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# Regional convergence in Mexico (1941-2010): the contribution of road infrastructure

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To analyze the preference in the learning approach of students with high academic performance, at the University of San Francisco Xavier de Chuquisaca. Subjects and methods. The study was conducted on 392 students with high and high average academic performance of the faculties of health sciences, social, economic and technology at University of San Francisco Xavier [Sucre, Bolivia]. The questionnaire ASSIST Entwistle [1993] was applied, which evaluates the approaches or approximations of students to studying. SPSS V.21 with Chi square, Student T and Crosstabs was used in the statistical processing.Results. The preference for the study approach differs by gender; there is more preference for the strategic approach on females and for deep approach on males. This increased preference for strategic approach shows the use of organizing techniques of study, awareness to the demands of the tasks, achievements and effectiveness monitoring and, in the case of males the use of evidence and interest in ideas.Conclusions. The learning approach has important gender differences and their relationship to high performance is significant. It shows the need to think of a differentiated pedagogy that enhances the techniques that each group applies.

**Regional convergence, highway infrastructure**

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## Introduction

It is very common to find the idea that there is a strong correlation between investment in transportation infrastructure and the corresponding economic growth, and that this correlation is much larger than any that exist between economic growth and investment in other infrastructure and even other economic activities. For example, an OECD document states that investment analysis of transport infrastructure should go beyond the calculation of direct benefits to users, because the infrastructure has broad implications for regional development, and these effects must also be taken into account in order to ensure an efficient allocation of resources (OECD, 2002:4). In fact, besides some benefits from job creation, social inclusion and environmental costs reductions, the new transport infrastructure would ensure time and cost savings to the local industry, and improvements in access to markets. As a key result, there is an increase in regional productivity (OECD, 2002:9). However, Vickerman recognizes that this is a very controversial debate that occurs not only among scholars who seek a robust method for identifying and measuring the size of the supposed economic benefits of investment in transport infrastructure, but also among policy makers who are looking for a sound basis in order to justify or reject the investment in a specific investment project (Vickerman, 2007:3).

The aim of this study is to explore the theoretical and empirical foundation that has the link between investment in road transport infrastructure and regional economic development in Mexico. In particular, we analyze if the increase in the road stocks observed in the Mexican states in the last years is contributing to the process of regional convergence in per capita GDP.

## 1 Aschauer and the debate on the impact of infrastructure investment

The concern about the real contribution that investment in transport infrastructure has on economic development can be found in the literature for several decades. [13] However, it is from a study by Aschauer (1989a) on the role of infrastructure investment that the debate deepens. Indeed, in an analysis of productivity observed in the economy of the United States between 1950 and 1985, Aschauer finds that public capital stocks are much more important in determining productivity than current spending, and basic infrastructure (i.e., highways, airport, public transportation, drainage, fresh water, etc.), has the highest explanatory power for the observed productivity (Aschauer, 1989a:177).

He concludes that the decline in productivity growth (observed in the U.S. economy in the period mentioned) is coincident or slightly forward, with a sharp drop in the increase in net stocks of infrastructure and public facilities (Aschauer, 1989a:195). It is around this statement that begins the debate about the true impact of public capital investments. In fact, Aschauer goes further in a study on the productivity observed (between 1960 and 1980) in the seven most industrialized economies of the world. He founds that the general setting of government spending priorities (which prefers the current spending versus investment in public capital), is related negatively with their productivity, and therefore recommends that public capital would be included as a vital ingredient in the strategy for economic growth (Aschauer, 1989b: 24).

[13] See, for example, the contributions made by Owen (1959), Voigt (1964), or Fromm (1980).

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Later, in a subsequent econometric analysis of road transport performance in the U.S. economy (in the period 1960-1985), Aschauer concluded that a greater quantity and quality of the road capacity expands transport services and, thus, increases the marginal product of private capital. This, in turn, induces more investment in physical capital and increased per capita income and (Aschauer, 1990:14, 22).

Although this causal relationship was corroborated by other studies (see, for example, Munnell, 1990), it also generated a variety of criticisms, most notably the following three: first, that the magnitude of the statistical correlation found between public capital and private capital was weak; second, that Aschauer ignored other variables that could explain the observed decline in productivity; and third, that he was not considering the possibility of reverse causation, i.e., that the drop in productivity was a cause of the decline in public capital investment, and not vice versa. Aschauer's response was that the existence of other variables could not neglect in the importance of public capital. Moreover, He found methodological inconsistencies in criticisms of other researchers, which make their argument unconvincing (Aschauer y Holtz-Eakin, 1993:20).

However, Aschauer recognized the need to incorporate in its analysis of the optimality of public capital stocks compared to maximizing the productivity of private capital. Moreover, in the same work the author presents evidence of a low provision of public capital in the U.S. economy, not congruent with the existence of a rate of return of public capital that was above the corresponding to private capital (Ibid: 11-14).

Other studies by Aschauer have allowed him to refine their analytical instruments, and corroborate, in general, the ideas previously postulated. Indeed, in a study conducted in 1998, Lachler and Aschauer found empirical evidence that Mexico's economic growth began to collapse while public investment did.

However, they also note that although this decrease seems to be coinciding with the decline in capital investment for infrastructure (in particular, in three strategic sectors: electricity, transport and communications), they do not find a strong statistical support. Thus, when performing time series analysis of the relationship (observed in Mexico) between total factor productivity and the ratio of public and private investment, only found correlation coefficients ranging from 0.21 to 0.43 (Lachler y Aschauer, 1998:7).

Aschauer's findings have been corroborated or extended by other researchers, but also widely questioned.

The first major review of the debate is done by Gramlich in 1994, who found that the major problem is the definition of infrastructure capital: in most of econometric studies, publicly owned infrastructure is used as the main independent variable, but other definitions could include investments in privately owned infrastructure, investment in human capital and even in research and development oriented to infrastructure.[14]

Moreover, Gramlich (1994: 1177) identifies the availability of information as a factor hindering the use of broader definitions of capital infrastructure.

[14] In the article by Rozas and Sanchez (2004) one can find a conceptual review of these topics.

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In particular, he emphasizes several important econometric problems: cointegration of the time series of the variables used in the analysis, the absence of important explanatory variables (such as energy prices), and the problem of causality between capital investment infrastructure and the level of productivity in the economy. Thus, Gramlich concluded that this diversity of approaches and the econometric problems are the main reasons that explain conflicting or mixed responses in the study of the economic impact of infrastructure investment, so that the empirical evidence is inconclusive (Gramlich, 1994:1193). Later, another researcher updates the state of the debate on the subject corroborating that the type of infrastructure analyzed can have a differential impact on productivity growth (Bangqiao, 2001). He notes that simple econometric specifications have always parameter estimates higher and more statistically significant than the mathematically more sophisticated specifications, which are not only weak and minor estimates but (in some cases) negative. Moreover, according to this author, the macro-level studies are not able to provide proper guidance to make a decision on a specific project transport infrastructure, which requires using the tools of microeconomic analysis, such as social cost-benefit analysis (Bangqiao, 2001: iii).[15]

More recently, Angel de la Fuente made an analysis of the first twenty years of debate. In fact, he not only corroborates and emphasizes the problems of different empirical specifications, but also reiterates the common problem of data quality and lack of homogeneity, all of which makes very difficult to find conclusions from comparisons between studies conducted in different contexts or countries (de la Fuente, 2010:2).

However, he founds, as Gramlich and Bangqiao, inconclusive the empirical evidence mainly because their interpretation is complicated by the unresolved econometric problems. In particular, he notes that the use of first differences or the introduction of fixed effects in panel data eliminates the significance of the accumulation of fixed capital on regional productivity (de la Fuente, 2010:38). Nonetheless, he finds that investment in public infrastructure itself contributes significantly to productivity growth, at least in countries where the saturation point has not been reached (de la Fuente, 2010:2). This conclusion is similar to that reached in a study of Calderón and Servén (2005). In this analysis of aggregated data over 100 countries, they found a strong relationship between infrastructure stocks and GDP growth, but highlighted the inverse relationship of inequality in income distribution in countries with higher quantity and quality of infrastructure (Calderón and Servén, 2005:26).

It is important to note that the above authors perform their analysis considering the impact of public infrastructure, but not necessarily emphasize the role of transport infrastructure. Instead, a special edition of "The Logistics and Transportation Review" in 1996, includes articles that focus on the analysis of the impacts of transport infrastructure investment in economic development. In fact, in these articles we cloud find essentially the same arguments of the debate, which have been already mentioned above. However, in one of the papers, is emphasized the argument that investment in transport can have spillover effects, which could facilitate the expansion and innovation in other sectors (Garrison and Souleyrette, 1996:5).

[15] For a detailed discussion of this topic, see Weisbrod (2008: 519).

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Morever, in another article Gillen explored the idea about the possibilities of complementarity and substitutability between transport and other factors of production, although their results are not conclusive (Gillen, 1996: 55).

More recent studies show not necessarily matching results. For example, Montolio and Solé conducted a study in 2007 to measure the impact of investment in road infrastructure in the growth of total factor productivity observed in the industries of the Spanish provinces over the period 1984-1994.

By including in their analysis the road "traffic intensity" and road "congestion level" variables, find a positive effect of road investment in the performance of regional productivity, depending on the magnitude of these variables.

In the case of Mexico, Noriega and Fontenla found a complementarity between public investment in infrastructure and private investment in Mexico (Noriega and Fontenla, 2007:885). In particular, these authors review the long-term effects that have had increases in telephone infrastructure, road and telephone in growth of real GDP.

These authors found that the effect of the increase in kilometers of road has its noticeable effect only after seven or eight years. In fact, a similar result found Leduc (2012) who conducted a study of federal investment in roads (in the U.S. between 1993 and 2010).

He found a positive effect on regional GDP, but only as local and temporary impacts, even noticeable only after 6-8 years and disappearing after 10 years (Leduc, 2012:38).

Thus, these results contradict the aforementioned findings of Lachler and Aschauer study, although the analysis of these authors emphasizes on the effects on total factor productivity.

One striking feature of the debate on the economic importance of infrastructure investment (and in particular, investment in road infrastructure) is the frequent absence of analysis of the contribution that investment can have on reducing inequalities observed in the regional economic growth of a country like Mexico. For example, Gerardo Esquivel developed in 2000 an important study that explored the causes of economic development of regions in Mexico. The study includes some variables as representative of the infrastructure (access to water, sanitation and electricity, although excludes transport infrastructure). Esquivel found not enough statistical significance, and concludes that the climate and the vegetation are the variables determining the observed differences between the states on their levels and rates of growth of per capita income (Esquivel, 2000: 44).

More recently, Weiss and Rosenblatt conducted an analysis of the average growth of regional per capita GDP. They have included road infrastructure as part of the analysis, and found that road density[16] is only significant at a level of significance of 10%, lagging behind of other five variables with much greater explanatory power (Weiss and Rosenblatt, 2010:19). Notwithstanding, all the previous debate about the effects of investment in economic growth has not enough focus on the potential impact of more road infrastructure in the most backward regions of the country in order to accelerate their growth and contribute to a more balanced regional development.

[16] That is, the relationship between the number of kilometers of roads and the amount of square kilometers of each state.

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In this sense, in this paper we use the theory of regional convergence as an approach that could be highly relevant in the analysis. The next section of the paper is devoted to the review of this approach.

## 2 The debate about regional convergence

More than twenty years ago, Barro and Sala-i-Martin published his most important articles on regional convergence, which exploded exponentially the existing interest in the possibility that countries may or may not be converging towards economic development.[17]

This debate has focused on the possibility that poor countries are closing the gap that separates from rich countries.

A very similar idea is handled when is analyzed the economic convergence between different regions within a country.

Of course, there are not only different concepts and measures of economic development but also multiple econometric tools applied to different econometric specifications. Each model could be based on a specific theoretical proposal and could include different variables and factors that may affect economic development.

Clearly, it is not possible to address this diversity of analysis in this paper, since it could divert attention from the issue at hand which is the contribution of road stocks to regional convergence in Mexico. Thus, the analysis focuses on the contributions that are considered most relevant and, indeed, are based on the work of Barro and Sala-i-Martin.

In the concerned literature there are two basic concepts of convergence in regional per capita income (Barro and Sala-i-Martin, 2004:462): "Sigma convergence (**δ**)" and "convergence Beta (β)". The Sigma convergence (**δ**) is a measure of convergence that occurs when the dispersion (estimated by the standard deviation of logarithm of the values of per capita income observed in the regions under study) decreases over time. That is, it measures the possible reduction in the dispersion of per capita income (Esquivel, 1999:727).

Instead, under the unconditional convergence Beta (**β**) is postulated the convergence when a poor economy tends to grow faster than a rich economy, so that the poor economy tends to reach the richest economy in terms of per capita levels of product. Thus, we estimate the rate of convergence of regions to a steady state, which is common to all regions, although some regions are temporarily ahead. In fact, for a positive convergence rate is required to have a negative correlation between the two variables under analysis: the initial levels of per capita income observed in each region and the corresponding growth rates.

However, Barro and Sala-i-Martin have observed that while the Beta convergence tends to generate Sigma convergence, this process could be affected by factors that tend to increase the dispersion: "β convergence is a necessary but not sufficient condition to for δ convergence" (Barro and Sala-i-Martin, 2004:464). In fact, Thirwall noted that the estimation of Beta convergence implies a very important assumption: investment rate, population growth, technology and other factors affecting labor productivity must be the same for all regions being compared (Thirwall, 2003:154).

[17] We refer to papers published by these authors in 1991 and 1992 (see references).

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Considering that the previous assumption is difficult to enforce, Barro and Sala-i-Martin proposed the concept of conditional convergence which implies the inclusion in the analysis of those variables postulated to affect the growth of per capita income, and the calculation of the corresponding parameters that measure the distortion effect of these variables on growth (Barro and Sala-i-Martin, 2004:465). In part, this is a response to the criticisms that have been made to the theory of convergence, because it has failed to capture the full potential of analysis that can allow the theory of endogenous development (Romer, 1994:11).

Of course, there are studies that question the importance of the theory of endogenous development in the process of economic convergence. For example, Hulten and Schwab have provided evidence that technological convergence does not explain the regional development of the manufacturing industry in the United States of America (Hulten and Schwab, 1993:23). Moreover, an important criticism to the application of the convergence hypothesis was given by Steven Durlauf in 2003.

According to him, although applications in the literature have identified some stylized facts about the process of economic development, its main problem is that their statistical tests have failed to find the notion of economic convergence in an interesting way from the economic point of view. In this regard, he proposed to pay more attention to the heterogeneity in the different development process of each country included in the regression analysis. Thus, he suggests the use of convergence clubs to integrate countries into groups with greater homogeneity.

Then, this approach would involve the identification of patterns in groups of observations before estimating parametric models (Durlauf, 2003:13-15).

In line with the proposal of Durlauf, some works have performed the analysis of the process of regional convergence in the provinces of some countries. For instance, De Souza and others managed to identify the different patterns of convergence at regional and sub-regional level in Spain, in the period 1955-2010.

However, they do not identify the causes of the disparity in patterns of convergence at sub-regional level. Thus, they let open an important question: why there are different responses in the sub-regions that implemented the same economic policies? (De Souza et al, 2011:14). In this regard, we explored in this study the possibility that a different policy on road infrastructure provision could explain, in combination with other factors, the existence of regional convergence across the country (see section 5). However, we do not address, in this work, the possibility of convergence at sub-regional level.

Other example of the analysis of possible differential effects that can have the application of certain economic policies, using the traditional approach of convergence, has been made by Spilimbergo and Xingyuan who reviewed the effect of certain structural reforms in the process of economic convergence of regions or states of a set of 32 countries (Xingyuan and Spilimbergo, 2012). From their analysis they found that domestic financial development, trade openness, better institutional infrastructure and certain labor reforms have facilitated the process of regional convergence.

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Also support the inverse relationship between the degree of dispersion of regional GDP per capita and the level of economic development. Specifically, they find that Mexico has one of the highest levels of dispersion in per capita GDP. In this regard, an interesting calculation made is the possible increase in per capita GDP national that Mexico could have if the income of the poorest regions increase in such amount that the ratio of income between the poorest and richest region were similar to the ratio observed in the U.S. in 2005. Thus Mexico again shows one of the highest percentages of increase (33.2%) in per capita GDP in order to reduce the regional disparity (Spilimbergo and Xingyuan, 2012:4).

However, an important methodological problem is mentioned by Bonnefond (2013:4) in a study of the convergence process in the provinces of China: there is a risk of finding biased results when one use as explanatory variables to those who are endogenous with respect to economic growth itself. In this regard, this research uses the system GMM (Generalized Method of Moments) in order to avoid this problem.

Of course, there are specific theoretical approaches that differ from the methodology of Barro and Sala-i-Martin. For example, in a recent study, Shi analyzed the impact of capital investment in infrastructure in the process of regional economic convergence of the provinces of China.

With the model developed to estimate the rate of growth of per capita GDP, Shi found that the expansion of the road network has indeed favored the regional convergence in China. However, in some regions road growth has been excessive, affecting capital infrastructure which becomes unproductive (Shi, 2012:24).

After the preceding discussion elements, we will proceed to the analysis of regional convergence in Mexico and the role that could be playing the existence of an increasing availability of road infrastructure in Mexico. We will follow the methodological framework of Barro and Sala-i-Martin, mainly because it would allow us to compare with previous work in Mexico, leaving open the future possibility of other approaches such as the identification of convergence clubs within Mexican territory.

## 3 Regional Convergence in Mexico: backgrounds

In a seminal article about the topic, Esquivel analyzed the effect that some demographic variables have in the observed differences in both the level and the growth rate of per capita income among the Mexican states. Therefore, he calculated the convergence rate $\delta$ (as the unweighted standard deviation of income per capita) observed between 1940 and 1995 (Esquivel, 1999: 725-761). This author finds that the value of $\delta$ was 0.62 in 1940, falling to a value of 0.44 for 1995, which means a significant reduction in the level of regional dispersion of per capita income states. However, this convergence process in Mexico is really slow (at a rate of 1.2 percent per year), occurring mainly between 1940 and 1960, and remaining relatively constant after 1960. It is noteworthy that Esquivel confirms these results when performing the analysis at the regional level, i.e., grouping the states as belonging to the North Pacific, Gulf and Capital regions that show a tendency to grow faster than the Southern, Central and North Central. In fact, the two factors that Esquivel found as possible explanations for the low rate of convergence between Mexican regions are "the low sensitivity of interstate migration to income differentials and increasing regional disparities in the provision of post-primary education."

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Esquivel's final conclusion in his article just gives a guideline for the purpose of our study, because he states that "it is necessary to outline and implement policy measures aimed at reducing regional disparities in terms of the stocks and the formation of human capital and, perhaps, basic infrastructure " (ibid.: 760, emphasis added).

Shortly after, the same researcher explores the potential role of geographical factors in the type of regional development observed in Mexico. In particular, their analysis finds that the possible influence of geographical variables (location, vegetation and climate) in regional economic development is through its effect on human capital, that is, "through its influence on life expectancy and in the acquisition of a higher educational level" (Esquivel, 2000:30). This conclusion of Esquivel is especially interesting because it reinforces our hypothesis that the roads could be a key factor in the development of the Mexican regions because, precisely, it can be assumed that access to education and health services depends on the physical accessibility provided by the road assets available in each state in the country, although it is possible that access to services remains determined by the total cost of transport, among other factors.

In the same year, Messmacher conducted an investigation to determine the effects of NAFTA on regional inequality in Mexico. Among its key findings, he corroborates the fact that an increasing regional inequality has favored the northern states of the country.

Moreover, the manufacturing activities and transportation and communications are the main factors that explain the dynamics of the states with highest growth (Messmacher, 2000:22).

Thus, although this author was not focusing in transport infrastructure, this finding could support the idea that the transport sector may be not growing because of a lack of adequate infrastructure. So, it is possible to assume that the states that have invested more in roads, for example, have supported the growth of manufacturing activities. Of course, these are precisely the issues within the research agenda of regional development.

Two years after the work of Esquivel, Luis Cabrera Castellanos publish an article about the empirical evidence of regional convergence between the Mexican states (Cabrera, 2002). Although the period of analysis (1970-1995) considered by this researcher is significantly lower than considered by Esquivel, reaches a qualitatively similar conclusion: the existence of absolute convergence is confirmed in Mexico. However, their results contradict Esquivel because Cabrera find that the convergence rate tends to grow in the last years of period since "the speed of absolute convergence is slightly more than 1% for the entire period, but of 3% for the last fifteen years" (Ibid: 18). As noted above, Esquivel (1999:760) finds that convergence has stagnated precisely from the sixties.

One possible explanation for this apparent contradiction is to compare the scale of the graphs of the sigma convergence offered by these two authors. So, taking into consideration a larger period of time, Esquivel find the period 1960-1995 as one with relative stagnation in the convergence rate.

Instead, Cabrera focus is on the last years makes the changes more visible and significant. This topic will be reviewed later in this paper.

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## 4 Measurement of absolute convergence in the period 1940-2010

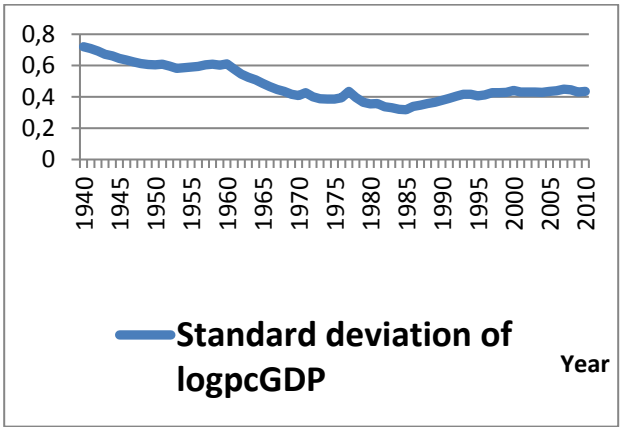
In this paper, the period for the analysis of absolute convergence has been selected by two criteria. First, it is important to have the widest possible range of years of regional economic development in Mexico, whenever we have a situation of relative political and social stability in the country. In other words, we analyze the possible effect of certain public policies in the economic development of regions, by taking into consideration a really long period, from the pacification of the country (i.e., after Mexican revolution). In fact, based on this idea, perhaps we could have taken the early thirties of the last century as the beginning of the period of stability. However, it should be recognized that it is not possible to obtain reasonably reliable information for the process of road construction in each of the states of Mexico, but from the year 1940.[18]

In adition, we are also looking for reliable information about economic growth. In this regard, it has been considered the per capita gross domestic product (hereinafter pcGDP) as one of the most representative variables for comparative analysis of economic growth in each of the regions.

Moreover, the work of Germán-Soto has enabled the availability of a very consistent estimation of pcGDP in Mexican states (Germán-Soto, 2005: 617-653). Thus, from his research, we have a data base of pcGDP (at 1993 prices) covering the period 1940 to 1992, and we combine it with the estimate made by the INEGI for the period 1993 to 2010 (INEGI, 2014).

With this database, it is possible to corroborate the behavior of nationwide pcGDP (in 1993 pesos): a generally rising trend (even with the negative but temporary effects caused by several crises in the Mexican economy). As a consequence, the average pcGDP observed in 2010 is 3.6 times higher than in 1940, i.e., there is an annual growth rate of 1.85% in the past seventy years. It is important to mention that, in the previous figures, we have exclude three Mexican states: Tabasco, Campeche and Baja California Sur, although we still have a behavior with the same general features, but without any temporal biases that involves the inclusion of the above states.[19]

Actually, the topic that interests us is the behavior of pcGDP observed in the states, as well as the degree of dispersion around the mean. This interest is because the hypothesis postulated under the absolute convergence δ implies a reduction in the standard deviation of the per capita GDP logarithm (hereinafter logpcGDP). Thus, Graphic I show the behavior of this pcGDP dispersion measure observed by Mexican states, between 1940 and 2010.




**Graphic 1**

[18] Thus, the information available about of road stocks in Mexican states can be obtained from statistical yearbooks provided by INEGI in PDF format on their website (see bibliography).

[19] In fact, we are following the idea of Esquivel (1999:740), excluding some states in order to avoid distortion of general behavior of country.

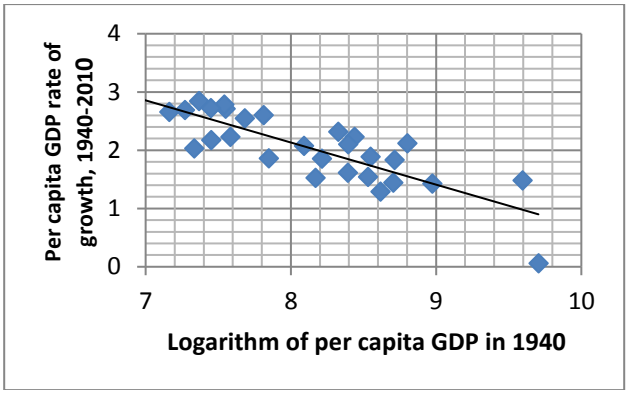
Note that the behavior and the estimated values of logpcGDP (plotted in Figure I) are, in general, closer to those reported by Cabrera (2002) than those found by Esquivel (1999: 740), in the corresponding periods in analysis.[20] In fact, when we take a much longer period of time, we also reach the conclusion of Cabrera: there is an increase in the dispersion of regional GDP between 1985 and 1995.

Thus the long-term trend shown in figure I indicate that indeed this phenomenon is occurring, but it really represents a recovery from the fall experienced by the standard deviation of logpcGDP in the previous decade.

Moreover, we also corroborate the central conclusion of Esquivel: the overall trend between 1940 and 1995 indicates a decrease in state pcGDP disparities, but with two quite distinct periods, one sharp decline between 1940 and 1970, and a subsequent increase towards stabilization.

However, as can be seen in Graphic I, in fact the period of decrease of the dispersion reaches the mid-eighties.

After that date, there seems to be a process of increase in the standard deviation, i.e., an increasing inequality in pcGDP of Mexican states. In fact, following the methodological process of Barro and Sala-i-Martin (2004:466), in Graphic II we show the relationship between the pcGDP growth rate and the logarithm of initial pcGDP observed in the corresponding Mexican state (in the initial year, 1940).




**Graphic 2**

The corresponding simple regression yields an $R^2$ of 0.69 and a negative and statistically significant coefficient.[21] Therefore, this analysis indicates that there is a process of economic convergence between the states of Mexico considering all the period from 1940 to 2010. However, in order to estimate the rate of this process of convergence, we have chosen the same expression used by Esquivel (1999:738).In this way, we will make some comparisons with the results that this researcher found in their study. The mentioned expression is:

$$\frac{y_{i,t} - y_{i,t-\tau}}{\tau} = \alpha - \beta y_{i,t-\tau} + \mu_{i,t} \quad (1)$$

Where $y_{i,t}$ is the per capita income observed in the ith region in the t-th period, $\mu_{i,t}$ is the stochastic term, $\alpha$ is the constant that includes the level of income in the steady state, $\beta$ is a parameter directly related to the rate of convergence to a common steady state in the economy in all regions studied, and $\tau$ is the time interval in which the convergence is measured.

[20] Probably, this is because Esquivel (1999: 740) have different sources of information to those used in the present work.

[21] It is noteworthy that we also perform the analysis with the inclusion of BCS, Campeche and Tabasco, but did not find many differences, although the $R^2$ decreases slightly (now is 0.67).

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As shown, the explanatory variable is the logarithm of initial pcGDP. Table 1 shows the results of estimating the above expression in three different periods of interest for our analysis: 1940-2010, 1940-1985, and 1986-2010. The fourth regression also corresponds to the period 1986-2010, but excludes the states of Baja California Sur, Campeche and Tabasco, for the reasons already mentioned.

| | | Convergence rate of growth | | | |
|---|---|---|---|---|---|
| Regression | Period | Coefficient | Standard deviation | $R^2$ | Cases |
| | | | | | |
| 1 | 1940-2010 | 0.0070 | 0.0009 | 0.672 | 32 |
| 2 | 1940-1985 | 0.0138 | 0.0023 | 0.537 | 32 |
| 3 | 1986-2010 | 0.0135 | 0.0035 | 0.346 | 32 |
| 4 | 1986-2010 | 0.0025 | 0.0037 | 0.016 | 29 |

**Table 1**

From table 1 we note that there is a convergence rate relatively lower than that reported by Esquivel and Cabrera. So while Esquivel (1999) estimated for the period 1940-1995, an annual average of nearly 1.2 percent convergence, our analysis for the period 1940 to 2010 is 0.7 percent. The difference may have two reasons. The first one is the database used, not the period of time. Thus, a regression (not reported in Table 1) made for the same period analyzed by Esquivel (i.e., 1940-1995) still shows a lower rate of convergence (i.e., 0.9%).[22] The second reason (which probably adds to the previous reason), is because we could find, precisely in the last years of the period, a tendency to increase regional disparities in pcGDP.

In fact, this apparent change in the tendency of the convergence rate had been interpreted by Esquivel as stagnant tendency and not a reversal of the trend. Therefore, it is important to separate the analysis in the two periods (see Figure I): the first period (from 1940 to 1985) shows a convergence trend, but the second period (from 1986 to 2010) seems to have a divergence tendency or at least to remain in a stagnation process in the growth of the convergence rate.

As also shown in Table 1, by analyzing only the period from 1940 to 1985, we found a convergence rate even higher than that estimated for the entire period. This is an expected result and also consistent with the values reported by Esquivel (1999:740). However, the estimate of the rate observed between 1986 and 2010 also reports a rate value greater than found for the whole period convergence. Although the estimate is not statistically significant even at 10%, this result requires an explanation.

One possibility involves an analysis excluding Baja California, Campeche and Tabasco. Thus, regression 4 (in Table 1) indicates the existence of a very low convergence rate, although again the estimate is not statistically significant.

Clearly, it is necessary to deep the analysis of convergence in Mexico. However, the review and updating we have done in this part of the work could be sufficient for the purposes of this paper, because the main findings corroborate the previous work on the topic: there is a trend of economic convergence among the states in Mexico, but this process has a very low growth rate.

[22] Again, the differences may be mainly because Esquivel (1999) used a different database to the one used in the present study data, which is provided by the German-Soto (2005).

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We now turn to analysis of the role that could be playing the investment in road infrastructure on the process of convergence.

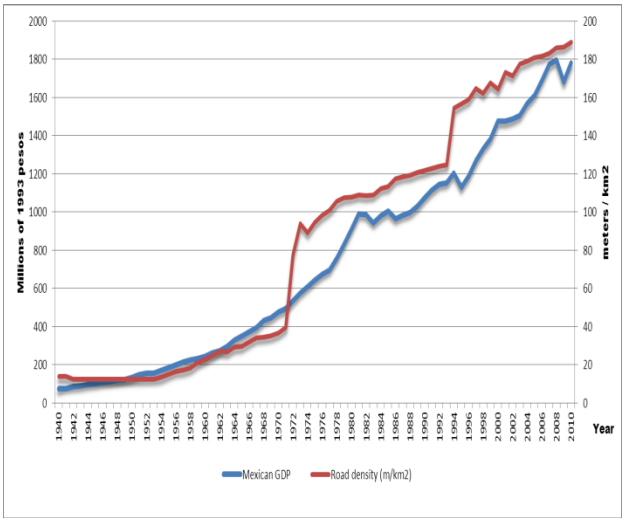
## 5 Growth of the road network in Mexico

As can be seen in graphic III, the accumulation of road stocks in all the country shows a similar growth in relation to the behavior of GDP. Based on the road density indicator (linear meters of road per square kilometer of territory), one can see that the country is gradually covered by a growing quantity of roads, although the process shows two atypical times of strong growth (1972-1973 and 1994).

Of course, the dynamics under a higher road density is not sufficient, by itself, to conclude that the expansion of the road network has been tailored to the needs of mobility posed by economic development in all regions.

In addition to the quantity of roads, it is important to analyze the effect of some qualitative aspects, such as the type of roads built (paved, semi paved or unpaved) or the number of lanes available to the road.[23]

Moreover, there is the possibility that the roads are built but not where they are needed or where they contribute more to the economic development of the region (Islas, 1990:73).




**Graphic 3**

For example, as shown in Table 2, not all states have reached a similar level of density in its road network, nor had the same growth rate of roads during the period in analysis.[24] Thus, there is a group of states that have achieved a high level of road density, but this is mainly explained by their relatively smaller total area. Such is the case of Tlaxcala, Morelos, Aguascalientes, Guanajuato, Colima and Tabasco.

One exception is the case of Campeche which has always been a much lower density than the national average. Moreover, there are Mexican states showing a low level of road density, which is partly explained by the large size of its land area, as are the cases of Chihuahua, Coahuila, Baja California Sur, Sonora and Durango.

[23] Which results into a greater capacity of the road, although an increase in capacity is not a factor strictly related to increased security (see, for example, Karlaftis, M. (2002)

[24] Although we are analyzing the total of roads, the growth tendency of paved roads was also analyzed. Thus, in spite of significant differences, they do not change the main argument: the different tendencies of road stocks in the states of the country.

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However, we found several cases where the extension is not huge factor to prevent a relatively high level of road density, as shown by the behavior of Veracruz, Chiapas and Oaxaca.

| | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Aguascalientes | 11.2 | 45.0 | 95.5 | 123.3 | 367.1 | 355.5 | 389.9 | 408.1 |
| Baja California | 9.1 | 11.1 | 17.4 | 20.7 | 50.0 | 111.2 | 167.3 | 166.2 |
| Baja Calif. Sur | 3.7 | 8.3 | 21.2 | 13.8 | 67.9 | 82.3 | 87.7 | 74.0 |
| Campeche | 1.5 | 4.5 | 14.9 | 21.7 | 47.5 | 100.2 | 85.8 | 98.4 |
| Coahuila | 7.6 | 8.7 | 16.8 | 19.3 | 63.9 | 63.4 | 55.5 | 58.0 |
| Colima | 31.3 | 37.0 | 66.5 | 98.1 | 284.5 | 287.3 | 382.4 | 406.2 |
| Chiapas | 7.6 | 9.7 | 24.7 | 41.4 | 134.1 | 149.7 | 275.9 | 302.7 |
| Chihuahua | 3.9 | 4.7 | 7.6 | 12.3 | 39.1 | 46.3 | 51.1 | 53.7 |
| Durango | 12.0 | 10.1 | 14.7 | 18.2 | 74.8 | 74.9 | 103.0 | 130.0 |
| Guanajuato | 23.4 | 23.8 | 46.9 | 84.0 | 197.3 | 245.8 | 361.6 | 406.4 |
| Guerrero | 11.4 | 10.0 | 25.5 | 40.2 | 140.9 | 129.6 | 207.3 | 281.0 |
| Hidalgo | 39.6 | 45.8 | 72.7 | 124.6 | 292.8 | 301.3 | 438.7 | 537.5 |
| Jalisco | 14.3 | 19.4 | 27.1 | 41.2 | 125.1 | 142.3 | 309.7 | 339.6 |
| México | 87.1 | 45.8 | 96.4 | 170.3 | 361.7 | 459.7 | 462.4 | 638.8 |
| Michoacán | 51.5 | 24.7 | 41.5 | 61.9 | 168.6 | 157.4 | 221.1 | 268.5 |
| Morelos | 87.2 | 99.8 | 120.4 | 175.3 | 466.3 | 426.6 | 405.0 | 563.7 |
| Nayarit | 10.1 | 17.8 | 33.3 | 44.5 | 107.5 | 127.7 | 201.7 | 299.2 |
| Nuevo León | 16.9 | 14.4 | 27.7 | 39.4 | 91.4 | 137.4 | 111.2 | 113.7 |
| Oaxaca | 10.8 | 10.9 | 18.4 | 44.0 | 121.1 | 116.3 | 167.2 | 222.9 |
| Puebla | 30.7 | 31.8 | 42.1 | 73.1 | 216.2 | 218.6 | 251.1 | 289.5 |
| Querétaro | 49.2 | 25.3 | 36.3 | 90.4 | 291.5 | 313.7 | 282.6 | 279.9 |
| Quintana Roo | 0.7 | 2.7 | 8.3 | 23.5 | 83.3 | 116.6 | 119.8 | 129.2 |
| S. L. Potosí | 18.9 | 18.3 | 25.3 | 37.0 | 110.8 | 151.5 | 194.1 | 183.2 |
| Sinaloa | 15.5 | 16.2 | 38.4 | 51.7 | 198.2 | 189.0 | 327.5 | 336.8 |
| Sonora | 10.2 | 7.0 | 14.8 | 19.6 | 62.4 | 61.4 | 121.1 | 133.3 |
| Tabasco | 24.0 | 14.1 | 33.6 | 103.4 | 206.2 | 291.3 | 347.9 | 350.7 |
| Tamaulipas | 16.7 | 15.2 | 24.6 | 33.0 | 132.6 | 159.4 | 155.5 | 174.7 |
| Tlaxcala | 98.9 | 101.8 | 93.5 | 191.6 | 781.3 | 717.2 | 638.5 | 660.4 |
| Veracruz | 9.0 | 18.5 | 33.0 | 70.2 | 157.8 | 141.3 | 217.8 | 354.5 |
| Yucatán | 31.9 | 8.7 | 23.2 | 42.6 | 127.1 | 164.6 | 282.5 | 285.0 |
| Zacatecas | 7.8 | 7.8 | 14.9 | 33.5 | 121.9 | 134.1 | 136.6 | 152.7 |
| Total | 13.9 | 12.7 | 22.9 | 36.5 | 108.0 | 121.6 | 164.2 | 189.1 |

**Table 2**

However, it is important to note that even within the above groups of states do not appear to be a strictly inverse relationship between the size of the land area and road density. This observation is even most clear when we analyze the behavior of the rest of the Mexican states. Therefore, there are other factors that could be influencing a higher rate of densification road. For instance, we could assume that the level of economic activity is an important variable. In fact, this could be the explanation of the cases of Jalisco and Mexico. However, the case of Nuevo Leon is an outlier because we have a very high level of economic activity but a low rate of growth in the road density.

In fact, from Table 2 we could not find a stylized or similar trend in the road density of Mexican states. Moreover, it is interesting to notice that there are some states that show an unusual increase in the decade of the seventies. In contrast, in some other states is also observed an increase but more moderate in those years, while the largest increase was observed in the nineties or more recently.

Therefore, we have the following question: is the increased availability of road infrastructure in some states a special factor to reach (in a few years) the pcGDP that now have the richest states?

For instance, the state of Aguascalientes shows some short periods with a high rate of road construction (reflected in higher road density). However, these pulses do not appear to have a visible impact on the tendency of pcGDP. It is clear that we need to perform a more in depth analysis, not constrained to a particular case.

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## 6 Highway Infrastructure and regional convergence in Mexico

In order to have a more comprehensive analysis about the possible influence of greater road infrastructure availability in the economic convergence of Mexican states, we perform an analysis of conditional convergence, with special emphasis on one variable: the accumulation of road stocks. We use the following expression:

$$\log(y_{i,t} / y_{i,t-\tau}) = \alpha - \beta_1 y_{i,t-\tau} + \beta_2 x_{1it} + \beta_3 x_{2it} + \ldots + \beta_n x_{mit} + \mu_i \quad [2]$$

Where, besides the elements already described from the expression [1], we have the variables $x_{1it}$ to $x_{mit}$ assumed to that affect the growth of per capita income, which Cabrera (2002:14) identifies as "additional control variables of steady state".

For the regression analysis we considered the variables described in Table 3. Obviously, as part of the convergence analysis model, we include in all cases the LPIBPCIN variable. Then he included only one of the variables that could be used to measure the impact of the accumulation of road stocks (CARRPAV, CARRNOPAV, and CARRTOT) in runs for each of these variables separately (to avoid multicollinearity problems, given the existing high coefficients of correlation between these variables). Note that this separation is also important for analysis of the different policies of road infrastructure. Thus, it is interesting to compare the differential effect on economic growth of transport policies that focus on building more roads of poor specifications (i.e., semi-paved and unpaved), versus building fewer roads (being obviously more expensive) but paved with better specifications, or even a mixture of both policies.

| Variable | Description (information corresponds to each state in a given year). |
|---|---|
| LTDCREC | Logarithm of average annual growth rate of per capita GDP. |
| LPIBPCIN | Logarithm of per capita GDP in the initial year. |
| CARRNOPAV | Kilometers of semi-paved and unpaved roads. |
| CARRPAV | Kilometers of paved roads. |
| CARRTOT | Total of paved roads. |

**Table 3**

Following, to some extent, the above mentioned idea of Durlauf (2003:13-15) about convergence clubs, we have performed our analysis considering the Mexican states grouped in the regionalization most frequently used in Mexico. In fact, we made a preliminary regression exercise considering the 32 Mexican states, but the results were statistically weaker than those obtained with the regionalization shown in Table 4.

| Region | States in the region |
|---|---|
| Noroeste | Baja California Norte, Baja California Sur, Sinaloa, Sonora. |
| Noreste | Coahuila, Chihuahua, Durango, Nuevo León, Tamaulipas. |
| Centro-Occidente. | Aguascalientes, Colima, Guanajuato, Jalisco, Michoacán, Nayarit, Querétaro, San Luis Potosí, Zacatecas. |
| Centro | Distrito Federal, Hidalgo, México, Morelos, Puebla, Tlaxcala. |
| Sureste | Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Tabasco, Veracruz, Yucatán. |

**Table 4**

The results obtained in the different regressions related with model postulated in expression 2, are shown in Table 5.

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| Independent variable | Dependent variable: LTDCREC | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Constant | 0.042484 (16.18577) | 0.044387 (17.57108) | 0.042830 (12.75309) |
| LPIBPCIN | -0.015009 (-20.76352) | -0.015170 (-19.80483) | -0.015001 (-20.31570) |
| CARRPAV | 0.000355 (1.07366)** | | |
| CARRNOPAV | | -3.45E-05 (-0.12017)** | |
| CARRTOT | | | 0.000267 (0.70656)** |
| Adjusted $R^2$ | 0.167 | 0.167 | 0.167 |
| F-statistic | 225.958 | 225.274 | 225.565 |

**Table 5**

In table 5 we corroborate the relationship between the growth rate of per capita GDP (i.e., LTDCREC) and the initial level of per capita GDP (LPIBPCIN). Although the parameter value is relatively low (around 0.43 in all regression runs), it has a negative sign and it is statistically significant.

This result is consistent with the main conclusion from the above analysis of absolute convergence (see the previous section 4): there are clear indications that the Mexican states are in a process of convergence but at a relatively slow rate in the period 1941-2010.

In contrast, the parameter estimates for the different variables that measure the road stocks, are actually very low,[25] particularly if they are compared with the parameter obtained for the initial GDP per capita. Actually, it is important to note that the adjusted $R^2$ of regressions is 0.167. This finding corroborates the low explanatory power of the variables measuring the road stocks. Therefore, we need to include other variables (i.e., $x_{mit}$ type, in expression [2]), if we have the aim to find the variables that really explain the regional convergence process in Mexico.

Considering the above, and even considering that this explanation is not a central part of this work, we have included in the analysis some variables typically associated with the growth of per capita GDP. Thus, this analysis will allows us to compare the performance of the variables associated with the growth of road stocks of Mexican states.[26]

Unfortunately, we have not had the availability of complete and reliable information for the entire period of the previous analysis (1941 to 2010) but only for recent years (in fact, from 1994 to 2010). Nevertheless, it can still be useful because it would allow also compare the performance of the road stocks in a recent period.

Firstly, we are adding the life expectancy as a variable that is assumed to be a proxy that measures the human capital available to each Mexican state.[27]

[25] Although that parameters are not statistically significant in all cases.

[26] However, the comparison with the effect of initial per capita GDP must be taken carefully, given the theoretical importance of this variable.

[27] "Life expectancy" is defined as the expected average number of life years of resident population (see CONAPO, 2012).

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In fact, from the analysis of our database (for the period 1994 to 2010) we found a correlation coefficient (hereinafter CC) between life expectancy and growth rate of pcGDP of 0.29, which is the greatest of all the CC calculated for the variables in the analysis.

Secondly, we originally included in the regression the average years of schooling because it is frequently used to measure the impact of human capital on economic growth.[28] In addition, it shows a CC of 0.19 in relation with the growth rate of pcGDP. However, schooling was removed from the analysis because it has a very high CC in relation with life expectancy and also with initial pcGDP. In fact, the same problem arose with another variable that originally we have assumed could help in the analysis, i.e., foreign direct investment. Thirdly, instead of this two variables, we included the net population migration (hereinafter, MIGN) [29] because this variable shows relatively low CC in relation with initial pcGDP and life expectancy.

Moreover, MIGN shows a negative correlation with the pcGDP rate of growth, implying that states that retain or even attract more people (that is, with greater immigration than emigration) tend to economic growth. It important to note that the additional variables finally included in the regression (i. e., schooling, life expectancy, and interstate migration) have low values of CC in relation with the variables representing the road stocks.

In fact, this low correlation was not expected because we commonly may assume, for instance, that there is greater life expectancy in the states with more road stocks. Nevertheless, this situation let us to include the variables as shown in Table 6, which contains the results of the regression analysis, made for the period 1994-2010.

| Independent variable | Dependent variable: LTDCREC | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Constant | -0.28633 (-6.6014) | -0.29671 (-6.74794) | -0.29737 (-6.78897) |
| LPIBPCIN | -0.00624 (-2.97244) | -0.00787 (-3.76426) | -0.007399 (-3.51883) |
| CARRPAV | 1.50E-06 (3.57889) | | |
| CARRNOPAV | | 1.45E-07 (1.10129)** | |
| CARRTOT | | | 1.96E-07 (1.81277)* |
| ESPVIDA | 0.004126 (6.78371) | 0.00438 (7.15997) | 0.004359 (7.14397) |
| MIGN | -7.38E-08 (-1.73026)** | -6.38E-08 (-1.47848)** | -6.38E-08 (-1.48395)** |
| $R^2$ | 0.1189 | 0.0999 | 0.1034 |
| F-statistic | 14.5211 | 11.95028 | 12.40996 |

**Table 6**

Again, in all cases, we found statistical significance (tested at 99%) of the parameters associated with the level of initial per capita GDP, with the correct (negative) sign for the theoretical approach, but their parameters show relatively low values.

[28] For example, in a recent study of conditional convergence in China, in the period 1995 to 2009, Bonnefond found that both investment in physical capital and education have played a very important role in promoting economic growth and reducing regional disparity (Bonnefond, 2013: 12).

[29] Calculated as the difference between the thousands of people who migrated to another Mexican state, and the thousands of people who migrated to the corresponding Mexican (see CONAPO, 2012).

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Indeed, these parameters are even lower than the values found in the analysis of the period 1941-2010 (see Table 5). These results are congruent with the findings reported in section 4.

In particular, from regression 1 we conclude that CARRPAV has the best statistical performance even if the parameter value is actually very low compared to the corresponding parameter to life expectancy and much less representative if it is compared to the corresponding parameter of LPIBPCIN (initial level of per capita GDP).

Instead, regression 2 shows that CARRNOPAV (i.e., unpaved roads in the state) is a variable not statistically significant. Similarly, CARRTOT (i.e., total roads) is only significant at 95%. These results are consistent with the findings of Weiss in the sense of lower statistical significance of road stocks in comparison with other variables with greater explanatory power about regional growth in per capita GDP (Weiss, 2010: 19).

## 7 Conclusions

The road transport system in Mexico has grown throughout the country. Although part of this quantitative and qualitative growth may have been happened in response to the detection of specific needs (and, perhaps, looking for an appropriate allocation of resources), there is the possibility that another part of the road infrastructure has been built for reasons unrelated to economic rationality or without a better understanding of the interrelationship between road infrastructure investment and the process of economic development of the regions where such infrastructure is built.

Of course, the topic is really complex. From a literature review, mainly centered around the debate generated by Aschauer contributions, we found a richness in the past analysis of the issue, with a great diversity of possibilities of approaches and argumentation. In fact, the current state of the debate indicates that there are not conclusive elements to be sure that road infrastructure investment will be, ipso facto, an undisputed factor of economic growth, as seem to be assumed by the vast majority of government programs that are oriented to look for greater economic development.

In particular, some of these programs also assume the idea that infrastructure investments contribute to a more balanced regional development. However, there are not enough and rigorous analysis of the extent to which the largest endowment of road infrastructure is really contributing to reduce disparities in regional development.

Therefore, in this paper we apply the conceptual framework that studies the process of regional convergence, particularly based on the methodological contributions of Barro and Sala-i-Martin. Thus, we took into account the previous work made about absolute and conditional convergence process of Mexican states, focusing in the results of Esquivel (1999) and Cabrera (2002). In addition to corroborate the main findings of these researchers (in the sense of the existence of a process of absolute convergence in the evolution of per capita GDP in Mexico, but at a very low rate) our analysis was made on a period of analysis substantially greater than that considered by the authors.

Thus, in this paper we analyzed the possibility of absolute convergence between 1940 and 2010, meanwhile Esquivel (1999) studied it from 1940 to 1995 and Cabrera (2002) did from 1970 to 1995.

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Indeed, our greater period of analysis seems to explain why these authors have some conflicting results: Esquivel (1999) finds the years 1960-1995 as a relative stagnation in the behavior of the convergence rate, while Cabrera (2002) found an increase in the dispersion of regional GDP between 1985 and 1995. In fact, when analyzing a period larger time, we have corroborated this increase but only as part of a slight reversal in the trend towards regional convergence in recent years, while Esquivel (1999) identifies a stagnation period.

In the case of conditional convergence analysis from our long-term analysis (i. e., taking the period 1941-2010), we find that the estimated parameters for the different variables that measure the road stocks, are really very low, particularly when compared with the parameter obtained for the initial GDP per capita. Moreover, they are not statistically significant in all cases. In fact, the adjusted $R^2$ is very low, in spite of the inclusion of road stocks variables. Thus, even considering that the full explanation of the process of regional convergence is not the central part of the present work, we have included in the analysis some variables typically associated with the growth of GDP per capita: life expectancy and state net migration (although only for the period 1994-2010).

The main conclusion from the analysis of conditional convergence in this period is that only paved road stocks are statistically significant, but only with a barely perceptible effect on the growth rate of convergence of regional per capita GDP.

Moreover, this effect is rather limited compared with the corresponding to the "life expectancy" and much less representative compared to the initial levels of per capita GDP.

In sum, these results indicate that there are not many conclusive arguments (either in terms of statistical significance or relative contribution) to accept that road stocks are contributing to convergence in regional economic development in Mexico, though the debate is far from being overcome.

We need to continue the work, following the recommendations of Gramlich, Bangqiao, Durlauf, among others, on the use of various econometric tools; the improvement in the availability of more reliable information; the use of more sophisticated econometric specifications (for example, with more variables or not linear relationships); and, the improvement on the economic significance of regional analysis (for example, it is very important to corroborate the existence of spillover effects and possibilities of complementarity of transport with other economic sectors).

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