number of regressions estimated was 17 age groups × 2 sexes × 6 lags = 204.

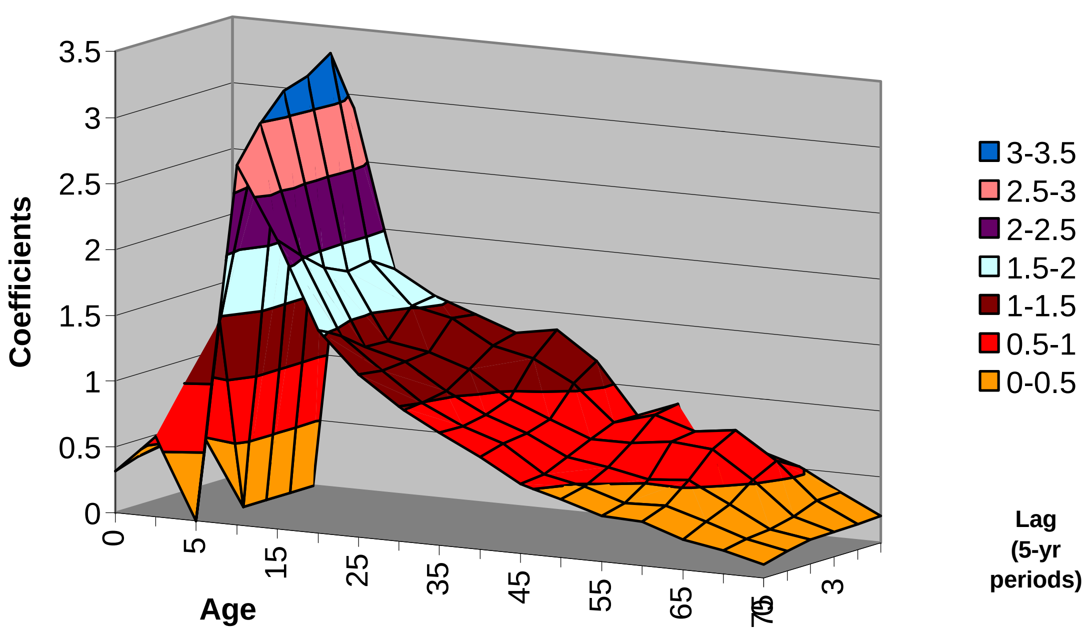
RESULTS

The regressions were estimated by generalized least squares, correcting for heteroskedasticity and correlation in the errors between countries. The main statistics of these regressions are found in Tables 13 and 14. It can be observed that initial income obtains a consistently negative sign (as expected by the hypothesis of conditional convergence) and is somewhat or very significant. “Average years of primary schooling for ages 25 and over” obtains a consistently significant negative sign (contrary to what is expected, as in Barro, 1991). Investment obtains a consistently positive sign (as expected from economic theory) which is somewhat or very significant. The coefficients of the remaining variables change sign. Additionally, the R squared, F and Durbin-Watson statistics are very good for all of the regressions. Considering that each regression includes only 52 observations, the results are very good.

Figure 5

Coefficients of the Lagged Probability of Survival in 204 Economic Growth Regressions (18 Latin American Countries, GLS, CSW, White)

Coefficients Significant at the 1% level, Women

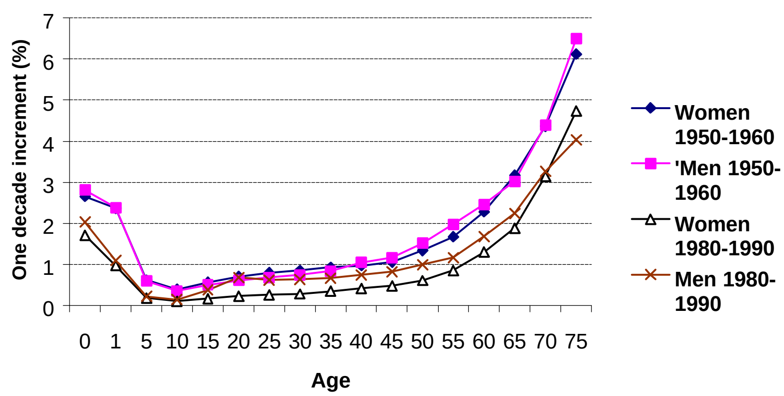


The coefficients of the female health variables are shown in Figure 5, with non-significant coefficients (less than 1% confidence) set to zero. The coefficients obtained by the male health indicators are somewhat smaller and less significant, as holds almost generally in the studies on Mexico and Brazil, but nevertheless follow the same pattern. The shape of the graph restricted to a zero lag is similar in shape and magnitude to the graph obtained for the Brazilian case (Figure 1). The highest coefficients are concentrated at the 10 year old age group, and diminish towards the younger and older age groups. What is important from the point of view of the long-term analysis is that the coefficients increase significantly towards the past for almost all the age groups. The coefficients of the adult age groups become larger (and in the case of the male indicators, more significant). Such an increase would not take place, for example, if the lagged variable was income *per capita*.

These results are very similar to those obtained in the case of the study on Mexico. They confirm that there is a long-term relationship between health and economic growth, and that in this relationship adult health plays an important role.

Figure 6

Percentage Increase in the Probability of Survival by Age Group and Sex for 1950-1960 and 1980-1990 (18 Latin American Countries)



We analyze the magnitudes that these interactions between health and growth represent in real terms. To do this, we take into account the percentage increase in the probability of survival of men and women that actually occurred in the decades 1950–1960 and 1980–1990 and calculate the economic growth rates with which these health improvements would be associated. Figure 6 shows that these health increments are lower for the later decade, especially for women. Figures 7 and 8 show the economic growth associated with these decades' health increments, obtained by using the coefficients of the regressions corresponding to the longest available lag (25 years to the initial period). That is, the coefficients are multiplied by the health increments to obtain the associated economic growth.[16]

Since improvements in the probability of survival are relatively small between the ages of 5 and 15 (Figure 6), the shape of these graphs is different to the shape of Figure 5 of the coefficients. The contribution of the different age groups is much more uniform, and the contribution to growth associated with the health increments of the old stands out. The male and female health increments of 1950–1960 are associated in the long term with income growth rates of about 0.8% and 1.1%, while the growth associated with the health increments of the older segment of the population would be even higher. The contribution that would be associated with the health increments of 1980–1990 is much smaller. In this case men would contribute more than women, but the typical level would descend to 0.6% or more for adults, with female contribution running at 0.3%. Only in the case of 20 year old men is the 1950–1960 level of contribution preserved. However, this seems to happen because of a notable negative perturbation in the health of this sector of the population occurring in 1975 and 1980 (which extends to a lesser degree to 35 years of age).

Contribution by Age Group and Sex of Increments in the Probability of Survival to the Annual Income Growth Rate (5-Year Period Beginning with a 25-Year Lag)

Health Increments Typical of the Decades 1950-1960 and 1980-1990

Figure 7

Women

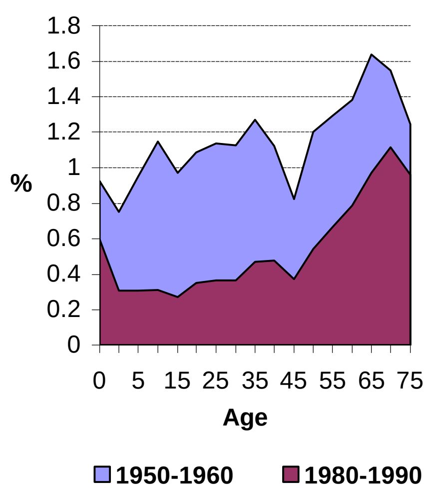
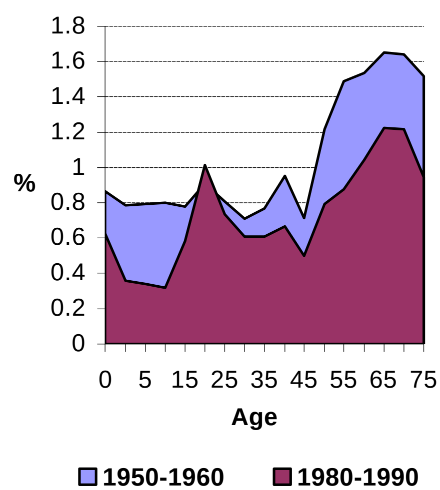


Figure 8

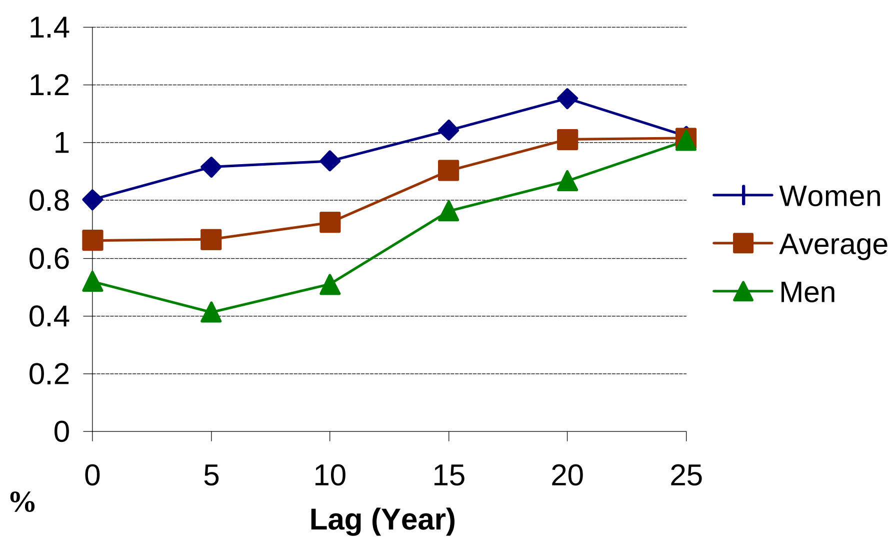
Men



The comparison shown in Figures 7 and 8 between the levels of economic growth associated with the health increments of two different decades has important implications. The changes in the quantity and distribution of health improvements can considerably affect long-term economic growth. The impact of each age group and sex on economic growth is very sensitive to the health improvement experimented by each sector of the population. Even when the coefficients of female health indicators are larger and more significant, male health improvements may contribute more to growth. The diminished health *increments* of the 1980–1990 decade (compared with those of the 1950–1960 decade), if not recuperated, may diminish income permanently between 4% and 8%.[17]

Overall, we can conclude that each health increment contributes permanently with an income increment, which takes time to fully take effect. The trajectory of the impact of health increments on income over time is shown on Figure 9, taking averages over female and male health indicators, and also over all of the indicators (the vertical axis measures income in terms of percentage increments). Taking the form of this impact into account, as well as the different contributions for each five-year period the approximate contribution of health increments to income in Latin America over the years 1950 to 1985 is shown on Figure 10 (the vertical axis measures income in terms of percentage increments from 1950).

Figure 9
Temporal Trajectory of the Impact of Health on Income

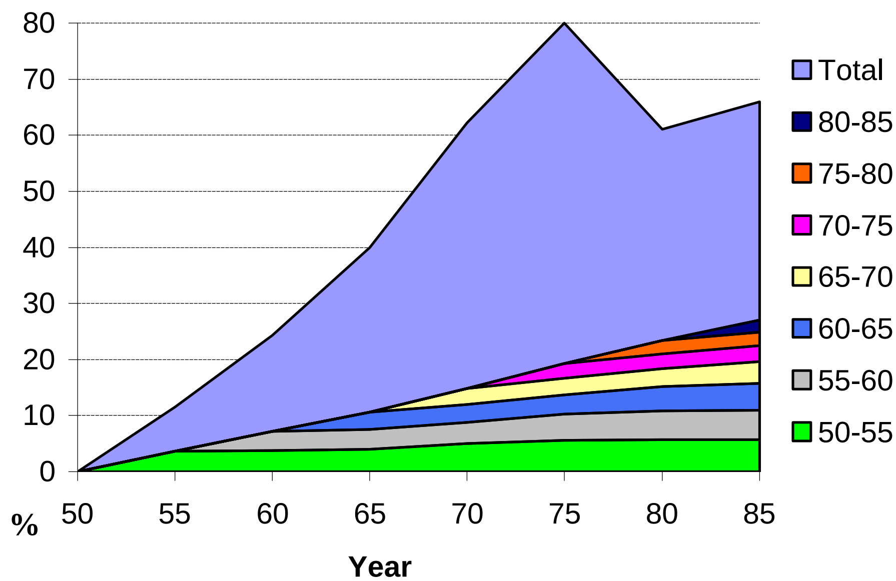


CONCLUSIONS

With regard to the long-term relation between health and economic growth, this study confirms the results of the study on Mexico, namely that there exists long-term conditional Granger causality from health to economic growth. The horizon of this phenomenon is not exhausted by the available information, which includes a lag of up to 25 years on the initial period, that is, a total of 30 years of lagged effects.

With regard to the coefficients of the impact on growth that the different age groups exert, there is a marked consistency between the results for Brazil and Latin America, in which the largest coefficients correspond to young age groups and the most significant to women. When the real changes in health are taken into account, the results coincide with those of the Mexican study, in that adult health has a considerable long-term impact, which could be linked with intergenerational processes.

Figure 10
Approximate Contribution to Income Growth of 5-Year-Period Health Increments (1950 to 1985, Latin America)



The impact of actual health increments at the longest lag of the analyzed period is found to be considerable, having an order of magnitude of between 0.8 and 1.5% of annual economic growth. The impact that different age and sex groups may have depends on the health improvements each group may experiment. In particular, it is notable that health improvements in the old can contribute more than other age groups.

The results in the different studies show a high degree of consistency. Thus the detailed and complex phenomena observed for Brazil, in which health has an impact on income, education, economic participation and fertility, as well as the causality results for Mexico, probably take place not only in these countries, but also in the Latin American region as a whole.

Conclusions and Policy Recommendations

David Mayer
Humberto Mora
Rodolfo Cermeño

The five research projects we present here conclude that health plays an important role in economic growth.

In the basic regressions of the Barro type (1991, 1996) on Latin America, as well as in the regressions for Brazil, Colombia, and Mexico, health plays a stronger role than does education. The extreme limits test of Levine and Renelt (1992), which may be considered to be too strict, is confirmed in the case of Brazil for YLPD (Years Lost to Premature Death), and in no case for an educational indicator. From the point of view of economic theory, these analyses use relatively lax functional specifications, in particularly when compared with the augmented Solow model, which incorporates health as a determinant of human capital.

We include health in an application of the method of Islam (1995), who tests the augmented Solow model of economic growth of Mankiw, Romer and Weyl (1992). The results may be considered as strong evidence of a reciprocal relationship between health and growth, given that significant results are obtained in the context of the economic constraints implied by a Solow-type growth model. In this same application, and contrary to expectations, the relationship between education and growth is generally negative, possibly because the indicators capture the level of education in age groups where it represents investment.

The panel regressions based on the method of Islam (1995) test an augmented Solow model in which health contributes to human capital. The results can be considered as evidence of a positive relation between health and growth, since significant results are obtained in the restricted framework implied by the economics of the model.

The study on the long-term correlation between health and future income shows a very strong link for Mexico for the years 1955–1995, with lags of up to 15 and 20 years. These imply that there exists conditional Granger causality. The effects, which can be of up to 2% annual growth, cluster around the health of the economically strongest segment of the population and on maternity. The inverse causal relationship, from income to changes in health, also exists, although it is detected to be smaller. A larger residue is also present in these regressions. Improvements in health seem to depend more on public policies and on technological and behavioral changes, as in the case of fertility.

The study on the role of health in the economic and demographic transition of Brazil (1980–1995) reveals complex relationships that induce both positive and negative correlations for all the indicators. This fact in itself explains the difficulties encountered when trying to find consistent and significant results in studies with a lower level of information, such as state level studies or studies using samples of countries. With more information, a consistent picture emerges wherein health plays a role that is not too different from what common sense would indicate.

Health increases income growth by fostering education, productivity, and economic participation, especially for women. The maximum positive range detected for these components, in a context of low growth and low and even negative health improvements, was 0.35%, 0.19% and 0.13% percentage points of income respectively. The channel with the largest contribution is education. These effects can be larger in the long term, as is established by the studies on Mexico and Latin America.

However, health increases fertility at low and medium incomes. This tends to reduce both income and schooling, except at high-income levels. The choice between working and staying at home, which occurs due to maternity, plays an important role as well.

Health also has an impact on income distribution. In Brazil, its poor distribution leads to divergence processes in the income of the lowest 40% of the population. The lowest 10% even see their income reduced due to increases in economic participation that lead to reductions in real wages.

It is important to observe that the coefficients obtained by female health indicators tend to be larger and more significant. Health has economic impacts through maternity and female participation decisions, which may also have secondary impacts on education. Thus, studies on the impact of health intersect with studies on woman and the family.

The study on the long-term correlation between health and future income in the Latin American case confirms then results of the study on Mexico, this time for a 25 year horizon. This study also reproduces the distribution of the regression coefficients by age groups and sex obtained for Brazil. It also shows that once the real increments in health are taken into account, the contribution of adult and old age health improvements is the highest. The relative importance of male and female health depends on the health improvements that actually take place. Finally, the impact of the health improvements lost during the 1980-1990 decade may have a considerable impact on long-term economic growth.

Economic growth is linked to higher levels of health. Due to characteristics inherent to the health sector, an optimal allocation of investment resources in health necessarily involves the implementation of adequate public policies that not only make the health sector efficient but also take into account its effects on growth. These are long-term effects, an important portion of which occur through improvements in human capital in education. Since this is another sector in which public policies are important, the efficiency problems are compounded. Except in the high income levels, health may increase fertility and through this mechanism curb the increase in *per capita* income and education, which means that consistent policies must be maintained in health, education, and fertility. Policies that support women during motherhood and make the choice between working and staying at home easier may also be successful. Health policies should also take distributive aspects into account. If the benefits do not reach the lower income population, they contribute to a polarization of income and cease to have an effect on those sectors of the population for whom health investments produce the highest yield.

With regard to the magnitude of the aggregate impact of health on economic growth, the last three studies (on Mexico, Brazil and Latin America) give a consistent picture, once the different contexts are taken into account. The 2% estimate for the Mexican case corresponds to a high growth environment with considerable health improvements. In the Latin American case, with an estimate of between 0.8% and 1.5%, the environment is one of medium growth with good health improvements. However, the parameters obtained for this case would yield a long-term contribution of only between 0.4% and 1% for the health improvements of the 1980–1990 decade. Finally, for the case of Brazil, which corresponds to this last period, and for which the environment is of low or negative growth, the total short term contribution obtained is a maximum of 0.67%, without taking into account some possible negative effects. In any case, these magnitudes must be considered as tentative, because the methodologies applied are not designed specifically for the purpose of estimating them, and because of the deficiencies of the economic indicators in the databases.

Given the complexity of the interactions of health, and its relationship to education, the efficient implementation of public policies in a changing environment requires that information be sufficient to evaluate effects, costs, and benefits. The database we have worked with here represents a bare minimum that is nonetheless absent in practically every country in Latin America. We believe that the systematic development of information sources of the breadth and depth necessary for these purposes should be promoted systematically both inside and outside the sphere of public services and health. This would yield enormous results. These sources should systematically cross-reference demographic (including maternity) and health indicators with information on education, economics, and the effect of public subsidies. Information should be obtained comprehensively from broader household surveys and from the institutions that furnish the various public services.

We now address the subject of efficiency in the allocation of resources among age groups. Recall first that economic growth is not an objective in itself. The theory of economic growth rests on the optimal allocation of consumption over time, in keeping with individual preferences. In this context, for example, health may increase the number of women who choose to remain at home rather than work, as occurs in high-income households in Brazil due to a wealth effect; and a lower income may result. Far from being a negative effect, what we see here is a phenomenon whereby households are better able to pursue their preferences. Analogously, the differentiated impact of health improvements by age and sex on increases in income, economic participation and education only imply that an *additional* proportional weight should be given to the health of these groups, accounting for the *intertemporal aspect* of the allocation of health resources. A topic for subsequent research could be the rigorous determination of these weights, which would also provide the economic basis for the weights involved in the formulation of life-year-type health indicators and would estimate the benefits to be obtained from using these to rationalize public spending. A related subject would be the precise determination of the preferences that underlie the individual decisions that lead to the dynamics we have analyzed. This requires the development of theoretical and technical tools that include both the consideration of epidemiological risks and of household decisions on fertility, on whether mothers work or stay at home, and on education versus work at different stages in the family cycle. It is feasible to base this study on the information generated by this project.

Besides efficiency, technological absorption and development play an important role in the health sector, as they do in economic growth. It must be taken into account that facilitating the implementation of new health technologies, as well as updating existing health systems, has the potential of generating large benefits in terms of health and future economic growth, at a cost which may be relatively low.

It is clear that to carry out systematic analyses that incorporate the differences and socioeconomic and demographic characteristics of the various countries, it is necessary to count with enough comparable and periodic information. Such information must be obtained from household and/or life quality surveys including questions on health, income, expenditure, availability of public services, economic participation, childcare, etc., for all members of the household. Based on this information, it would be possible to evaluate, in each period, the successes and limitations of those policies most closely related to economic growth, the alleviation of poverty, and development. It is to be expected that the relations between economic growth and health, analyzed in this study, may differ between countries and that therefore the emphasis on specific population groups which public policies must have could also be different.

Surveys incorporating measures of the state of health and of the use of health services by household members have been developed. Nevertheless, there exists an ample potential to obtain information that can be combined with other sources so as to periodically measure such indicators as YLPD or years of healthy life. In this study it was possible to establish that such precise indicators can capture relationships with economic variables which are not significant when less accurate indicators are used.

This study analyzes the relationship between health and economic growth. However, it is necessary to investigate the processes that determine the conformation of a population’s particular state of health, or, in other terms, how health capital is accumulated. The questions raised by this subject are quite numerous. For example, it is necessary to analyze whether different subsidy schemes have different effects on the population’s health; whether the access to health services is differentiated across socioeconomic groups and service systems or conditioned by employment; whether the insurance system induces the selection of risks among the population; etc.

From the economic point of view, health and education are both important components of human capital. However, the existing measures of one or the other variable do not incorporate the simultaneous determination of these two dimensions of human capital, nor their reciprocal interactions. The development of coherent and integral measures of these two dimensions of human capital as a factor of production is very important. However, besides productivity, health has other important channels of impact. One of them is education, in which important temporal lags exist. Another is female economic participation. Indicators complementary to health capital can be developed to account for the role of health as a factor of production of education, and as a conditioning factor of female participation. Together, these different measures would highlight different aspects of a population's health. They could be used as observational variables for the evaluation of the effects of public policy in the areas of education and health, as well as in the analysis of the relation of health with other social, demographic and economic variables. The measurement of the component of human capital that is determined by education has contributed valuable instruments for the analysis of such economic relations and for policy design. However, a notable gap exists in relation to the economic effects of health.

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NOTES

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[1] The full text of each of the studies summarized in this document is available through the Pan American Health Organization.

[2] The information on health was prepared by Dr. Rafael Lozano, FUNSALUD; Dr. Suzanne Duryeau, IDB; Dr. Maria Helena Prado de Mello Jorge, Departament of Epidemiology, University of São Paulo, Brazil; and Dr. Henry Mauricio Gallardo of the Corona Foundation in Colombia.

[3] For an extensive list of works on economic grown that analyze the impact of different variables of interest, see for example, Levine and Renelt (1992).

[4] Levine and Renelt also consider the share of investment in GDP a potential variable to be included in Matrix I. However, for the reasons explained by these authors, this variable will not be included in the regressions. This is primarily due to the ambiguity of the relationship: investment as a determinant of economic growth, or economic growth as a determinant of investment. If investment is included, the only mechanism through which other variables affect growth is through more efficient resource allocation.

[5] For life expectancy we use the transformation – ln (80 – EV); for the other health indicators we use logarithms.

[6] We used least square estimates for 31 states of Mexico, i.e., all the states including the Federal District, with the exception of the state of Campeche. We excluded this latter state since the oil boom it experienced and is recorded as part of its income introduces considerable distortions in the regressions.

[7] We write the results by their confidence intervals according to the following scheme. Better than 1% ($|t| \geq 2.61$): bold face; between 1% and 5% ($1.97 \leq |t| < 2.61$): bold face and italics; between 5% and 10% ($1.65 \leq |t| < 1.97$): italics.

[8] The variable is − ln(80 − EV), as above, and minus the rate of growth of (80 − EV) is estimated. The independent variables are life expectancy in the initial period (for the same sex); *per capita* income, either at the beginning of the period or with a lag of 5, 10, or 15 years; indigenous language; public spending by unit of income and the percentage of the population under the age of 4.

[9] This is the work of Dr. Suzanne Duryeau of the IDB.

[10] This is the work of Dr. María Helena Prado de Mello Jorge, Department of Epidemiology, University of São Paulo, Brazil.

[11] 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%.

[12] 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.

[13] 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.

[14] 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.

[15] The five variables are GDPSH5, PYR, INVSH5, GOVSH5 and FERT from the well-known Barro Lee database (available on the World Wide Web). The same database is used in this project for the Latin American economic indicators, and is described in the second section of this paper.

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[16] We replaced the non-significant coefficients that occur for the 5 year old age groups and for the 55 year old female age group with the average of the neighboring coefficients.

[17] Examination of the health increments over the period 1950 to 1990 shows that the possibility that health improvements decrease in the long-term plays a small role in the low performance of the 1980–1990 decade.

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