The Role of Telecommunications Infrastructure and Human Capital: Mexico's Economic Growth and Convergence

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Abstract

In the absence of other information, initial levels of human capital and infrastructure capital in Telecommunications, together with the initial level of per capita income, are strong predictors of a country's economic growth. Incomes across states tend to converge to a common level in the long run by the inclusion of the digital economy. In other words, lower-income states in Mexico will tend to grow more rapidly than states at a higher level of income with consideration of Internet usage and human capital. These effects are robust; when cross state growth regressions are augmented with other variables in Mexico, such as the effects of human and infrastructure capital, we find that both human capital and infrastructure capital, in the form of internet users, have a significant impact on growth rates. Mexico is slowly getting digital infrastructure but some barriers remain in order for the emerging digital economy to play a part in the economic growth of the country.

Mexico has 1.5 million active Internet users, but poverty, education and inequality remain barriers for growth. The results suggest a complementary educational policy and a policy of developing telecommunications infrastructure in developing countries, in order to exploit the benefits of the digital economy. Mexico's poorly developed telecommunications infrastructure is a major impediment to economic growth of its national and states market.

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1. Introduction

Infrastructure capital and human capital play an important role in the economic growth process of a country. However, both infrastructure capital and education provision have particular problems if left entirely to the market. Historically, infrastructure has had the attributes of a natural monopoly with economies of scale in production. Railway lines, road networks, telecommunications networks, and electricity distribution systems require links that represent large fixed costs, with relatively low marginal costs of use. Monopoly problems, together with the problems the private sector can face in raising the large initial capital outlays involved, have led to infrastructure being publicly provided in many countries.

The natural monopoly arguments for public provision have become weaker during the past decade. There has been increased recognition that public provision of infrastructure services can be very inefficient. Without the profit motive, and in the absence of competition, public provisions can be a very high cost method of producing and maintaining infrastructure. In addition, in the absence of market prices, supply may very well fail to respond to demand.

New developments in technology have also been undermining the traditional arguments for public sector provision of infrastructure. Mobile telephones can operate independently of the older landline system. Cable television connections can be used as telephone lines. High bandwidth links are required for Internet data transmission, links that can also be used as telephone lines. The supply of telephone services in developed countries is becoming very competitive as seen in Harris and Kraft (1997) and Waverman and Sirel (1997). In developing countries there have been a number of successful initiatives to deregulate the industry (Spiller and Cardilli (1997)). A competitive private sector telecommunications industry, with regulation of any monopoly elements that remain, seems to be preferred model to follow.

A real problem with the movement to private sector provision of infrastructure in Mexico is the need for continuing government regulation of prices and access to competitors for the monopoly elements that remain. Such regulation has proved to be very complex, since the monopolist usually has many non-price methods through which he can exert market power, and, in addition, may have an information advantage over the regulator. In the presence of real competition these problems are not very worrisome since market discipline can be expected to prevent excesses. However, when there is a lack of real competition there may be a need for a highly sophisticated regulatory institution to oversee the operation of the market and perhaps construct internal markets.

Education in Mexico has also its own sets of problems. In the case of investments in education, there are severe problems of capital constraints for children from poor families. Even if the rate of return to education is high, poor families may lack the collateral required to borrow in order to finance this form of investment. In addition to this market failure argument there is also an argument that the state should intervene in the interests of children.

In addition to the supply-side arguments for public provision there is also the possibility that infrastructure and education create large externalities in the form of positive spillovers, so that their contribution to total output exceeds the private returns to their purchasers. Rates of return estimates for infrastructure, using cost-benefit methods on individual projects as estimated by the World Bank (1994), and education, using the wage premium that accrues to educated workers estimated by Psacharopoulos (1994), give estimates in the range of 5% to 20% annual rates of return. However, these private rates of return may underestimate the social rates of return if there are important externalities to infrastructure and education.

Communications infrastructure may increase the extent of the market, allowing the exploitation of economies of specialization and scale, and generating increased competition. Education may have externalities in raising the capacity of the economy to absorb new ideas. This implies that even without supply problems there may be a case for subsidies, or public provision in excess of the competitive market level, in order to gain from these externalities. A central problem however with the externality argument is the difficulty in measuring these externalities. By their very nature they accrue to society as a whole rather than to the individual using the infrastructure or education directly. Different researchers have come up with wildly different estimates of the macroeconomic effects of infrastructure and education on economic growth. Gramlich (1994) has reviewed the empirical evidence on the aggregate output effects of infrastructure investment. While many cross-country studies find that education has a significant impact on economic growth like Barro (1991), Barro and Sala-i-Martin (1995), and Birdsall and O'Connel (1999), the result is not very robust and in some specifications education appears to have little or no effect on growth once we account for other variables. In particular, the inclusion of geographical variables seems to reduce the role of education, as seen on Gallup and Sachs (1998) that find education to be insignificant, while Sachs and Warner (1997) drop education measures completely from their growth regression.

While there is mixed evidence for the growth effects of education and infrastructure, the problem may lie more in the estimation techniques employed rather than in the nature of the underlying relationship. Infrastructure investment and education rates are the result of decisions that are subject to economic and political forces. For example, the demand for education rates may depend on life expectancy, since the payoff to education increases with the length of time it can be used, and access to international technology if the main purpose of education is to allow the adoption of new techniques.

2. The Effects of Infrastructure and Human Capital on Economic Growth

Although most economists would date the birth of the modern theory of economic growth to the 1950’s, the classical economists like Adam Smith, David Ricardo, were the first to discuss many of the basic ingredients of modern growth theory. In particular, their emphasis on competitive behavior, equilibrium dynamics, and the impact of diminishing returns on the accumulation of labor and capital are integral elements of what is called the neoclassical approach to growth theory. During the 1950s, this approach to understanding growth was formalized by Solow (1956) and Swan (1956), and was later extended by Cass (1965) and Koopmans (1965). The basic assumptions underlying the neoclassical growth model are that the productive capacity of the economy can be adequately characterized by a constant-returns-to-scale production function with diminishing returns to capital and labor, the firms are price takers in a competitive market place and technological change and productivity growth is entirely exogenous and independent of the actions of the consumers and producers.

The implications of the neoclassical model of growth are straightforward. The first major implication is that sustained increases in per-capita income can be supported only by sustained increases in total factor productivity. In this model, output per worker can rise only if the ratio of capital per worker increases or total factor productivity increases. Since this model assumes diminishing returns to capital, there is a limit to how much capital accumulation can add to output per capita. The only way to increase output per worker in the long run is to have sustained productivity growth. This is a major weakness of the neoclassical growth model, since long run growth is exogenous, and determined by an element that is entirely outside of the model. The implication of this model is the conditional convergence thesis, which says that economies with lower initial levels of real output per worker relative to the long-run level should experience faster economic growth. This property follows from the assumption of diminishing returns to capital: the lower the ratio of capital per worker, the higher the return to investing in capital. Hence, the lower the ratio of capital per worker, the faster the rate of capital accumulation and the faster the growth rate of output per worker. This implies long run convergence in output per capita. Convergence is said to be conditional here since the long-run level of capital per worker and output per worker depend on the saving rate, the growth rate of the population, and the existing technology factors that are unlikely to be identical across countries. The convergence thesis is strengthened with the assumption that all countries can acquire technological progress at no cost.

In the 1980's, a number of newer, more sophisticated growth models have been developed where technological change is not assumed to be exogenous. The endogenous growth models try to explain where technologically driven productivity growth comes from. In particular, the accumulation of knowledge plays the important role in driving productivity growth in these models.

There are essentially two strands in the endogenous growth literature. Romer (1986) and Lucas (1988) assume that knowledge to be an input of production with increasing returns to scale. In this class of models, it is possible for per-capita output to grow without bound. In addition, convergence of per-capita incomes need not occur in the long run. A survey of some of the developments in this area can be found in Romer (1994). The second strand of endogenous growth models also takes its departure from Romer (1990) but has been extended by Grossman and Helpman (1991), Aghion and Howitt (1992), and others. In these models, the microeconomic environment is modeled in which firms accumulate knowledge. In particular, the assumption of perfect competition is dropped.

This is because the acquisition of knowledge through research and development activity is costly and can only be rewarded if firms have some ex post market power. Firms are assumed to compete in a monopolistically competitive environment, and per capita output growth can occur without bound since there need be no tendency for the economy to run out of ideas. Convergence across regions may not occur in the long run. Much of the new research also includes models of the diffusion of technology as seen in Grossman and Helpman (1994) where technological progress is transferred across countries and location of research and development (R&D) activity may matter. Another feature of the endogenous growth models is that the long-run growth rate can depend on government actions. In the basic neoclassical growth model, government does not have an impact on the long-run growth rate. In the new endogenous growth framework, however, government policy can affect the long run rate of growth, since government policy actions like provision of infrastructure, regulations, maintenance of law and order, and taxation can affect the underlying rate of inventive activity.

In recent years, significant empirical work has been conducted to test a number of the predictions of both the neoclassical and endogenous models of growth. Tests of the neoclassical model have focused on the conditional convergence thesis and the results have generally been mixed. While most studies reject the hypothesis of convergence across all countries, many find support for convergence across more homogenous subsets of countries or regions. Baumol (1986) finds support for the convergence thesis among OECD countries, while Barro and Sala-i-Martin (1991, 1992a, 1992b) find support for the convergence thesis across American states, regions of several European countries, and prefectures of Japan. Empirical work has also been done to test a weaker version of the convergence thesis in which convergence occurs among countries, holding constant such factors as initial levels of human capital, measures of government policy, political stability, and so on. The seminal work is Barro (1991) and Mankiw, Romer and Weil (1992). These studies find that the rate of convergence is about two percent per year. This implies that it takes about 35 years for an economy to eliminate half of the gap between its initial level and its long-run level of per-capita income. From the economic growth literature we can obtain a few broad conclusions. While endogenous and neoclassical growth models offer different explanations for the growth process, in both models, growth in total factor productivity (technological change) is an essential component of economic growth. In the neoclassical model, technological progress is essential for long-run growth in per capita output. In endogenous growth models, productivity growth results from spillovers from human capital accumulation or inventive activity and this is what generates long run growth in per-capita income. A robust result is that productivity growth or working smarter as opposed to working harder is an essential component of overall economic growth. The development of new technologies and their diffusion across firms and nations are critical components of the growth process as in Lipsey (1996). Clearly, a region that is able to adopt new technologies faster is able to grow faster. Institutional factors such as government regulations, taxes, provision of basic infrastructure and political stability clearly matter for long run economic performance as mentioned by North (1990). This is because the accumulation of factors of production and the development of new technologies do not occur in a vacuum. Rather, economic exchange and production occurs in the real world where the incentives matter. How public policy is set over the long run will therefore influence productivity growth and economic growth since public policy is a critical determinant of the institutional environment.

While economic theory addresses the issue of the aggregate effect of public capital on economic growth, in particular emphasizing the possibility of spillovers to human capital as in (Lucas (1988)), and the tradeoff between the benefits of public capital and the distortions caused by the taxes needed to finance it. How important are human and infrastructure capital to growth and which types of education and infrastructure are most important? Evidence on the rates of return from education and infrastructure capital produces figures that are comparable with rates of return on private capital. Bils and Klenow (1996) review the evidence on rates of return to education using studies that cover 48 countries and conclude that each additional year of schooling raises wages by about 10%. The World Bank's World Development Report (1994) gives rates on return on infrastructure investments between 5% and 25% per year. This suggests that infrastructure capital has roughly the same rate of return as private capital. We begin with a set of simple cross-section state growth regressions in which initial income, education and telecommunications infrastructure are the only determinants of future economic growth and find both types of capital have large and statistically significant impacts. The importance of capital inputs such as education and infrastructure in growth regressions is that capital inputs are endogenous and tend to grow with economic growth. A serious problem in estimating such a relationship is the possibility of reverse causality from output to the capital inputs. Under some assumptions about the nature of the disturbances in the model, the production function can be estimated consistently with a mutual interaction of the variables. This has a natural interpretation as a cross-regions growth regression in which the growth rate of output responds to the initial level of income per capita and capital stocks per capita. That is, the growth regression is estimated simultaneously by all variables, where the explanatory variables are restricted to those that our theory puts in the structural equation being estimated. By implementing the methodology, both human capital and infrastructure capital appear to be important factors in the production function. In addition the model supports the idea that there are constant returns to capital taken as a whole, such as the endogenous growth model.

The review of select issues linking physical infrastructure and economic growth suggests that infrastructure investments influence regional growth. However, the effects of these investments on output, incomes, and capital formation depend on level of development, initial endowments, and inter-jurisdictional spillovers, among other factors. It is important to be sensitive to temporal and spatial effects of these investments during policy making as well as estimating the relationship between all factors.

Table 2.1 Infrastructure and Regional Growth Regressions ***The magnitude sign +/- = sign of coefficient in the corresponding growth regression. * = Claimed to be significant _ = claimed to be insignificant***		
R.H.S. Variables		Studies
Infrastructure Proxies		• Easterly and Levine (1997) (+,*) • Blomstrom, Lipsey and Zejan (1996) (-,_) The conclusion of the study is in line with the last 25 years of research in development economics, which shows that the path to growth and development is much more than simply raising saving and investment rates from 5 to 15 percent.
Investment Infrastructure Type	Technology Equipment or Fixed Capital	• De Long and Summers (1993) (+,*) • Sala-i-Martin (1997) (+,*)
	Non-Equipment	• Sala-i-Martin (1997) (+,*)

The following part of the paper presents the foundation to build a model showing the effects of economic telecommunications infrastructure investments on regional output in the Mexican states. The empirical findings from the study are shown to be linked to some of the key ideas that emerge from the review of the literature.

3. Emerging Digital Economy and Regional Economic Growth

While the recent introduction of the Internet does not allow a time series evaluation of its economic impact. Several studies on the effect of other forms of telecommunications infrastructure, such as telephone systems, suggest that a large impact on economic growth is possible. Gramlich (1994), World Bank (1994), Sanchez-Robles (1998), and Canning (1999) give supporting evidence. Given the desirability of a high level of Internet use, it is interesting to observe how influential is the internet in determining the extent of growth in a country. Mexico's had 1,350,000 cybernauts in 1998 with a 1.3% penetration. The percentage of Men using the web was around 74% in 1998, while only 37% of all users were shopping online. The total spending online in Mexico during 1999 reached 25 million dollars, and it s expected to reach 1,542,000,000 USD in 2005. Mexico ranks second among Latin American countries in Internet users with 1.5 million in the year 2000. However, future Internet growth will be slowed by poverty and infrastructure development constraints. At least 6.4 million Mexicans will be actively using the Internet by 2004, while Internet penetration rate will remain in single digits for the next few years, rising from 2.2% of the population in 2000 to 8.6% in 2004. Similarly, Mexico's share of the region's Internet market will remain unchanged through 2004, at a 15% share. Mexico's GDP (Gross Domestic Product) per capita is around $5,452 in 2001 and a population of more than 100 million. With a total GDP of $866 billion, Mexico has the largest economy in Latin America. Uneven income distribution, combined with a poorly developed, overburdened telecommunications infrastructure, has resulted in a low Internet penetration rate of 2.2%.

The use of personal computers in Mexico is currently quite small when judged by U.S. or European standards. In the United States, 51 out of every 100 people own or have access to a PC in 2000. During the same year, PC penetration in Mexico is just under 5 out of every 100 people for the same time period. The greatest likelihood is that computer growth will continue to be fast for the next several years while tapering off afterward as PCs become more common throughout Mexico. PC penetration in Mexico will never get as high as it is in the United States, but it will eventually be much higher than today. A figure above a 66.24% penetration rate is overly optimistic in Mexico for the next decade. The variables used in the study are estimates of the total number of people with access to the Internet in the country by state. The data on Internet users comes from Nielsen//NetRatings, Global Internet Trends report on Internet access and penetration. Data on real income per capita by state in 1970 and 2000 comes from INEGI and Bank of Mexico. The data on education comes from the Ministry of Education. The human capital index was constructed by taken the literacy rate of people over the age of 15 multiplied by 2 and the average of the years of schooling by the general population divided by 12 years. The sum of both measures is divided by 3. Data on TV and radio stations comes from Dirección General de Sistemas de Radio y Televisión at the Ministry of Transport.

3.1 Empirical Model

We start by trying to explain cross-state variations in the regional convergence model using human capital variables, other telecommunications infrastructure and Internet usage. This section aims at presenting the growth model with exogenous savings, telecommunications infrastructure variables and fixed effects to be used in the study. Consider the production function, with labor augmenting technical progress:

$$Y(t) = K^{\alpha}(t)\left(A(t)L(t)\right)^{1-\alpha} G$$

Where Y = product, K = capital, L = labor and G = telecommunications infrastructure capital. Public input is thus complementary to private inputs, and we have:

$$L(t) = L(0)e^{nt}$$
$$A(t) = A(0)e^{gt}$$

where n and g are the (exogenously determined) population and technology rates of growth.

Capital accumulation per effective worker in the steady state will be given by:

$$\frac{dk}{dt} = s\hat{y} - (n + g + \delta)\hat{k}$$

where s = savings rate, and delta is the depreciation rate.

$$\hat{y} = \frac{Y(t)}{A(t)L(t)}, \hat{k} = \frac{K(t)}{A(t)L(t)}$$

This equation implies steady state levels of capital and product (per effective worker) are described by:

$$\hat{k}* = (\frac{sG}{n+g+\delta})^{\frac{\alpha}{1-\alpha}}$$

$$\hat{y}* = (\frac{sG}{n+g+\delta})^{\frac{\alpha}{1-\alpha}} G^{\frac{1}{1-\alpha}}$$

With the product per effective worker given by $\hat{y}(t) = \hat{k}^{\alpha}(t)G$, we can approximate its time variation around the steady state to get (in logs):

$$\frac{d\ln(\hat{y}(t))}{dt} = \lambda[\ln(\hat{y}*) - \ln(\hat{y}(t))]$$

where $\lambda = (n+g+\delta)(1-\alpha)$.

The growth of per-capita product around the steady-state will be represented in the following manner:

$$\ln y(t2) - \ln y(t1) = \left(1 - e^{-\lambda\tau}\right)\frac{\alpha}{1-\alpha}\ln(s) - \left(1 - e^{-\lambda\tau}\right)\frac{\alpha}{1-\alpha}\ln(n + g + \delta) +$$
$$\frac{\alpha}{1-\alpha}\left(1 - e^{-\lambda\tau}\right)\ln G + \left(1 - e^{-\lambda\tau}\right)\ln y(t1) + g\left(t2 - e^{-\lambda\tau}t1\right) + (1 - e^{-\lambda\tau})\ln A(0)$$

where we know that: $\ln(\hat{y}(t)) = \ln(y(t)) - \ln(A(0)) - gt$

By including human capital in the production function we obtain the following:

$$Y(t) = K^{\alpha}(t)[A(t)L(t)]^{1-\alpha-\phi} H^{\phi}(t) G$$

and around the steady state we will then have:

$$\ln y(t2) - \ln y(t1) = -(1-e^{-\lambda t})\ln y(t1) + (1-e^{-\lambda\tau})\frac{\alpha}{1-\alpha-\beta}\ln s - (1-e^{-\lambda\tau})\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) +$$
$$(1-e^{-\lambda\tau})\frac{\beta}{1-\alpha-\beta}\ln(h^{*}) + (1-e^{-\lambda\tau})\frac{\alpha}{1-\alpha-\beta}G + (1-e^{-\lambda\tau})\ln A(0) + g(t2-e^{-\lambda\tau})$$

where G* and h* are infrastructure capital and human capital investment as a fraction of income in the steady state.

4. Econometric Methodology and Empirical Results

The main aim of the paper is to investigate the roles of telecommunications infrastructure and human capital variables on growth. The method of estimation is generalized least squares. For that purpose we propose the following econometric model:

$$\Delta y_{it} = \gamma y_{it-1} + S_i + \beta_1 H_{it} + \beta_2 G_{it} + \eta_t + \varepsilon_{it}$$

Where:

$$y_{it-1} = \ln y(t1),$$
$$\Delta y_{it} = \ln y(t2) - \ln y(t1)$$
$$\gamma = (1-e^{-\lambda\tau})$$
$$S_i = (1-e^{-\lambda\tau})\frac{1}{1-\alpha-\beta}[\alpha\ln s - (\alpha+\beta)\ln(n+g+\delta) + \ln A(0)/\frac{1}{1-\alpha-\beta}]$$

$$\eta_t = g(t2 - e^{-\lambda\tau}t1)$$

where *G* and *H* are telecommunications infrastructure capital and human capital variables.

The results are very interesting and significant. In regional growth regressions such as these, a negative coefficient on initial income and growth in income between 1970 and 2000 is often taken as evidence of convergence. If no other variables (apart from a constant term) were included, a negative coefficient on initial income would indicate unconditional convergence; rich regions grow more slowly than poor regions, such that states in Mexico tend to become more similar in terms of their income levels as time passes. The results indicate that there is tendency for income levels to converge over time using telecommunications infrastructure. However, we observe a positive significant coefficient with no other variables included signifying divergence over time, or rich states grow faster than poor regions in the period 1970 –2000 in Mexico.

Table 4.1. GLS Convergence Growth Regressions on 30 Year Period				
Dependent Variable: Change in Income per Capita Growth 1970-2000				
Constant	-0.051	-0.018	0.456*	0.642*
	(0.52)	(-0.202)	(2.91)	(3.86)
log income per capita	0.212*	-0.225*	-0.046**	-0.013**
	(2.41)	(2.82)	(4.79)	(5.29)
Internet Usage		0.0006*	0.0058*	0.005*
		(2.73)	(2.66)	(2.36)
Education Index			0.940**	0.726*
			(3.46)	(3.04)
Radio Stations				.001*
				(2.34)
TV Stations				0.001
				(0.95)
R squared	0.16	0.33	0.53	0.61
R squared adjusted	0.13	0.28	0.484	0.54
F Stat (Prob F statistic)	5.85 (0.021)	7.29 (0.002)	10.71 (0.00)	8.31 (0.000)
Note: T statistics in parenthesis. Significance at 90%* Significance at 95%**.				

A close analysis of the results indicates that once we add education, the number of radio and TV stations and Internet usage, we find strong evidence of conditional convergence, with the initial capital stocks having a negative and statistically significant impact on subsequent economic growth. Rich states in Mexico grow more slowly than poor states but, for a given level of initial income, we would expect a country with a higher level of education, or a greater number of Internet usage, to grow more quickly. In this case, states in Mexico will converge over time, but not to the same level of income. They each converge to their own steady state level of income where the negative effect of their income level exactly offsets the positive effects of internet access, telecommunications infrastructure and education stocks.

The human capital variable reflects the acquisition of skills and know-how through education, experience and research. A significant human capital index coefficient shows that together with trade and other international interactions, is apparently a necessary condition to absorb knowledge from other countries through the internet and contribute to the growth process. States have to be careful in over-investing in higher education relative to basic education, before the economy has reached the stage of development at which graduates with higher education can be usefully employed, and know how to use the available technology.

Capital accumulation in telecommunications infrastructure is easily identified determinant of future living standards in the states of Mexico. What is less clear, however, is whether capital accumulation in the form of the digital economy or the accumulation of any factor of production, can drive growth in per capita terms for an indefinite period of time.

The regressions show the role of digital capital, particularly telecommunications infrastructure capital, and Internet usage in economic growth. This includes the Internet and other forms of telecommunications networks. While it is intuitive that telecommunications infrastructure accumulation should raise output, it has been difficult to determine whether spending in this area has a greater pay-off than other forms of investment. Some authors have pointed out that, as with any capital investment, changes in the stock of telecommunications capital should be less important than changes in the flow of productive services that obtain from that stock, and the eventual effects on growth. Hence, Internet infrastructure can have a large impact on output. One strand of the new growth literature identifies another channel through which internet infrastructure investment can affect the growth rate of output: if telecommunications infrastructure networks increases in the regional markets of a country, it can foster a faster rate of technical innovation (and hence of productivity growth), and eventually economic growth

Using just these telecommunications variables gives a fairly average R^2 with each of the variables being statistically significant (at the 10% significance level). Adding our telecommunications capital stock variables to this base regression gives much larger coefficients, and more statistical significance. One interpretation of these results is that, once we control for other telecommunications variables, the effects of education and Internet usage on long-run economic growth are significant.

5. Conclusion

Cross-state growth regressions in Mexico need to be interpreted with care. In general, their estimated coefficients are combinations of parameters from the reduced form and structural models of the underlying growth process. The importance of initial levels of human capital and telecommunications infrastructure variables in long-run cross-regional growth regressions is entirely compatible with there being important inputs into the production function.

A central hypothesis in the paper is that incomes across states tend to converge to a common level in the long run by the inclusion of the digital economy. In other words, lower-income states in Mexico will tend to grow more rapidly than states at a higher level of income with consideration of Internet usage and human capital. There are two important kinds of catch-up. First, given the right economic structure and educational environment, poor states tend to have high rates of return to capital. The accumulation of digital physical and human capital, whether financed by domestic saving or capital inflows, leads to rapid growth. They also tend to have rapid rates of growth by emulating the technologies and innovations of the more advanced economies through the Internet. Growth can therefore be facilitated as much through the accumulation of Internet and telecommunications infrastructure as through increases in the efficiency of the use of these factors through education.

The discussion of other factors that researchers have identified as possible determinants of a country's long-term economic performance leads us to point out factors to be included in further research such as: investment in private and public capital, education and training, digital financial intermediation, macroeconomic stability, openness with respect to trade and investment, equality of income distribution and stability of political and social conditions.

To summarize, the study finds that the strongest determinants of countries' long-term growth rates are investment in physical and human capital (especially investment in telecommunications infrastructure and education). Without such investment, the Mexican states seem to diverge in the long run.

6. References

Akamatsu, K. (1962), "A Historical Pattern of Economic Growth in Developing Countries," The Developing Economies March-August.

Alesina, Alberto, Sule Ozler, Nouriel Roubini, and Phillip Swagel, (1992), "Political Instability and Economic Growth," Harvard University, June.

Alesina, Alberto, and Dani Rodrik, (1994), "Distributive Politics and Economic Growth," Quarterly Journal of Economics, May.

Barro R. J. (1990), "Government Spending in a Simple Model of Endogenous Growth," Journal of Political Economy, Vol. 98, pp 103-125.

Barro R. J. (1991), "Economic Growth in a Cross Section of Countries," Quarterly Journal of Economics, Vol. 106, pp 407-444.

Barro, Robert, and Xavier Sala-i-Martin, (1992), "Convergence," Journal of Political Economy.

Barro R. J. and Lee J.W. (1993), "International Comparisons of Educational Attainment," Journal of Monetary Economics, Vol. 32, pp 363-394.

Barro R.J. and Sala-I-Martin X. (1995), Economic Growth, McGraw-Hill Inc., New York.

Barro, Robert, (1995), "Inflation and Economic Growth, NBER Working Paper #5326.

Benabou, Roland, (1996), "Heterogeneity, Stratification and Growth: Macroeconomic Implications of Community Structure and School Finance," American Economic Review, June.

Bencivenga V., and B. Smith, (1991), "Financial Intermediation and Endogenous Growth," Review of Economic Studies, April.

Ben-David, Dan, (1993), "Equalizing Exchange: Trade Liberalization and Income Convergence," Quarterly Journal of Economics 108, August, 653-679.

Bhagwati, Jagdish, (1988), "Export Promoting Trade Strategy: Issues and Evidence," World Bank Research Observer, Jan. 3, no.1, 27-57.

Bils M. and Klenow P.J. (1996), "Does Schooling Cause Growth or the Other Way Around?", mimeo, Graduate School of Business, University of Chicago.

Birdsall N. and O'Connell L., (1999), "Putting Education to work in Egypt," Carnegie Endowment for International Peace, Working Paper No. 1999-05.

Bloom D.E. and Williamson J.G (1998), "Demographic Transitions and Economic Miracles in Emerging Asia," World Bank Economic Review, Vol. 12, pp 419-456.

Bloom D.E., Canning D. and Malaney P., (1999), "Demographic Change and Economic Growth in Asia," Center for International Development Working Paper No. 15.

Blomstrom, Magnus, Robert E. Lipsey and Mario Zejan (1996), "Is Fixed Investment the Key to Economic Growth?" Quarterly Journal of Economics 111(1): 269-276.

Borner, Sylvio, Aymo Brunetti and Beatrice Weder, (1995), Political Credibilty and Economic Development, Macmillan Press.

Bradford, Colin, Jr., (1994), From Trade-Driven Growth to Growth-Driven Trade: Reappraising the East Asian Development Experience, Organisation for Economic Cooperation and Development, Paris.

Bradford, Colin, Jr, and Naomi Chakwin, (1993), "Alternative Explanation of the Trade-Output Correlation in the East Asian Economies," OECD Development Centre Technical Papers No. 87, Paris (August).

Canning D. (1998), "A Database of World Infrastructure Stocks, 1950-1995," World Bank Economic Review, Vol. 12, pp 529-548.

Coe, David, and Elhanan Helpman, (1993), "International R&D Spillovers," National Bureau of Economic Research Working Paper No. 4444 (August); European Economic Review 1995.

De Gregorio, Jose and Pablo Guidotti, (1995), "Financial Development and Economic Growth," World Development, Sept.

DeLong, Bradford, and Lawrence Summers, (1991), "Equipment Investment and Economic Growth," Quarterly Journal of Economics 56, 2, 445-502.

deMelo, Jaime, and Sherman Robinson, (1991), "Productivity and Externalities: Models of Export-Led Growth," PRE Working Papers, WPS 387, The World Bank.

Dollar, David, (1992), "Outward-oriented Developing Economies Really Do Grow More Rapidly: Evidence from 95 LDCs: 1976-1985," Economic Development and Cultural Change 40, 523-544.

Easterly, William, 1995, "Explaining Miracles: Growth Regressions Meet the Gang of Four," Fourth Annual NBER East Asian Seminar on Economics, San Francisco, June 1993. In Growth Theories in Light of the East Asian Experience edited by T. Ito and A. Krueger, University of Chicago Press, Chicago.

Easterly, William, Michael Kremer, Lant Pritchett, and Lawrence Summers, 1993, "Good Policy or Good Luck? Country Growth Performance and Temporary Shocks," National Bureau of Economic Research Working Paper No. 4474, September. Journal of Monetary Economics.

Easterly, William, and Sergio Rebelo, 1994, "Fiscal Policy and Economic Growth: An Empirical Investigation," Centre for Economic Policy Research Working Paper No. 885, London, January.

Easterly, William and Ross Levine (1997), "Africa's Growth Tragedy: Policies and Ethnic Divisions" Quarterly Journal of Economics 112(4): 1203-1250.

Edwards, Sebastian, 1992, "Trade Orientation, Distortions, and Growth in Developing Countries," Journal of Development Economics, June 39, no.1, 31-57.

Edwards, Sebastian, 1993a, "Openness, Trade Liberalization, and Growth in Developing Countries," Journal of Economic Literature XXXI, September, 1358-1393.

Edwards, Sebastian, 1993b, "Trade Policy, Exchange Rates and Growth," National Bureau of Economic Research Working Paper No. 4511 (October).

Esfahani, Hadi, 1991, "Exports, Imports, and Economic Growth in Semi-Industrialized Countries," Journal of Development Economics, January, 35, no.1, 93-116.

Eusufzai, Zaki, 1996, "Openness, Economic Growth, and Development: Some Further Results," Economic Development and Cultural Change 44, no. 2, January, 333-350.

Feder, Gershon, 1982, "On Exports and Economic Growth," Journal of Development Economics, Feb./Apr., 12, no. 1, 59-73.

Fischer, 1993, "The Role of Macroeconomic Factors in Growth," NBER Working Paper #4256.

Frankel, Jeffrey, 1995, "Recent Changes in the Financial Systems of Asian and Pacific Countries," Sixth International Conference of the Institute for Monetary and Economic Studies, Bank of Japan, Tokyo, Oct. 28-29, 1993; in Financial Stability in a Changing Environment, Kuniho Sawamoto, Zenta Nakajima, and Hiroo Taguchi, eds., MacMillan Press, 161-200.

Frankel, Jeffrey, David Romer, and Teresa Cyrus, 1996, "Trade and Growth in East Asian Countries: Cause and Effect?" NBER Working Paper #5732.

Frankel, Jeffrey, and Shang-Jin Wei, 1996, "ASEAN in a Regional Perspective", written for the Southeast Asia and Pacific Department, International Monetary Fund, May 1996. CIDER Working Paper No. C96-074, U.C. Berkeley, November.

Frankel, Jeffrey A. (1997). Determinants of Long Term Growth. Background Paper for the Morning Session of the Meeting of the Asia-Pacific Economic Cooperation Economic Advisers, Vancouver, Canada, November 20, 1997.

Fukuda, Shin-ichi, and Hideki Toya, 1995, "Conditional Convergence in East Asian Countries: The Role of Exports for Economic Growth," Discussion Paper No. 57, Economic Research Institute, Economic Planning Agency, Tokyo (October 1993). In Growth Theories in Light of the East Asian Experience edited by T. Ito and A. Krueger, University of Chicago Press, Chicago.

Gallup J.L. and Sachs J.D. (1998), "Geography and Economic Development," mimeo, Harvard Institute for International Development.

Garcia-Mila T., McGuire T. J. and Porter R. H. (1996), "The Effect of Public Capital in State Level Production Functions Reconsidered," Review of Economics and Statistics, pp 177-180.

Ghali K. H. (1998), "Public Investment and Private Capital Formation in a Vector Error-correction Model of Growth," Applied Economics, Vol. 30, pp 837-844.

Gramlich E. M. (1994), "Infrastructure Investment: A Review Essay," Journal of Economic Literature, Vol. XXXII, pp 1176-1196.

Greenwood, Jeremy, and Boyan Jovanovic, 1990, "Financial Development, Growth, and The Distribution of Income," Journal of Political Economy, March.

Grossman, Gene, and Elhanan Helpman, 1991a, Innovation and Growth in the Global Economy, MIT Press: Cambridge.

Grossman, Gene, and Elhanan Helpman, 1991b, "Trade, Knowledge Spillovers, and Growth," European Economic Review 35, no. 2-3, April, 517-526.

Gwartney, James, Robert Lawson, and Walter Block, 1996, Economic Freedom of the World: 1975-1995, Fraser Institute, Vancouver.

Hall, Robert and Charles Jones, "The Productivity of Nations," Manuscript, NBER Economic Fluctuations and Growth Meetings, January 31, 1997.

Harris R.G. and Kraft C.J. (1997), "Meddling Through: Regulating Local Telephone Competition in the United States," Journal of Economic Perspectives, Vol. 11, No. 4, pp 93-110.

Harrison, Anne, 1995, "Openness and Growth: A Time-Series, Cross-Country Analysis for Developing Countries," NBER Working Paper No. 5221, August; Journal of Development Economics, March 1996.

Harrison, Anne, and Anna Revenga, 1995, "The Effects of Trade Policy Reform: What Do We Really Know?" NBER Working Paper #5225.

Helliwell, John, 1992, "International Growth Linkages: Evidence from Asia and the OECD," National Bureau of Economic Research Working Paper No. 4245 (December). In Macroeconomic Linkages: Savings, Exchange Rates, and Capital Flows, NBER - East Asia Seminar on Economics, Volume 3, Takatoshi Ito and Anne Krueger, editors, University of Chicago Press, 1994.

Helliwell, John, 1995, "Asian Economic Growth," in Wendy Dobson and Frank Flatters, eds., Pacific Trade and Investment: Options for the 90's (International and Development Studies Institute, Queen's University: Kingston, ONT.).

Helpman, Elhanan. 1987. "Imperfect Competition and International Trade: Evidence from Fourteen Industrial Countries," Journal of the Japanese and International Economies 1: 62-81.

Helpman, Elhanan. 1988, "Growth, Technological Progress, and Trade," National Bureau of Economic Research Reprint no. 1145.

Helpman, Elhanan and Paul Krugman. 1985. Market Structure and Foreign Trade, Cambridge, MIT Press.

Hoeffler A.E. (1999), "The Augmented Solow Model and the African Growth Debate," mimeo, Balliol College, Oxford.

Hulten, Charles, 1993, "Growth Accounting when technological change is embodied in Capital," American Economic Review, Sept.

Hulten C.R. (1996), "Infrastructure Capital and Economic Growth: How Well You Use It May Be More Important Than How Much You Have," mimeo, University of Maryland.

Hutchison, Michael, and Nirvikar Singh, 1987, "Exports and Growth in Developing Economies: Identifying Externality Effects," Working Paper, University of California, Santa Cruz.

Islam N. (1995), "Growth Empirics: A Panel Data Approach," Quarterly Journal of Economics, Vol. 110, pp 1127-1170.

Keller, Wolfgang, 1996, "Trade and the International Transfer of Technology," NBER Working Paper #6113.

Kim, Jong-Il, and Lawrence Lau, 1994, "The Sources of Growth of the East Asian Newly-Industrialized Countries," Journal of the Japanese and International Economies

King R., and R. Levine, 1993, "Finance and Growth: Schumpeter Might be Right," Quarterly Journal of Economics.

Klenow P.J. and Rodriguez-Clare A. (1997), "The Neoclassical Revival in Growth Economics: Has it Gone Too Far?," mimeo, Graduate School of Business, University of Chicago.

Kohli, Inderjit, and Nirvikar Singh, 1989, "Exports and Growth: Critical Minimum Effort and Diminishing Returns," Journal of Development Economics, April, 30, no. 2, 391-400.

Krueger, Anne, 1978, Foreign Trade Regimes and Economic Development: Liberalization Attempts and Consequences, Ballinger for National Bureau of Economic Research.

Krueger, Anne, 1990, "Asian Trade and Growth Lessons," American Economic Review Papers and Proceedings 80, no. 2, May.

Krugman, Paul, 1994, "The Myth of Asia's Miracle," Foreign Affairs 73, no. 6, Nov./Dec., 62-78.

Kwan, C.H., 1994, Economic Interdependence in the Asia-Pacific Region, Routledge, London.

Levine R. and Renelt D. (1992), "A Sensitivity Analysis of Cross-country Growth Regressions," American Economic Review, Vol. 82, pp 942-963.

Lucas R.E. (1988), "On the Mechanics of Economic Development," Journal of Monetary Economics, Vol. 22, pp 3-42.

Mankiw N.G., Romer D. and Weil D.N. (1992), "A Contribution to the Empirics of Economic Growth," Quarterly Journal of Economics, Vol. 107, pp. 407-437.

Michaely, Michael, 1977, "Exports and Growth: An Empirical Investigation," Journal of Development Economics March, 4, no.1, 49-53.

Nielsen//NetRatings, Global Internet Trends report on Internet access and penetration, Fourth Quarter 2001.

Pack, Howard, and John Page, 1994, "Accumulation, Exports, and Growth in the High-Performing Asian Economies," Carnegie-Rochester Series on Public Policy 40, 199-236.

Pack, Howard, and Lawrence Westphal, 1986, "Industrial Strategy and Technological Change: Theory vs. Reality," Journal of Development Economics 22, 87-126.

Page, John, 1994, "The East Asian Miracle: Four Lessons for Development Policy," NBER Macroeconomics Annual, MIT Press: Cambridge, 219-280.

Parente, Stephen L., and Edward C. Prescott, "Barriers to Technology Adoption and Development," Journal of Political Economy, 1994, vol. 102, no. 2, pg. 298-321.

Psacharopoulos G. (1994), "Returns to Investment in Education: A Global Update," World Development, Vol. 22, pp1325-1343.

Pritchett L. (1996), "Mind Your P's and Q's, The Cost of Public Investment is Not the Value of Public Capital," Policy Research Working Paper, No. 1660, Policy Research Department, World Bank.

Quah, Danny, and James Rauch, 1990, "Openness and the Rate of Economic Growth," Working Paper, University of California, San Diego, Oct.

Rodrik, Dani, 1993, "Trade and Industrial Policy Reform in Developing Countries: A Review of Recent Theory and Evidence," National Bureau of Economic Research Working Paper no. 4417 (August).

Rodrik, Dani, 1994a, "King Kong Meets Godzilla: The World Bank and The East Asian Miracle," CEPR Discussion Paper No. 944, April.

Rodrik, Dani, 1994b, "Getting Interventions Right: How South Korea and Taiwan Grew Rich," 20th Panel Meeting of Economic Policy; NBER Working Paper No. 4964, December.

Romer, David, 1993, "Openness and Inflation: Theory and Evidence," Quarterly Journal of Economics, 108, No. 4, November: 869-903.

Romer, Paul, 1989, "What Determines the Rate of Growth and Technical Change?" World Bank Working Paper No. 279.

Romer, Paul, 1990, "Endogenous Technological Change," NBER Working Paper #3210, Journal of Political Economy.

Sachs J.D. and Warner A.M. (1997), "Fundamental Sources of Long Run Growth," American Economic Review", Vol. 87 (2), pp 184-188.

Sachs, Jeffrey, and Andrew Warner, 1995, "Economic Reform and the Process of Global Integration," Brookings Papers on Economic Activity 1, pp.1-95.

Sala-i-Martin, Xavier, (1991), "Comment," NBER Macroeconomics Annual 6, 368-378.

Sala-i-Martin, Xavier, (1997), "I Just Ran 2 Million Regressions," American Economic Review, May.

Sanchez-Robles B. (1998), "Infrastructure Investment and Growth: Some Empirical Evidence," Contemporary Economic Policy, Vol. XVI, pp 98-108.

Sarel, Michael, 1995, "Growth in East Asia: What We Can and What We Cannot Infer From It," Productivity and Growth, Proceedings of a Conference, Palle Andersen, Jacqueline Dwyer and David Gruen, eds., Reserve Bank of Australia, 237-259.

Schleifer, Andrei and Robert Vishny, 1993, "Why is Rent Seeking So Costly to Growth?" American Economic Review, May.

Spiller P.T. and Cardilli C.G. (1997), "The Frontier of Telecommunications Deregulation: Small Countries Leading the Pack," Journal of Economic Perspectives, Vol. 11, No. 4, pp 127-138.

Summers R and Heston A. (1991), "The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988," Quarterly Journal of Economics, Vol. CVI, pp 327-336.

Turnovsky S. J. and Fisher W. H. (1995), "The Composition of Government Expenditure and its Consequences for Macroeconomic Performance," Journal of Economic Dynamics and Control, Vol. 19, pp 747-786.

van den Berg, Hendrik, 1994, "Foreign Trade and Economic Growth: Time Series Evidence from Latin American," Journal of International Trade and Economic Development 3, no. 3, Nov., 249-268.

Waverman L. and Sirel E. (1997), "European Telecommunications Markets on the Verge of Full Liberalization," Journal of Economic Perspectives, Vol. 11, No. 4, pp 113-126.

Wei, Shang-Jin, 1997, "How Taxing is Corruption on International Investment?" NBER Working Paper #6030.

World Bank, (1993), The East Asian Miracle: Economic Growth and Public Policy, Oxford University Press: New York.

World Bank, (1994), World Development Report, Infrastructure for Development. Washington D.C.

Yamazawa, Ippei, 1990, Economic Development and International Trade: The Japanese Model, East-West Center, Resource Systems Institute: Honolulu, Hawaii.

Young, Alwyn, 1992, "A Tale of Two Cities: Productivity Growth in Hong Kong and Singapore," NBER Macroeconomics Annual 1992, National Bureau of Economic Research: Cambridge, MA.

Young, Alwyn, 1994, "Lessons from the East Asian NICS: A Contrarian View," European Economic Review Papers and Proceedings, May.

Young, Alwyn, 1995, "The Tyranny of Numbers: Confronting the Statistical Reality of the East Asian Growth Experience," Quarterly Journal of Economics 110, no. 3, August, 641-680.

Appendix A. Evolution of Registered Internet Domains in Mexico by Date							
Data	.com.mx	.gob.mx	.net.mx	.edu.mx	.org.mx	.mx	Total
31-MAR-2002	63,418	1,418	653	1,361	2,905	177	69,932
28-FEB-2002	63,431	1,392	657	1,324	2,871	177	69,852
31-JAN-2002	62,626	1,367	656	1,280	2,799	177	68,905
31-DEC-2001	61,496	1,278	662	1,245	2,759	177	67,617
30-NOV-2001	62,041	1,250	673	1,224	2,772	177	68,137
28-FEB-2001	60,523	990	783	914	2,627	177	66,014
31-JAN-2001	58,830	965	782	885	2,524	177	64,163
31-DEC-2000	56,769	935	761	855	2,399	177	61,896
31-JAN-2000	27,520	523	662	584	1,282	177	30,748
31-DEC-1999	25,026	510	639	557	1,221	177	28,130
31-JUL-1999	17,522	424	515	482	948	177	20,068
30-JUN-1999	16,698	404	511	471	940	177	19,201
31-MAY-1999	15,421	392	498	449	851	177	17,788
31-JAN-1999	11,356	358	421	377	654	189	13,355
31-DEC-1998	10,661	350	395	359	622	189	12,576
30-NOV-1998	10,505	346	398	344	615	189	12,397
31-OCT-1998	9,964	336	384	333	589	189	11,795
30-SEP-1998	9,135	322	355	301	557	189	10,859
31-AUG-1998	8,634	302	332	293	511	189	10,261
31-JUL-1998	7,976	290	306	277	487	189	9,525
30-JUN-1998	7,428	284	296	254	469	189	8,920
31-MAY-1998	7,082	262	272	243	448	189	8,496
31-JAN-1998	6,402	212	272	180	408	188	7,662
31-DEC-1997	6,043	201	262	168	389	188	7,251
30-NOV-1997	5,736	179	254	160	367	188	6,884
31-JAN-1997	2,556	81	154	19	164	188	3,162
30-SEP-1996	1,412	48	114	0	104	162	1,840
31-JAN-1996	234	13	29	0	16	104	396
31-DEC-1995	180	12	20	0	13	101	326
10-OCT-1995	100	9	14	0	5	83	211
31-JUL-1994	5	1	0	0	0	44	50
30-JUN-1994	5	0	0	0	0	40	45
05-APR-1992	1	0	0	0	0	1	1
25-SEP-1991	0	0	0	0	0	1	1
28-FEB-1989	0	0	0	0	0	1	1