

CONVERGENCE AND ECONOMIC GROWTH IN MÉXICO

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ABSTRACT

Recently, much attention has been paid in the literature on economic growth to the phenomenon of conditional convergence or the tendency of regional economies with lower level incomes to grow faster, conditional on their rate of factor accumulation. This study uses the standard neoclassical growth theory, to obtain the empirical approximation of the convergence hypothesis in human capital between the 31 states and the Federal District in Mexico, using educational indices. The study finds that the annual rate of convergence of human capital per capita in Mexico ranges from 3.55% to 4.58%. It also estimates the convergence of income per capita conditional on human capital variables.

RESUMEN

Recientemente, se ha puesto mucha atención en lo escrito sobre crecimiento económico, el fenómeno de convergencia condicional o la tendencia de las economías regionales con niveles bajos de ingreso a un crecimiento rápido, como condicional en su tasa de acumulación de factores. El estudio utiliza teorías neoclásicas de crecimiento estandarizadas, para obtener la aproximación empírica de la hipótesis de convergencia sobre el capital humano entre los 31 estados y el Distrito Federal en México, utilizando índices de educación. El estudio encuentra que la tasa anual de convergencia de capital humano per cápita en México oscila del 3.55 al 4.58 por ciento. También estima la convergencia de ingreso per cápita condicional en variables de capital humano.

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INTRODUCTION¹

An important economic question for Mexico is whether or not poor regions tend to converge towards rich ones. Another important question is whether or not economic growth is driven by the role of human capital in the form of education.

Economic growth has been explained by many components. For example, the rate of investment, the rate of return to capital, the rate of growth of the labor force in numbers or in hours worked, the contribution of human capital or of the increment in the average quality of labor, and the residual representing real cost reduction. These are all sufficiently different from each other. This is why Harberger (1998) recommends the study of each component of growth separately.

The economic gap between Mexico and other nations has widened notably over the past quarter century. In 1960, Mexico's per capita GDP was practically the same as Spain's and more than twice that of the Republic of Korea. In the 1990's, Mexico's per capita GDP is estimated to be barely one quarter of Spain's and a third of Korea's.² This has occurred both because Mexico has had a relatively low rate of economic growth since the early 1970s and because the country has maintained a relatively high rate of demographic growth in most regions.^{3 4}

Fischer (1991) states that macroeconomic policy matters for growth, but not that only macroeconomic policy matters.⁵ For Mexico, reasonable macroeconomic

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² In 1997, the performance of the economy exceeded every expectation, real GDP grew 7 percent, the strongest performance since 1981. Furthermore, the 97 economic expansion was accompanied by a significant decrease in inflation, low fiscal and current account deficits and by higher domestic savings. Nevertheless, Mexico has not recovered the level of economic well being it had before the 1994 recession.

³ Given Mexico's current population and demographic trends, and assuming a sustained annual rate of economic growth of 5%, it would take around twenty years to double the level of per capita income in Mexico.

⁴ Mexico had a rapid demographic growth beginning in 1930. In 1900, 13 million people lived in Mexico. By the year 2000, the estimated population will be around 99 million (25 million in the Mexico City Metropolitan Area). Source: INEGI.

⁵ Olson (1996), mentions that the large differences in per capita income across countries cannot be explained by differences in the access to the world's stock of productive knowledge or to its capital markets, by differences in the ratio of population to land or natural resources, or by differences in the quality of the marketable human capital or personal culture. By eliminating the factors of production as the possible explanations of most international differences in per capita income the other remaining explanation will be differences in the quality of institutions and economic policies. There is direct evidence of the linkage between better economic policies and institutions and better economic performance.

mic stability is necessary for sustained growth. But beyond the overall economic strategy pursued by the country, the market and outward orientation, and the size and role of government both in providing physical and social infrastructure, especially for human capital is crucial in order to achieve economic growth.

The growth of any economy depends on increases in its factors of production or the additions received with each passing year by the reservoir of physical and human capital used to produce goods and services within that economy. Growth is similarly influenced by the increased productivity of the factors of production. In any economy, there are only two possible sources for obtaining those resources: external savings and internal savings. Mexico's painful experience has shown that excessive dependence cannot be placed on external savings to finance domestic investment and consumption. External savings are necessary, but they should not exceed reasonable limits. Thus, the availability of internal savings is a factor of crucial importance in determining investment in the economy and, consequently, its growth rate.

While capital is often thought of as machinery and inventory, the stock of productive knowledge embodied in the workforce is also a form of capital. The country's human capital assets also influence growth, and can increase if greater resources are available. These resources must necessarily come from growth.⁶

Mexico is a small open economy where there are plenty of natural resources which are a poor substitute for highly skilled labor. This has led the economy to specialize in resource intensive sectors and to invest too little in human capital. Investment will encourage economic growth to finance greater investment in the human capital that sustains the entire general growth process.

Investments in education, training, and organizational experiments involve forgoing some consumption today in order to create better possibilities for production and consumption in the future. One might distinguish between the stock of knowledge and its embodiment in workers and organizations. The stock of knowledge available to an economy depends on its own investments in generating knowledge (scientific research) and its access to knowledge in other economies around the world. The knowledge embodied in workers in an economy depends on investments in education, training, and other forms of knowledge dissemination.

Within a growth accounting framework, human capital does not appear to be

⁶ Mexico's human capital assets are predominantly financed by domestic savings.

a major factor contributing to growth in the high performance East Asian economies. These economies have had relatively rapid growth in their wage weighted stock of workers' years of schooling.

One might argue, however, that education, training, and new ideas have contributed to growth in the high performance East Asian economies compared to other developing economies, in ways that are not captured by standard growth accounting methods. Some economists have emphasized that the spread of knowledge internationally does not happen automatically and that the acquisition of new ideas requires specific policies aimed at trade openness.

Some theoretical models of economic growth, such as Lucas (1988), Becker, Murphy and Tamura (1990), Barro and Lee (1993)⁷ and Mulligan and Sala-i-Martin (1992), emphasize the role of human capital in the form of educational attainment. Lucas (1990) mentions that great differences in per capita income are mainly explained by differences in human capital per capita, including cultural traits and skills of people in different regions. The average level of human capital in the form of occupational skills or education in a society can obviously influence the level of its per capita income. This study uses the standard neoclassical growth theory convergence hypothesis, to obtain the first approximation of the convergence in human capital between the 31 states and the Federal District in Mexico, using educational indices. It compares convergence in human capital growth for periods before and after trade liberalization. For the investigation of convergence, the recent work of Barro and Sala-i-Martin (1991, 1992) is used to analyze the convergence hypothesis in human capital.⁸

The present study is divided in the following parts. First I explain the endogenous and neoclassical growth literature and models, in order to compare and derive the convergence hypothesis. I derive the neoclassical model used, based on the model of Mankiew, Romer and Weil, and the Solow model. This paper explains the methodology used in the econometric analysis and estimates the annual velocity of conver-

⁷ Barro and Lee (1993), constructed estimates of educational attainment by sex for persons aged 25 and over. The values applied to 129 countries over five year intervals from 1960 to 1985.

⁸ Barro and Sala-i-Martin (1991, 1992) analyzed the striking reduction in the dispersion in per capita incomes among states in the U.S. since 1880. They used the neoclassical growth model as a framework to study convergence across the 48 contiguous U.S. states. For the U.S. states, they estimate the rate of convergence of per capita personal income from 1880 to 1988 to be around 2 percent per year within and across four geographical regions. They also find a rate of convergence of about 2 percent per year for per capita GDP across 73 regions of seven European countries from 1950 to 1985.

gence in human capital in Mexico for the period just before trade liberalization and after trade liberalization. Finally, some conclusions are formulated.

I. THE CONCEPT OF CONVERGENCE, EMPIRICS OF CONVERGENCE AND ECONOMIC GROWTH

In general terms, the economic literature has two types of models to explain growth in an economy, the neoclassical and endogenous growth models.⁹ One of the ways to distinguish the models is to point out the difference in the growth rate of the economy in the steady state. But neither the old nor the new growth theory leads us to expect either the observed overall relationship between the levels and rates of growth of per capita incomes or how the absolute gap in per capita growth has increased between regions over time.

The new growth theory attempts to deal with the major shortcomings of the traditional growth theory. It attempts to endogenize the role of technical change into the model. In general, the endogenous growth models do not have anything in their structure that predicts that the most rapid growth will occur in a subset of low income countries. Endogenous growth theory is a criticism of globalization. Some liberal economists have interpreted the association of trade and growth as one where causation runs from freer trade to faster trade growth to faster economic growth, or the export driven development will trickle down to all parts of the economy, and eventually, all countries will be at the same level.

Other economists mention that endogenous growth theory offers hope to developing economies, and alternative ways to develop without becoming dependent on trade. Traditional theories of growth focus on trade as the engine of growth; endogenous growth theory focuses on education, on-the-job training and development of new technologies for the world market. Human capital is almost always identified as a crucial ingredient for growing economies, but empirical investigations of cross regional growth have done little to clarify the dimensions of relevant human capital or any implications for policy.

⁹ Modern growth theories have been divided into 3 types stressing: civil institutions, the state or the market. Six cornerstone economic models include the Harrod Domar, Keynesian, Two Gap, Solow, Endogenous, and the dual sector economy models (including classical and neoclassical components).

Theoretical Model of Human Capital

In the recent economic growth literature, the basic question has been to determine the existence of convergence in per capita income between countries. Nevertheless, the hypothesis of convergence can be used to answer the question of human capital convergence between regions. If the level of human capital is related inversely to the rate of growth of human capital, then this could be an indicator for the existence of decreasing returns in human capital. The rate of growth for the more advanced regions will be lower than the rate of growth for the less advanced regions.¹⁰ As time passes, the level of human capital per capita will remain constant in a particular moment (steady state). In this case, the rate of growth of human capital will be equal to the rate of population growth.

To analyze the hypothesis of convergence in the rate of growth in human capital per capita, I develop a model that incorporates the Solow growth model to the existence of human capital in the factors of production.

I assume that the product for an economy can be represented by Y . This product can be obtained by the transformation of the following factors of production: K (physical capital), H (human capital), and L (labor). This transformation can be represented by the following Cobb Douglas production function:

$$1) \quad Y = A K^\alpha H^\beta L^\gamma$$

where A is the technological parameter. By assuming constant returns to scale ($\alpha + \beta + \gamma = 1$), the factors of production will show decreasing returns to scale.¹¹

The functions of physical and human capital accumulation are the following:

¹⁰From a partial equilibrium analysis for a small country, where human capital accumulation cannot be financed by borrowing, Barro, Mankiw and Sala-i-Martin (1995) show that low human capital countries grow faster. The persistent income inequality demonstrated by these authors generalizes to a steady state general equilibrium.

¹¹In the standard Solow growth model, diminishing returns to capital per worker has important implications for growth dynamics. Diminishing returns to capital means that capital accumulation cannot be a source of constant growth. As more capital per worker is accumulated, the additional output produced decreases, while the output required to cover capital depreciation and to equip new workers with capital constantly increases. Eventually any given investment rate will become sufficient only to cover capital depreciation and the capital needs of new workers. Thus investment will not contribute to increasing output.

$$2a) K = S_k A K^\alpha H^\beta L^\chi - \delta K$$

$$2b) H = S_h A K^\alpha H^\beta L^\chi - \delta H$$

where S_k and S_h represent the saved fractions of physical and human capital income respectively (with $0 < S_k, S_h < 1$), and assuming a depreciation rate for K and H . The rate of depreciation and the savings rates are considered to be exogenous and constant.

By defining physical capital and human capital per capita as $K/L = k$ and $H/L = h$, and by dividing equation 2a and 2b by L , equations 3a and 3b are obtained:

$$3a) K/L = S_h A k^\alpha h^\beta L^{\chi + \alpha + \beta - 1} - \delta k$$

$$3b) H/L = S_h A k^\alpha h^\beta L^{\chi + \alpha + \beta - 1} - \delta h$$

If the rate of population growth is defined as $L/L = n$, the accumulation of physical and human capital per capita will be defined as the following:

$$4a) k = d(K/L) dt = K/L - K L / L^2 = K/L - kn$$

$$4b) h = d(H/L) dt = H/L - H L / L^2 = H/L - hn$$

Substituting 4 in 3 yields the functions that indicate the terms of physical and human capital per capita accumulation.

$$5a) k = S_k A k^\alpha h^\beta L^{\chi + \alpha + \beta - 1} - (\delta + n) k$$

$$5b) h = S_h A k^\alpha h^\beta L^{\chi + \alpha + \beta - 1} - (\delta + n) h$$

If the rate of growth of k and h are defined by $g_k = k/k$ and by $g_h = h/h$, then by dividing 5a and 5b by physical capital per capita and human capital per capita respectively, yields

$$6a) \gamma_\kappa = S_k A k^{\alpha - 1} h^\beta L^{\chi + \alpha + \beta - 1} - (\delta + n)$$

$$6b) \gamma_\eta = S_h A k^\alpha h^{\beta - 1} L^{\chi + \alpha + \beta - 1} - (\delta + n)$$

The functions can be represented by:

$$7a) \gamma_{\kappa} = S k A k^{\alpha-1} h^{\beta} - (\delta+n)$$

$$7b) \gamma_{\eta} = S h A k^{\alpha} h^{\beta-1} - (\delta+n)$$

These expressions determine the dynamic adjustment towards the steady state of k and h , demonstrating that the physical and human capital per capita are inversely related to the rates of growth.

To determine the velocity of adjustment of human capital towards the steady state, an assumption is made about the equality of the marginal product of physical and human capital per capita,¹² $k = (\alpha/\beta) h$.¹³ By substituting in 7b) the following equation is obtained:

$$8) \gamma_{\eta} = S h A^I h^{\alpha+\beta-1} - (\delta+n)$$

where $A^I = A (\alpha/\beta)^{\alpha}$

By expressing 8 in logarithms:

$$9) \gamma_{\eta} = d(\ln h)/dt = S h A^I e^{(\alpha+\beta-1) \ln h} - (\delta+n)$$

Using a Taylor series expansion around the logarithm of human capital per capita in the steady state ($\ln h^*$) yields:

$$10) \gamma_{\eta} = S h A^I e^{(\alpha+\beta-1) \ln h^*} - (\delta+n) + (\alpha+\beta-1) S h A^I e^{(\alpha+\beta-1) \ln h^*} (\ln h - \ln h^*)$$

In the steady state $S h A^I e^{(\alpha+\beta-1) \ln h^*} = (\delta+n)$.

By substituting in 10) the following equation is obtained:

$$11) \gamma_{\eta} = (\delta+n) - (\delta+n) + (\alpha+\beta-1) (\delta+n) (\ln h - \ln h^*)$$

By defining $(1 - \alpha + \beta) (\delta+n) = \mu$, gives:

$$12) \gamma_{\eta} = -\mu (\ln h - \ln h^*)$$

¹²Both would be equal in the case of no credit constraints. The investment in physical and human capital in equilibrium should be equal.

¹³The return on physical and human capital are relatively close in Mexico.

The parameter μ in equation 12, will measure the velocity of convergence for a given level of human capital towards the steady state. This parameter depends on the depreciation rate, the level of population growth and physical and human capital participation levels in the product.

In equation 12, $\gamma \eta$ shows an instantaneous growth rate for human capital per capita. In order to estimate the velocity of convergence from two points in the trajectory towards the steady state, the following transformation of 12) is used:

$$13) \gamma \eta = d(\ln h)/dt = -\mu \ln h + \mu \ln h^*$$

$$14) [d(\ln h)/dt] + \mu \ln h = \mu \ln h^*$$

Expression 14 is the differential equation, where the factor of integration corresponds to:

$$e^{\mu t} dt = e^{\mu t}$$

By multiplying the factor, the expression becomes:

$$15) [d(\ln h)/dt] e^{\mu t} + \mu \ln h e^{\mu t} = \mu \ln h^* e^{\mu t}$$

$$16) d(\ln h e^{\mu t})/dt = \mu \ln h^* e^{\mu t}$$

$$17) \ln h e^{\mu t} = \int \mu \ln h^* e^{\mu t} dt$$

$$18) \ln h e^{\mu t} = \mu \ln h^* [(1/\mu) e^{\mu t} + C]$$

$$19) \ln h = \ln h^* + C \mu \ln h^* e^{-\mu t}$$

Evaluating C for h_0 in $t=0$ gives:

$$20) C = (\ln h_0 - \ln h^*) / (\mu \ln h^*)$$

Substituting 20 in 19 gives:

$$21) \ln h = \ln h^* + (\ln h_0 - \ln h^*) / (\mu \ln h^*) \mu \ln h^* e^{-\mu t}$$

$$22) \ln h = (1 - e^{-\mu t}) \ln h^* + e^{-\mu t} \ln h_0$$

TABLE I. *Notation.*

Y	Product for an economy
K	Physical capital
H	Human capital
L	Labor
A	Technological parameter
K, H	Physical and human capital accumulation
Sk and Sh	Represent the saved fractions of physical and human capital income respectively (with $0 < S_k$, and $S_h < 1$)
δ	Assumed depreciation rate for K and H. The rate of depreciation and the savings rates are considered to be exogenous and constant.
k, l	Physical capital and human capital per capita. $k = K/L$ and $h = H/L$
\dot{k}, \dot{h}	Accumulation of physical and human capital per capita.
N	$N = L/L$ rate of population growth.
γ_k, γ_h	Rate of growth of physical and human capital.
$\chi + \alpha + \beta = 1$	Constant returns to scale in production.
$K = (\alpha/\beta)h$	An assumption is made about the equality of the marginal product of physical and human capital per capita.
μ	Measure of the velocity of convergence for a given level of human capital towards the steady state. Also $(1 - \mu)$ $(+\mu)$. It governs the speed of adjustment towards the steady state. The higher μ , the greater the responsiveness of the average growth rate to the gap between $\ln(h^*)$ and $\ln(h(0))$, that is, the more rapid the convergence to the steady state.
$\gamma_b = -\mu (\ln h - \ln h^*)$	γ_b shows an instantaneous growth rate for human capital per capita.
$1/T \ln (h(t) / h(0))$	The average growth rate of h over the interval between dates 0 and T.
$\ln(h^*)$ and $\ln h(0)$	Average growth rate gap. The model implies conditional convergence.
T	A time date.
X	Steady state value. With conditional convergence given x and h^* , the growth rate is higher the lower $h(0)$. Growth rate of the technological change (exogenous).

By subtracting $\ln h_0$ in 22) gives:

$$23) \ln h - \ln h_0 = (1 - e^{-\mu t}) \ln h^* + (1 - e^{-\mu t}) \ln h_0$$

In this expression, the parameter m governs the speed of adjustment towards the steady state. This expression is similar to the functional form of the Mankiw,

Romer and Weil (1992)¹⁴ expression used to estimate convergence in physical capital.

The average growth rate of h over the interval between dates 0 and T is

$$24) \frac{1}{T} \ln (h(t)/h(0)) = x + (1 - e^{-\mu t}) (1/T) \ln (h^*/h(0))$$

Where x is the steady state value. The higher m , the greater the responsiveness of the average growth rate to the gap between $\ln (h^*)$ and $\ln (h(0))$, that is, the more rapid the convergence to the steady state. The model implies conditional convergence. In other words, given x and h^* , the growth rate is higher the lower $h(0)$.

By presenting decreasing returns in both types of capital in the economy, there is a theoretical basis for an inverse relation between human capital per capita and human capital per capita rate of growth. This property is used to analyze convergence between regions with respect to human capital per capita in education.

Empirical Model of Human Capital

To test the convergence hypothesis of human capital per capita and to estimate the annual velocity of convergence, I propose a new setup and estimate a new model that includes only the rate of human capital growth and convergence in human capital.¹⁵

The following non linear model is derived from equation 24.

$$25) \frac{1}{T} \ln (H_{t,t+T}/H_{it}) = (\ln (H_{it})) (1 - e^{-\mu t}) (1/T) + u_{it}$$

¹⁴In an influential paper Mankiw, Romer and Weil (1992) argue that evidence on the international disparity in levels of per capita income and rates of growth is consistent with a standard Solow model, once it has been augmented to include human capital as an accumulable factor. Their estimates are based in the log linear approximation around the steady state of an augmented Solow model. Mankiw, Romer and Weil empirical analyses uses the log of the change in income from 1960 to 1985 as the dependent variable, and the following explanatory variables: log of income in 1960, average investment to GNP ratio over the 1960 to 1985 period, measure of population growth in logarithms, measure of percentage population in school and dummies for non oil, industrialized nation and OECD nation.

¹⁵Romer says that if macroeconomists look only at the cross regional regressions deployed in the convergence controversy, it will be easy to be satisfied with neoclassical models in which market incentives and government policies have no effect on discovery, diffusion, and technological advance. But if we make use of all of the available evidence, economists can make progress toward a complete understanding of the determinants of long-run economic success. This will offer policy-makers something more insightful than the standard neoclassical finding of more saving and more schooling.

where:

H_i is the level of human capital per capita in region i , measured as the population with a certain human capital level in a determined age range, divided by the total population in that same range.

t is the initial time.

T is a period of time.

U_i is an error term for region i . The error terms will be assumed to be iid. with zero mean and variance σ^2 .

This equation applies to discrete periods to economy i and is augmented to include a random disturbance. Like in Barro and Sala-i-Martin (1995), the reason one should use this model instead of a linear model is that the parameter m shows directly the velocity of convergence.¹⁶ When taking discrete points in time, the velocity of convergence will be independent of the period of time. In the linear model, a subsequent larger period will have a lower value of the coefficient.

To estimate the velocity of convergence, nonlinear least squares were used in the analysis. When looking for the data set at the state level, only levels of instruction were found, without reference to the specific capacity of the inhabitants of each state. To conduct the estimation, only percentage variables or number of persons with a certain educational characteristic relative to the total population were used. This term represents a per capita relation.

The data used was obtained from the Mexico's Population Census 1960, 1970, 1980, 1990 and the Conteo of 1995. Data from the Ministry of Education was also used. The educational indicators are:

Literate, refers to the percentage of people that know how to read and write.¹⁷

Some level of instruction refers to the percentage of people that completed a level of education in the National Educational System.

Elementary is a variable that show the percentage of people with elementary studies completed.

Post Elementary is a variable that refers to the percentage of people that have more that elementary studies.

¹⁶ Although the coefficient μ can vary across regions, this is not taken into account in the analysis. The parameter A in equation 1 does not affect μ .

¹⁷ In 1920, 70% of the population didn't know how to read and write in Mexico. In 1998, 90% of the Mexican population know how to read and write. The level of instruction of the adult population in 1930 was of one year. In 1998, the national average was 7.2 years of schooling, with 92% of the children going to school.

For each indicator, two regressions were estimated, one for the 1960-1990 period and one for the period 1965-1995 to include the period of free trade in Mexico, in order to revise the changes of trade policies and the velocity of convergence. The interpretation is that the human capital stock may have a positive effect on growth, but one which depends on the ability of the economy to mobilize its human capital activities to produce technical process. This is likely to require a certain degree of trade openness, since the access to innovations produced in the rest of country and the world is in most countries a prerequisite of efficient innovative activities.

The hypothesis to test is that m has a positive sign.¹⁸ If this is not the case, the relationship between the growth rate and the initial level of human capital per capita is null or positive. This would imply that the human capital per capita doesn't present diminishing returns in the product and there would be no convergence between the states of Mexico. The results are presented in the following table:

TABLE II. *Estimated Results for the Velocity of Convergence of Human Capital per capita in the 31 states of Mexico.*

Measure of Human Capital	Period 1960-1990 Before Trade Liberalization		Period 1960-1995 After Trade Liberalization	
	μ	R2	μ	R2
Literate	0.0355 (0.0033)*	0.952	0.0359 (0.0031)*	0.963
Some level of instruction	0.0442 (0.0027)*	0.974	0.0458 (0.0025)*	.968
Elementary	0.0426 (0.0035)*	.948	0.0422 (0.0030)*	.965
Post Elementary	0.0385 (0.0035)*	.927	0.0361 (0.0029)*	.941

*Significance at 5% level.

NOTE: The North American Free Trade Agreement (NAFTA) was signed in 1994.

¹⁸ $\mu > 0$ corresponds to convergence in the sense that poor regions tend to grow faster than rich regions in human capital terms. In the absence of random shocks, convergence to the steady state is direct and involves no oscillations. This property reflects the absence of overshooting in the neoclassical growth model.

A number of interesting results stand out. With regard to the first column for the 30 year period just before trade liberalization, all explanatory variables have the predicted sign and only post elementary education turns out to be insignificant.

The estimates reported in the second column, for the period just after trade liberalization support the hypothesis about the role of trade openness as an explanatory factor of the contribution of human capital to growth. As it can be observed in table I, trade openness has a significant positive contribution in the velocity of convergence of human capital in Mexico.^{19 20}

The results suggest that there exists convergence between the states of Mexico with the four proposed measures of human capital per capita, due to the positive sign in the velocity of convergence or (m) coefficient and the statistical significance of the model. The augmented Solow model for human capital explains more than 90% of the variations in human capital per capita growth in the states of Mexico. The adjusted R2 for the 35 year period increases with respect to the 30 year period, indicating that for longer periods of time (including the trade liberalization gained by the access to NAFTA),²¹ the model explains better the results. The range of the velocity of convergence in human capital goes from an annual rate of 3.55% to 4.58%.²² Human capital convergence will depend on the trade openness of the economy. The data shows cross regional convergence in Mexico; with some persistence, immobility, and polarization, exemplified by convergence club from the wealthier states and Mexico City.²³

Empirical Model of Income Per Capita Convergence

Barro and Sala-i-Martin (1992) use the neoclassical growth model as a framework to study convergence across the 48 contiguous U.S. states. They exploit

¹⁹The null hypothesis is $\mu_{1960-1980} = \mu_{1960-1995}$

²⁰The recent literature of cross country convergence of per capita income has largely ignored international trade. Recent papers by Ben David and Sachs and Werner present evidence consistent with the claim that trade may help cause convergence.

²¹Include a measure of the degree of trade openness by time or region.

²²The implied half life for an annual rate of 3.55% is about 19.5 years.

²³This could have some implications on the nature of human capital externalities. Human capital externalities in Mexico may be spatial in nature, making more efficient the economic life of urban regions with high concentrations of human capital.

data on personal income in the US since 1840 and on gross state product since 1963. The U.S. states provide clear evidence of convergence, but the findings can be reconciled quantitatively with the neoclassical model only if diminishing returns to capital set in very slowly.

There's been quite a lot of convergence within the U.S. during the last one hundred years. The states with high incomes per capita at the end of the 19th century (the far West, the Northeast) grew much more slowly during the last hundred years than those states with low per capita incomes at the end of the 19th century (the South).²⁴ The results for per capita GDP from a broad sample of countries are similar if we hold constant a set of variables that proxy for differences in steady state characteristics.

Regardless of conditional convergence, perhaps the basic fact of modern economic history is massive absolute divergence in the distribution of incomes across countries. Discussions of long-run convergence or divergence have been hindered by the lack of reliable historical estimates of per capita income for poor countries. To draw reasonable inferences about whether incomes have converged²⁵ does not require historical estimates of per capita incomes combined with estimates of current income in poor countries places a binding constraint on their historical growth rates.²⁶

To test the convergence hypothesis of income per capita and to estimate the annual velocity of convergence, the following non lineal model is derived from equation 25.

$$26) (1/T) \ln(Y_{i,t+T}/Y_{it}) = \alpha - (\ln(Y_{it})) (1 - e^{-\mu}) (1/T) + \text{educational variables} + u_{it}$$

Where:

²⁴Similarly, there has been much convergence among the currently high income countries. The puzzle is why so many countries that were very poor 100 years ago are still very poor.

²⁵Empirical evidence suggests a negative answer, displaying a bimodal, ergodic cross-country distribution of income per capita. The poor on average stay poor, but it is still possible to observe intra distribution mobility. The standard neoclassical model, in its augmented versions, do predict club convergence, but cannot explain economic miracles, reversal of fortunes and growth disasters, due to the non ergodic properties of the predicted stationary distribution. In the standard stochastic version of the neoclassical model, every distributional characteristic is fully explained by nature, leaving little room for economics.

²⁶Between 1870 and 1985 the ratio of incomes in the richest and poorest countries increased by 600%, the standard deviation of (natural log) per capita incomes increased by between 60 and 100.

$Y_i t$ is the level of income per capita in region i .

t is the initial time.

T is a period of time.

μ is the velocity of convergence or the average annual rate at which economies get closer to the steady state. The higher the μ , the lower the period of time necessary for the system to reach the long run equilibrium. If $\mu < 1$ the system diverges.

U_i is an error term for region i . The error terms will be assumed to be iid. with zero mean and variance σ^2 .

The educational variables are used to condition the data. The variables used are:

TABLE III. *Estimated Results of the Velocity of Convergence in Income Per Capita conditional to human capital variables in the 31 states of Mexico and the Federal District*

Period	1970-1993	1970-1985	1970-1980	1980-1985	1985-1993	1988-1993
α	-0.0008 (-0.6671)	0.031 (2.04412)	0.046 (1.912221)	0.073 (1.9651)	-0.010 (-0.154815)	-0.056 (-0.93297)
μ	0.014* (1.6286)	0.031* (2.66965)	0.018 (1.2769)	0.074 (3.3491)	-0.014 (-0.619067)	-0.032 (-1.574614)
Elementary	.10572 (0.45752)	0.026328 (0.054561)	-0.08076 (0.088699)	-0.02151 (0.11559)	-0.8378 (0.175953)	0.108087 (0.199103)
Some junior high	-0.36605 (1.85177)	-0.176821 (0.181837)	-0.199977 (0.295608)	0.007461 (0.21249)	0.179284 (0.326657)	0.071830 (0.384583)
Finished junior high	6.01545 (1.85177)	2.43713 (2.16783)	5.120347 (3.524196)	1.3282 (0.9628)	-0.444767 (0.787447)	0.552881 (0.818661)
High school	1.8517 (0.56078)	0.704419 (0.668765)	0.860725 (1.08719)	0.16581 (0.368996)	0.114677 (0.435133)	0.299278 (0.51946)
College	-0.79644 (0.33947)	-0.187491 (0.404835)	-0.456506 (0.65813)	-0.079497 (0.331613)	-0.222821 (0.402699)	-0.421382 (0.475523)
Illiterate	0.017202 (0.00989)	-0.002294 (0.011798)	0.012342 (0.01917)	-0.05778 (0.02389)	0.000676 (0.005627)	-0.000476 (0.001745)
Half life	50.4	22	37.8	9.4	49.8 ²⁸	21.7
R ² adjusted	0.4	0.44	0.221	0.417	-0.068	-0.052
T(years)	23	15	105	5	8	5
Num. of obs.	30	30	30	30	30	30

*Significance at 5% level.

T stats in parenthesis.

Illiterate, refers to the percentage of people that know how to read and write.

Elementary is a variable that show the percentage of people with elementary studies completed.

Some junior high is a variable that refers to the percentage of people that have more that elementary studies, but haven't finished junior high.

Finished Junior High refers to the percentage of people that completed a level of education in the National Educational System.

High School refers to the percentage of people that completed a level of education in the National Educational System.

College refers to the percentage of people that are in college or completed a level of education in University studies.

For the period 1970 to 1993, the conditional convergence m parameter is the 1.4% positive and significant. The results indicate that the states of Mexico can reach a level of long run income.

For the period 1985-1993, the convergence parameter is negative 1.4%, but not significant indicating that states of Mexico were diverging in this period from the long run level in income per capita. In this period of time, Mexico had negative growth rates of income per capita, and a declining percentage of the population that went to elementary and junior high (population from 5 to 14 years of age).

For the period 1970-1993 the half life was 50.4 years. This is the number of years to cover half the distance of the logarithms of income per capita.²⁷ To examine if there has been a regime shift, a formal test for structural break in the series is set at 1985. This test (known as a Chow test) does suggest in some cases statistical difference in the properties of the series in the period 1970-1993 and 1985-1993, which might be part of a more general change and structural break of the economy. For the period 1970-1993 and 1985-1993, the convergence parameter clearly changes.

As for the results of the velocity of convergence regressions in income per capita conditional on human capital variables, the coefficients are not statistically significant for elementary, junior high and high school, especially in the period after 1980. Education as a form of human capital may not be contributing to the convergence in income per capita in Mexico in the post trade liberalization period. Age distribution and government size may have more impor-

²⁷The number of years necessary to cover half the distance of the income per capita will be larger.

tant effects than level of education in explaining the convergence rate for per capita income in Mexico. The current analysis takes age distribution and other variables as exogenous in conditional convergence regressions. Another result is that the average years of schooling may have a very small positive effect on growth. These findings are consistent with an explanation that the age distribution may reflect the growth effects of human capital accumulated through experience.

The fit of the regression, as measured by R^2 , is high for the first two regressions, however the fit is low for the the period after 1985. For the 1985-1993 sample, it is hard to make any qualified statements since the standard errors are large in relation to the coefficients in all cases, hence R^2 adjusted is low. This can be explained by the fact that the 1985-1993 sample is relatively small and above that relatively homogenous, meaning that the variance of independent variables is low.

Have initially poor states grown faster than initially rich states between 1970 and 1993? Our study did find convergence. As expected, the estimated speed of convergence is faster than that found in most earlier studies of regional economies of industrial countries (Australia, Canada, Japan, and the United States), and where the rate of convergence has been found to be about 2 percent per year. Moreover, the speed of convergence of Mexican states is slower than other Organization for Economic Cooperation and Development (OECD) countries, a not so surprising result since one would expect convergence within national boundaries to be faster than across borders.

CONCLUSIONS

The Mexican states provide clear evidence of convergence using human capital variables. These results are somewhat similar to studies for the U.S. and other regions. The value of the velocity or rate of convergence could be important to the educational policies in Mexico, because it is possible to estimate the length of time in which all states will have similar educational indicators. Consistent with one of my previous interpretations, a finding is the supportive role of trade in explaining the contribution of human capital to growth convergence between regions. Policies encouraging the accumulation of human capital, directly sup-

porting R&D activity and ensuring access to international knowledge and markets can improve growth prospects in Mexico.

Further work in the Mexican model of human capital growth should include age structure of regional population.²⁸ Further estimation of convergence between regions in Mexico, should consider technological characteristics. Also migration between states in Mexico could increase the speed of convergence.²⁹

A number of potential causes behind the Mexican economic slowdown could be explored in further research. Some of the causes may include: an increasingly inefficient process of capital formation; a shrinking share of the economy being exposed to international competition; long-run negative effects of activist stabilization policies; rapid growth of the public sector; deteriorating incentives for human capital formation; and weak incentives for implementing the results of R&D efforts. There may be other factors, aside from the forces of demand and supply: like sectorial and cultural composition of a region in Mexico, which could have an important effect on workers' experience premia, acting as externalities in human capital accumulation.

Public policies in Mexico must encourage investment in human capital and regional openness to enhance and speed up the economy's growth rate. Mexico's human capital economic policy should be complemented by financial stability, greater openness and expansion of external markets, increase productivity and income, promote deregulation and competition, stimulate internal savings, and increase the growth in the resources that the different government entities allocate to the formation of human capital.

²⁸Persson (1997) finds robust evidence that age structure matters for subsequent growth in per capita income across the US states 1920-1990. The age groups 25-65 year are positively related to subsequent per capita income growth. Another conclusion is that the average years of schooling affects subsequent per capita income growth positively when age structure is controlled for. Moreover, the estimated speed of convergence (see e.g. Barro and Sala-i-Martin, 1992) increases substantially when schooling and age structure are held constant in the income growth regressions.

²⁹Persson (1997) finds strong and robust evidence of convergence in per capita income across the twenty-four Swedish counties 1906-1990. It is found that migration has a small positive effect on the speed of convergence. Holding net migration constant, the estimated speed of convergence is around 3 percent.

APPENDIX 1. *The following table shows Mexico's demographic growth by regions in the 20th Century.*

Mexico's Demographic growth by regions in the 20th Century

<i>State</i>	1900	1910	1940	1960	1980	1990	1999
<i>National</i>	13607272	1516369	19653552	34923129	66846833	81249645	97441489
<i>Aguaascalientes</i>	102416	120511	161693	243363	519439	719659	945594
<i>B.C.</i>	47624	52272	78907	520165	1177886	16660855	2441316
<i>B.C.S.</i>	0	0	51471	81594	215139	317764	419474
<i>Campeche</i>	86542	86661	90460	168219	420553	535185	7059991
<i>Coahuila</i>	296938	362092	550717	907734	15557265	1972340	2285158
<i>Colima</i>	65115	77704	78806	164450	346273	824510	5820952
<i>Chiapas</i>	360799	438843	679885	1210870	2084717	3210496	3990152
<i>Chihuahua</i>	327784	405707	623944	12226793	2005477	2441873	3003509
<i>D.F.</i>	541516	720753	1757530	4870876	2831079	8235744	8554942
<i>Durango</i>	370307	483175	483828	760836	1182320	1349378	1470091
<i>Guanajuato</i>	1061724	1081651	1046490	1735490	3006110	3982593	4705549
<i>Guerrero</i>	479205	594278	732910	1186716	2109513	2620637	3134218
<i>Hidalgo</i>	605051	646551	771818	994598	1547493	1888366	2241821
<i>Jalisco</i>	1153891	1208855	1418310	2443261	4371998	5302689	6440163
<i>México</i>	934463	989510	1146034	1897851	7564335	9815795	12768360
<i>Michoacán</i>	435808	991880	1182003	1851876	2868824	3548199	4040322
<i>Morelos</i>	160115	179594	182711	386264	947089	1195059	1592627
<i>Nayarit</i>	150098	171173	216698	389929	726120	824643	935035
<i>Nuevo León</i>	327937	365150	541147	1078848	2513044	3098736	3833451
<i>Oaxaca</i>	948633	1040398	1192794	1727226	2369076	3019560	3492056
<i>Puebla</i>	1021133	1101600	1294620	1973827	3347685	412601	5033849
<i>Querétaro</i>	232389	244663	244737	355045	739605	1051235	1369432
<i>Quintana Roo</i>	0	9109	18752	50169	225985	493277	843760

<i>San Luis Potosí</i>	575432	627800	678779	1084297	1673893	2003187	2330020
<i>Sinaloa</i>	296701	323642	492821	838404	1849879	2204054	2538661
<i>Sonora</i>	21682	265383	364176	783378	1513731	1823606	2243013
<i>Tabasco</i>	159834	187574	285630	496340	1062961	1501744	1900809
<i>Tamaulipas</i>	218948	249641	458832	1024182	1924484	2249581	2690093
<i>Tlaxcala</i>	172315	184171	224063	346699	556597	761277	955656
<i>Veracruz</i>	981030	1132853	1619338	2727899	5387680	6228239	7260547
<i>Yucatan</i>	309652	339613	418210	614049	1063733	1362940	1667942
<i>Zacatecas</i>	462190	477556	565437	817831	1136830	1276323	1382624

SOURCES: INEGI, Banamex, Bancomer, Mexico's Ministry of Finance.

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