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An analysis of the relationship between infrastructure investment and economic growth in Mexican urban areas, 1985-2008

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Abstract

The relationship between infrastructure investment and economic growth in Mexican urban areas 1985-2008 is analyzed using several panel cointegration tests that control for heterogeneity and serial correlation. Data are found to be stationary in first differences but not levels. The long run cointegrated relationship between certain kinds of infrastructure measures such as water supply, a global infrastructure index, road infrastructure, vehicle density, highways, and a social infrastructure index combined with the finding of no relationship with other measures favors a policy of targeted infrastructure investments by both the private and public sectors.

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1. Introduction

The relationship between infrastructure investment and economic growth in important Mexican urban municipios is explored. A cointegration method with panel data incorporates individual non-stationary variables that are cointegrated. While the importance of infrastructure investment to increased productivity is well known, we explore such investment for Mexican urban areas. As the investment may impact with a lag, we use a long enough time period to incorporate a lagged impact and a long run equilibrium as theory predicts.

Mexico is one of the Latin America countries that have not reduced its poverty (OECD, 2013, and Sedesol, 2014). Recent government reports highlight an additional two million people falling below the poverty line to create a total of 55.3 million poor people in 2014 (Sedesol, 2014, and Viesti, 2015). Poverty is measured as the lack of one or more services like housing, education, health services, social services, water supply, and electricity consumption. Poverty persists because of low growth, weak social policies and infrastructure investments not targeted at low income households. Low growth is somewhat unexpected as Mexico opened the economy over 30 years ago with increased deregulation, privatization and scaling back of government interventions.

To measure infrastructure, we use data on roads (km^2), the percentage of households that have basic utilities, and two indices of human capital and social investment. Economic growth is measured in three ways: per capita Gross County (municipio) Product (GCP), labor productivity defined as GCP per worker, and GCP per adult (older than 15 years). Data covers the economic censuses of 1985, 1988, 1993, 1998, 2003 and 2008. County statistical yearbooks supplement these national data. As 87% of overall GDP is found in only 71 urban areas, we focus on this smaller sample.

Section two reviews the literature on growth and infrastructure while section three describes the data. The fourth section describes the method and section five discusses the results. Section six concludes.

2. Literature Review

2.1. The infrastructure-economic growth link

Infrastructure is an important contributor to economic growth and is often built out by the government (Biehl, 1988). Occasionally, infrastructure is an explicit input in a production function (Aschauer, 1990, and Barro and Sala-i-Martin, 1992).

A large literature extols the benefits of infrastructure to economic growth (Aschauer, 1989, 1990, and 2000; see also Munnell, 1992, Evans and Karras, 1994a, Cutanda and Paricio, 1994, Mas and Maudos, 2004, and De La Fuente, 2008). However, the literature also highlights some econometric problems such as unit roots and spurious correlations that accompany a lagged impact on growth that need to be addressed (Sánchez-Robles, 1998, and Lall, 2007). Applying regression equations in first differences or including fixed effects is suggested but there is a loss of statistical significance (Evans and Karras, 1994b, and Holtz-Eakin and Schwartz, 1995). More recently, panel stochastic analysis and spatial econometric methods have addressed these concerns. For example, Zhang (2008) uses spatial econometrics to demonstrate that transport infrastructure and economic growth create a spatial cluster in China. Mizutani and Tanaka (2010) find that infrastructure investment by the national government accelerates the sub-national government investment done by Japanese prefectures. Pereira and Andraz (2012) show that investment in highways positively affects the gross state product in the U.S. Herrerías and Orts (2012) provide evidence on equipment investment and human capital as determinant factors of long run Chinese productivity growth.

Evidence from Mexico shows positive effects of expanding infrastructure in electricity, communication and transport (Fuentes and Mendoza, 2003), but with highways the evidence is mixed (Feltenstein and Ha, 1995). Lächler and Aschauer (1998) emphasize the long term nature of investments as little short run evidence is found with additional support for their conclusions a decade later found in Noriega and Fontenla (2007).

2.2. Causality, endogeneity, and serial correlation

In analyzing the link between infrastructure and economic growth, we focus on three issues: causality, endogeneity, and serial correlation. The first may depend on the stage of overall economic development of the country. If a country is relatively undeveloped, infrastructure investment is a necessary but not sufficient condition to raise the growth rate. Infrastructure should be examined explicitly and causes growth. If a country is well developed, growth can cause infrastructure to expand suggesting causality reverses over development stages. Results can also vary over different time periods and economies. The uncertainty calls for a method beyond OLS such as GMM which can address endogeneity. We use panel data and assume variables lagged by one period control for endogeneity. Serial correlation is addressed with first differencing and/or using rates of growth instead of levels of variables. We test for unit roots and if we find them use standard linear combination methods to get a stationary series.

3. The Data

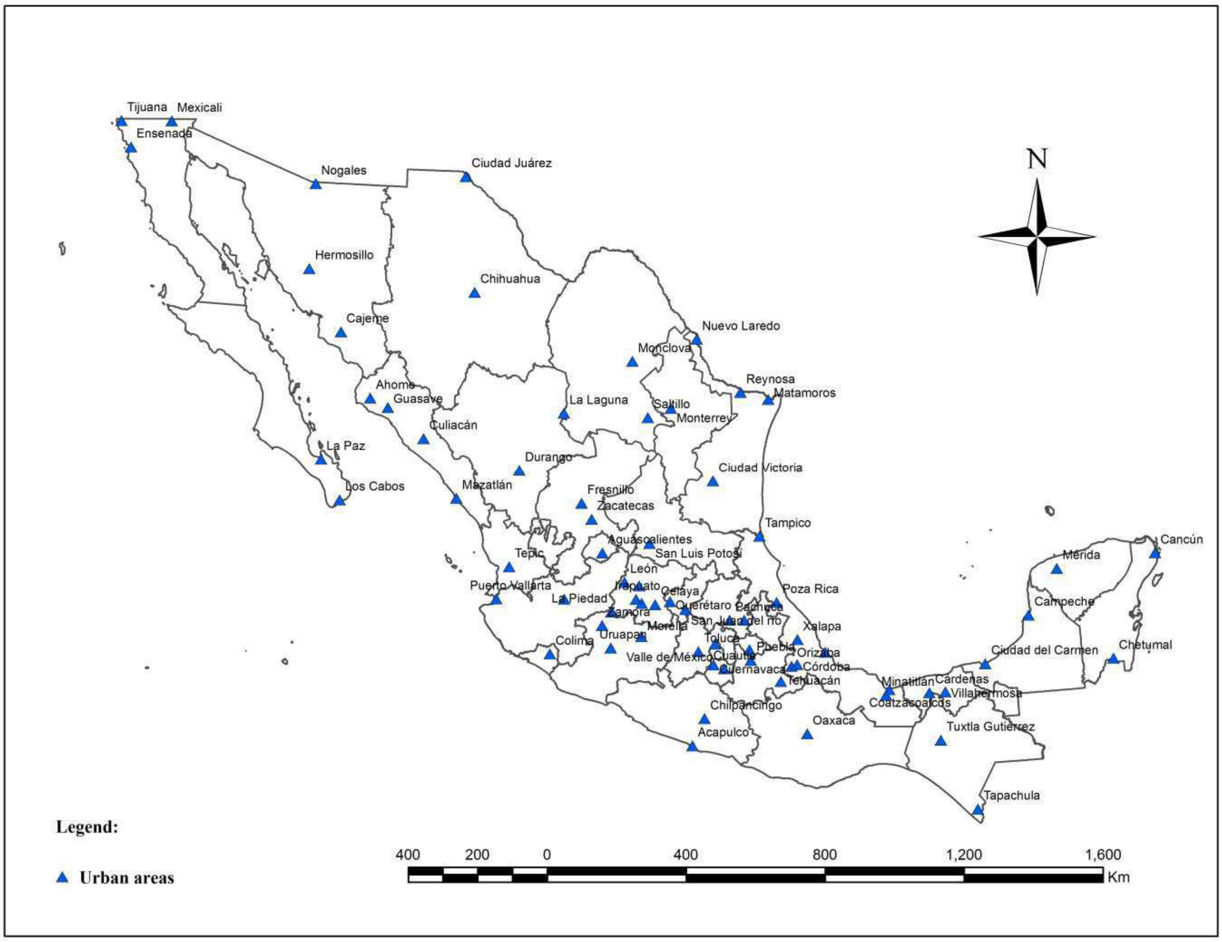
Mexican urban areas often do not have long time series data making the use of panel data essential. What data there are may not be comparable over time as well especially as we are attempting to cover 23 years, 6 economic censuses and 71 urban areas with adjustments for large inflationary episodes such as the 1995 Peso crisis. Most data is from the quinquennial economic censuses published by INEGI (the official Mexican institute of statistics), the national council of population (CONAPO) and the statistical yearbook released by INEGI (2010). For example, value added output (*Y*), labor (*L*), fixed investment in physical capital (K) and the total product in real prices come from those sources. Labor is direct hires by firms and is used to measure labor productivity. The value added and the physical capital are measured in Mexican pesos.[1] For human capital (HC) the percentage of the population that has completed secondary school as in Barro and Lee (1996) is used. This is a popular measure of HC in Mexico (see Díaz-Bautista, 2000, Ocegueda-Hernández and Plascencia-López, 2004, and Mayer-Foulkes, 2007, among others). For physical infrastructure, access to water (WAT), drainage (DRA), and electricity (ELE) are calculated for every thousand adults (over 15 years old). A road infrastructure index is calculated using Biehl's (1988) method. In the construction of this index we assume that different kinds of roads have differing impact on the development of a region or urban area. We weight road length by kilometer area of a region or city. Data allow analysis of only two types of roads - paved and unpaved – with the latter a greater barrier to development. We also use a highway index (RII) that accounts for whether a highway is federal or state maintained. Vehicle density (VD) accounts for varying heavy traffic in cities. A social index (SII) is a weighted measure of utility availability weighted by the population. A global infrastructure (GII) index is the geometric mean of the SII and RII indices as suggested by Biehl (1988). The area with the highest score is assigned a score of 100 and all others are ranked relative to this score.

Our cross section sample represents only urban areas drawn from municipios and metropolitan areas with more than 200 thousand habitants. In Mexico, 46 metropolitan areas have a population

[1] All the monetary variables were adjusted for inflation using the GDP deflator.

density of 200 thousand habitants or more and these areas are divided among 320 municipios. Another 25 municipios have a high population density (more of 200 thousand habitants) and are included also. Overall, therefore, there are 345 municipios integrated in 71 urban areas. In 2010, the 71 sample cities (Figure 1) accounted for 64 percent of the total population of the country and 87 percent of the GDP.

Figure 1. The geographical location of the sample Mexican urban areas.



Source: author’s calculations and map.

4. Unit root and cointegration tests

Based on Maddala and Wu (1999), we conduct several separate tests of the data to account for potential sensitivity of any one test’s results to econometric issues such as unit root problems with heterogeneous, serially correlated and nonstationary panels. For each panel unit-root test the data generating process (DGP) assumed is:

$$y^{*}_{i,t} = fi(t) + r_{i,t} + \varepsilon_{i,t}$$
$$r_{i,t} = r_{i,t-1} + u_{i,t} \qquad (1)$$

$fi(t)$ is a deterministic component that can include a constant or a linear trend. Depending on the length of the time period (T) the conclusions could be biased towards non-stationarity or stationarity even when there is a notable rate of stationarity. First, we apply Levin, Lin and Chu’s

(2002) panel unit root test for each cross-section (the LLC test). Under the null hypothesis that each time series contains a unit root against the alternative one that each time series is stationary, they formulated the following specification:

$$\Delta y_{it} = \rho y_{it-1} + \sum_{L=1}^{p_i} \theta_{iL} \Delta y_{it-L} + f(t) + \varepsilon_{it} \tag{2}$$

where p_i is an unknown lag which is allowed to vary across individuals and y_{it} is the variable of interest. The LLC test is useful for panel data sets of moderate size. Like other tests as T goes to infinity the LLC becomes more powerful and if T is small, the statistic will be consistent if N is large. However, the null hypothesis equation (2) requires that ρ be homogeneous across i so it is sensitive to the assumption of cross-sectional independence.

Second, Im, Pesaran and Shin (2003) propose an alternative testing procedure (the IPS test) when ε_{it} is serially correlated and the cross-section is heterogeneous. They modify equation (2) by adding autoregressive terms to the white noise error term:

$$\Delta y_{it} = \rho_i y_{it-1} + \sum_{L=1}^{p_i} \theta_{iL} \Delta y_{it-L} + f(t) + \varepsilon_{it} \tag{3}$$

where $\varepsilon_{it} = \sum_{j=1}^{p_i} \varphi_{ij} \varepsilon_{it-j} + v_{it}$. The IPS test often performs better than the LLC test. Consistency requires a minimum $T = 5$ in regressions with an intercept and $T = 6$ in regressions with an intercept and trend. Maddala and Wu (1999) note that the IPS test is really a special case of the combined p-values of a Fisher distribution and they propose an alternative test (the MW test) based on the Fisher distribution. The Fisher method combines the *p-values (P)* of the unit-root tests for every cross-section of i for the unit-root test of panel data. P is distributed as χ^2 with *2N* freedom degrees and $T_i \rightarrow \infty$ for every N:

$$P = -2\sum_{i=1}^{N} \ln p_i \tag{4}$$

Fourth, Hadri (2000) proposes testing the stationarity in the panel directly as the null hypothesis. He develops a residual-based Lagrange multiplier as follows (Hadri, 2000, and Baltagi, 2008):

$$y_{it} = f_{it}^{'} \gamma + r_{it} + \varepsilon_{it} \tag{5}$$

where f_{it} and r_{it} are as in the equation (1) and the stationarity hypothesis is $H_0 : \sigma_u^2 = 0$, the LM statistic is calculated as:

$$LM_1 = \frac{\frac{1}{N}\left(\sum_{i=1}^{N} \frac{1}{T^2} \sum_{t=1}^{T} S_{it}^2 \right)}{\hat{\sigma}_\varepsilon^2} \text{ and } LM_2 = \frac{1}{N}\left(\sum_{i=1}^{N} \left(\frac{1}{T^2} \sum_{t=1}^{T} S_{it}^2 / \hat{\sigma}_{\varepsilon i}^2 \right) \right)$$

where LM_2 is a specification allowing for heteroskedasticity across i, with $S_{it} = \sum_{s=1}^{t} \hat{\varepsilon}_{it}$ the partial sum of OLS residuals from (5). Finally, we also verify the stationarity in panels using the Larsson, Lyhagen, and Löthgren (2001) likelihood ratio test (LLL test). Since the first-order integrated variables, $I(1)$, might have a cointegration relationship, it is necessary to know if there is such relationship when a group of variables are individually integrated in the same order and there is at least one stationary linear combination of variables. If so, then the related variables are cointegrated (Karaman Örsal, 2007). The idea of cointegration in the LLL test is very similar to the IPS statistic, but is based on the individual rank and trace statistic of Johansen (1995):

$$LR_s(r \mid k) = \sum_{i=1}^{N} LR_i(r \mid k) \tag{6}$$

where $LR_i(r \mid k)$ is the likelihood ratio index of Johansen (1995) for all i. Larsson, Lyhagen, and Löthgren (2001) investigated the small sample properties through Monte Carlo simulations and found that a long time series is essential. A key advantage of the LLL test is that it controls for cointegration in heterogeneous panel data and provides estimates of the elasticity of infrastructure variables relative to productivity.

5. Results

The existence of panel unit roots and stationarity is unclear using the first three tests (Table I). The LLC statistic suggests eleven out of fourteen series have a unit root when the DGP has no deterministic component. When an intercept is included only ten series have a unit root. Even with both a constant and linear trend, the null hypothesis is consistently rejected in all the cases. However, it is possible that the LLC test results are biased because the residuals are not white noise because they are correlated. Only a few time series reject the null hypothesis with 'none' and 'intercept' components in the DGP, while the null is firmly rejected when the DGP includes an intercept and linear trend.

Table I. Results of unit-root test in levels.

	None		Individual intercept			Individual intercept and trend		
	LLC	MW	LLC	IPS	MW	LLC	IPS	MW
YPC	-0.0005	69.62	-13.96 *	-1.04	195.93 *	-16.46 *	1.64	141.22
Y15	-2.27 *	105.75	-17.19 *	-3.58 *	317.21 *	-16.58 *	1.02	210.91 *
YL	-7.55 *	246.04 *	-11.44 *	0.15	129.58	-18.69 *	1.24	152.3
WAT	6.73	71.15	4.52	6.73	49.89	-14.77 *	1.58	183.03 *
DRA	48.06	1	-1.53	5.2	230.94 *	-18.49 *	0.34	271.89 *
ELE	8.97	19.12	3.22	6.6	42.48	-35.18 *	-1.59	348.46 *
RII	2.22	81.01	1.67	5.96	128.29*	-4.88 *	2.84	163.27
SII	26.07	1.32	5.55	8.98	25.88	-28.00 *	-1.26	368.00 *
GII	16.4	12.61	0.11	5.71	74.75	-40.43 *	-0.31	205.93 *
L	32.91	6.93	14.36	12.44	13.88	-26.38 *	-2.11 *	441.45 *
HC	12.25	5.49	7.52	8.49	8.17	-20.41 *	1.35	198.58 *
K	-12.90 *	169.82	-56.37 *	-7.08 *	271.39 *	-44.45 *	-3.60 *	425.71 *
VD	11.09	24.32	2.06	5.37	85.92	-19.69 *	1.52	161.09 *
ROAD	2.22	81.01	1.67	5.96	128.29	-4.88 *	2.84	163.27

Notes: * Indicates rejection of the null hypothesis at the 0.05 or less. Automatic lag length selection based on BIC.
Source: own elaboration.

The IPS test results are more consistent with the null hypothesis of nonstationarity in levels. Only three time series have the opposite result: product per person older than 15 years (Y15), physical capital stock (K) and labor (L). The Hadri test is more consistent with levels and first differences in the DGP (Table II) with nonstationarity in levels and stationarity in first differences. Only the physical capital stock series shows a weak result because the DGP with intercept doesn't reject the null hypothesis, although it could due to a specification problem because the option with intercept and linear trend has a coefficient in the right direction.

Table II. Results of the Hadri test.

	Variables in levels		First differences of variables	
	Individual intercept	Individual intercept and trend	Individual intercept	Individual intercept and trend
YPC	18.11 *	70.73 *	9.72	86.78
Y15	16.60 *	84.32 *	13.06	85.97
YL	13.66 *	82.36 *	14.72	85.84
WAT	12.29 *	67.13 *	9.56	44.03
DRA	13.17 *	79.81 *	9.1	75.65
ELE	12.84 *	64.25 *	8.85	57.43
RII	13.92 *	83.68 *	14.91	84.36
SII	12.89 *	59.74 *	10.93	62.31
GII	13.56 *	80.13 *	12.86	78.29
L	12.46 *	84.17 *	11.45	87.33
HC	12.60 *	86.73 *	11.52	81.14
K	9.94	73.75 *	13.41	85.42
VD	13.63 *	67.83 *	12.92	79.29
ROAD	12.89 *	59.74 *	10.93	62.31

Note: * Indicates rejection of the null hypothesis of stationarity at the 0.05 level or less. Automatic bandwidth selection through Newey-West procedure.

Source: own elaboration.

All three unit-root tests are estimated in first differences (Table III) with consistent stationarity revealed with a few exceptions. For example, the LLC test rejects a unit-root for every variable except for the specification that no includes deterministic component in the labor series. However, this particular result is reversed in the other two specifications of the test. A similar situation happens with IPS test on drainage (DRA), social index infrastructure (SII) and labor (L), but the conclusion is reversed with the specification that includes the intercept, although non-rejections prevail in the specification that also includes linear trend. The MW test also rejects the null hypothesis in a majority of cases.

An analysis of the results indicates that all variables are stationary under the three tests and also under the process that only includes an intercept.[2] In any case, the evidence is overwhelming with one or another DGP and test. In this way, we can say that the first differences of all fourteen variables are stationary. For some series, it seems natural that tests have different results because they are measuring different processes.

We now add cointegration tests to the discussion. We use the LLL test, which is based on the Johansen (1995) test of maximum likelihood. We chose this test because it avoids the use of unit-root test over the estimated model residuals and it can also relax the assumption on the cointegration vector.

[2] An exception is the result for human capital index (HC) of MW test.

The followed strategy to estimate the LLL test is assuming a DGP where independent variables evolve with one or two lags. Cointegration relationships according to the trace statistic are shown in Table IV.

Table III. Results of unit root tests in first differences.

	None		Individual intercept			Individual intercept and trend		
	LLC	MW	LLC	IPS	MW	LLC	IPS	MW
YPC	-23.29 *	481.31 *	-19.37 *	-4.59 *	217.29 *	-47.04 *	-1.07	174.67 *
Y15	-28.23 *	615.17 *	-24.31 *	-7.32 *	271.09 *	-43.80 *	-2.09 *	214.16 *
YL	-23.21 *	450.65 *	-20.85 *	-5.09 *	222.33 *	-62.01 *	-0.71	139.08
WAT	-7.76 *	226.38 *	-48.63 *	-4.86 *	225.11 *	-48.63 *	-12.87 *	426.66 *
DRA	-2.12 *	142.54	-19.59 *	-7.67 *	277.65 *	-112.93 *	-54.89 *	422.90 *
ELE	-10.45 *	278.75 *	-51.38 *	-14.80 *	389.83 *	-81.32 *	-8.23 *	387.83 *
RII	-4.73 *	350.35 *	-6.80 *	-1.74 *	210.03 *	-14.34 *	-0.87	257.40 *
SII	-4.22 *	147.46	-34.92 *	-13.10 *	397.47 *	-189.03 *	-34.36 *	474.31 *
GII	-9.49 *	244.24 *	-56.86 *	-10.95 *	280.83 *	-157.48 *	-12.35 *	354.50 *
L	-1.5	115.01	-24.46 *	-9.92 *	424.54 *	-35.27 *	-1.89 *	267.26 *
HC	-8.97 *	214.86 *	-14.32 *	-2.61 *	165.34	2.43	1.83	113.53
K	-37.02 *	580.85 *	-34.74 *	-15.56 *	429.38 *	-37.83 *	-12.12 *	447.46 *
VD	-14.33 *	353.84 *	-28.61 *	-5.74 *	221.72 *	-547.07 *	-49.01 *	473.44 *
ROAD	-4.73 *	350.35 *	-6.80 *	-1.74 *	210.03 *	-14.34 *	-0.87	257.40 *

Notes: * Indicates rejection of the null hypothesis at the 0.05 level or less. Automatic lag length selection based on BIC.

Source: own elaboration.

For each dependent variable (YL, YPC, and Y15), the hypothesis of no cointegration is rejected in practically all independent variables. Other variables such as water supply (WAT), global infrastructure index (GII), road infrastructure index (RII), social infrastructure index (SII), vehicular density (VD) and ROAD accept the hypothesis of one cointegrating relationship with per capita income (YL). This amount of cointegrating relationships is similar to that found in the literature with other dependent variables. For example, the per worker income variable (YPC) is cointegrating with: water supply (WAT), global infrastructure index (GII), road infrastructure index (RII), vehicular density (VD), and ROAD. Meanwhile, product per person older than 15 years (Y15) is, additionally, cointegrating with social infrastructure index (SII).

Conversely, evidence of cointegration between each dependent variable and human capital (HC), drainage services (DRA), physical capital stock (K), the number of housing with electricity (ELE) and labor (L) was not statistically significant.

However, the first differences were significant indicating a lag process in their relationship with productivity. It means that the impact is not as immediate as initially proposed in agreement with previous results for Mexico (for example, Lächler and Aschauer, 1998, and Noriega and Fontenla, 2007).

Economies often have limited resources to invest in infrastructure. With purposes of efficiency criteria, we report the corresponding elasticities that were obtained from the estimates of normalized coefficients of cointegration. The size and direction of the effects can be useful as a guide to target resources toward efficient infrastructure building (Table V).

Table IV. Cointegration relationships in levels.

	YL		YPC		Y15	
	None	At most 1	None	At most 1	None	At most 1
WAT	80.27*	1.61	68.93*	1.06	138.27*	0.77
	(0.000)	(0.204)	(0.000)	(0.304)	(0.000)	(0.381)
HC	168.87*	68.77*	174.92*	78.22*	210.93*	63.2*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DRA	125.43*	33.22*	124.25*	40.27*	176.28*	47.47*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
K	334.13*	77.58*	312.7*	67.19*	376.17*	131.81*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
GII	79.5*	2.89	70.9*	1.67	146.76*	2.500
	(0.000)	(0.089)	(0.000)	(0.196)	(0.000)	(0.114)
RII	73.72*	0.22	68.15*	0.43	134.89*	0.230
	(0.000)	(0.639)	(0.000)	(0.511)	(0.000)	(0.632)
SII	83.45*	3.06	75.03*	3.98*	142.35*	3.300
	(0.000)	(0.080)	(0.000)	(0.046)	(0.000)	(0.069)
ELE	100.51*	7.21*	81.49*	10.3*	155.49*	11.050*
	(0.000)	(0.007)	(0.000)	(0.001)	(0.000)	(0.001)
L	324.88*	73.43*	300.01*	62.42*	378.14*	137.35*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
VD	77.12*	0.59	69.47*	0.79	143.29*	0.640
	(0.000)	(0.441)	(0.000)	(0.374)	(0.000)	(0.423)
ROAD	73.72*	0.22	68.15*	0.430	134.89*	0.230
	(0.000)	(0.639)	(0.000)	(0.511)	(0.000)	(0.632)

Notes: * indicates rejects of the null hypothesis of cointegration. The p-values are in parentheses.
Source: own elaboration.

Table V. Elasticity between economic growth and infrastructure indexes.

	YL	YPC	Y15		YL	YPC	Y15
WAT	0.014	0.193	-0.008	SII	0.252 *	1.915 *	-0.055
	(0.014)	(0.118)	(0.021)		(0.083)	(0.615)	(0.113)
HC	0.914 *	1.060	0.205	ELE	0.063 *	0.443 *	-0.005
	(0.138)	(0.769)	(0.161)		(0.017)	(0.139)	(0.024)
DRA	0.259 *	2.353 *	-0.013	L	0.001 *	0.006 *	0.000 *
	(0.040)	(0.306)	(0.042)		(0.000)	(0.000)	(0.000)
K	-0.000 *	0.001*	-0.000 *	VD	-0.008	0.115	-0.026
	(0.000)	(0.000)	(0.000)		(0.011)	(0.087)	(0.015)
GII	-0.014	-1.205	-0.120	ROAD	-1.199	-102.235	-2.808
	(0.078)	(0.663)	(0.109)		(14.071)	(112.663)	(19.605)
RII	-0.006	-0.519	-0.014				
	(0.071)	(0.572)	(0.099)				

Notes: * indicates significance at 5% or less. Standard errors in parentheses.
Source: own elaboration.

Private investment and occupied personnel are the only two variables with significant elasticity on the three proxies of productivity; but their impacts are quite small. The greater effects are from investments on human capital, drainage, social infrastructure, and electricity. Meanwhile, the elasticity of infrastructure indicators such as water supply, the global infrastructure index, roads, and vehicle density were not significant. The mixture of effects – where some investments improve productivity, while others do not means that the investments are poorly targeted in Mexican urban areas. Therefore, cointegration and elasticity results can guide an improvement in regional investment policies and save the government some money.

6. Conclusions

The link between Mexican infrastructure investment and economic growth in urban areas was analyzed. The results from a variety of tests indicate a lack of stationarity for all variables in levels but not with first differences. In addition, the panel cointegration tests find a cointegrating relationship between infrastructure variables and each dependent variable. These results indicate a stable evolution between productivity and infrastructure variables especially for water supply, the global infrastructure index, the road infrastructure index, vehicular density, investment in highways, and the social infrastructure index. Although this was not the result for other factors, we see this as a call for more research and detailed data, especially longer time series data. So our results can be seen as a first look at the impact of infrastructure investments in Mexican urban areas over a long period. Mexico needs to continue a policy directed at strengthening the quantity and quality of both public and private infrastructure plus the data used to evaluate them. Such attention would improve the standard of living and better target poverty reduction.

References

Aschauer, D. A. (1989) "Is Public Expenditure Productive?" *Journal of Monetary Economics* **23**, 177-200.

Aschauer, D. A. (1990) "Why is Infrastructure Important?" *Federal Reserve Bank of Boston, Conference Series* 21-50.

Aschauer, D. A. (2000) "Public Capital and Economic Growth: Issues of Quantity, Finance, and Efficiency" *Economic Development and Cultural Change* **48**, 391-406.

Baltagi, B. H. (2008) *Econometric Analysis of Panel Data*, John Wiley and Sons: Chichester.

Barro, R. and X. Sala-i-Martin (1992) "Public Finance in Models of Economic Growth" *The Review of Economic Studies* **59**, 645-661.

Barro, R. J. and J. W. Lee (1996) "International Measures of Schooling Years and Schooling Quality" *American Economic Review Papers & Procedings* **86**(2), 218-223.

Biehl, D. (1988) "Las infrastructuras y el desarrollo regional", *Papeles de Economía Española* **35**, 293-310.

Cutanda, A. and J. Paricio (1994) "Infrastructure and Regional Economic Growth: The Spanish Case" *Regional Studies* **28**(1), 69-77.

De la Fuente, A. (2008) "Inversión en infraestructuras, crecimiento regional y convergencia regional" *Papeles de Economía Española* **118**, 15-26.

Díaz-Bautista, A. (2000) "Convergence and Economic Growth in Mexico" *Frontera Norte* **13**, 85-110.

Evans, P. and G. Karras (1994a) “Is Government Capital Productive? Evidence from a Panel of Seven Countries” *Journal of Macroeconomics* **16,** 271-279.

Evans, P. and G. Karras (1994b) “Are Government Activities Productive? Evidence from a Panel of U.S. States” *The Review of Economics and Statistics* **76,** 1-11.

Feltenstein, A. and J. Ha (1995) “The Role of Infrastructure in Mexican Economic Reform” *The World Bank Economic Review* **9**(2), 287-304.

Fuentes, N. A. and E. Mendoza (2003) “Infraestructura pública y convergencia regional en México, 1980-1998” *Comercio Exterior* **53**(2), 178-187.

Herrerías, M. J. and V. Orts (2011) “The Driving Forces behind China's Growth” *Economics of Transition* **19**(1), 79-124.

Holtz-Eakin, D. and A. E. Schwartz (1995) “Spatial Productivity Spillovers from Public Infrastructure: Evidence from State Highways” *National Bureau of Economic Research Working Paper Series* number 5004.

Im, K. S.; M. H. Pesaran, and Y. Shin (2003) “Testing for Unit Roots in Heterogeneous Panels” *Journal of Econometrics* **115**, 53-74.

Johansen, S. (1995) *Likelihood-Based Inference in Cointegrated Vector Autoregressive Models*, Oxford University Press: Oxford.

Karaman Örsal, D. D. (2007) “Comparison of Panel Cointegration Tests”, SFB 649 Discussion Paper 2007-029, Humboldt-UniversitÄat zu Berlin.

Lächler, U. and D. A. Aschauer (1998) “Public Investment and Economic Growth in Mexico” *The World Bank. Policy Research Working Paper* **1964**, 17-18.

Lall, Somik V. (2007) “Infrastructure and Regional Economic Growth, Growth Dynamics and Policy Relevance for India” *The Annals of Regional Science* **41**, 581-599.

Larsson, R., J. Lyhagen, and M. Löthgren (2001) “Likelihood-Based Cointegration Tests in Heterogeneous Panels” *The Econometrics Journal* **4**(1), 109-142.

Levin, A., C. F. Lin, and C. S. J. Chu (2002) “Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties” *Journal of Econometrics* **108**, 1-24.

Maddala, G. S. and S. Wu (1999) “A Comparative Study of Unit-Root Tests With Panel Data and a New Simple Test” *Oxford Bulletin of Economics and Statistics* **61**, 631-652.

Mas, M. and J. Maudos (2004) “Infraestructuras y crecimiento regional en España diez años después” in *Competitividad regional en la Unión Europea ampliada* by Villaverde Castro, J., Ed., Instituto de Estudios Fiscales: Madrid, 143-168.

Mayer-Foulkes, D. (2007) “Fallas de mercado en capital humano. La trampa intergeneracional de la pobreza en Mexico” *El Trimestre Económico* **74**(3), 543-614.

Mizutani, F. and T. Tanaka (2010) “Productivity Effects and Determinants of Public Infrastructure Investment” *The Annals of Regional Science* **44**, 493-521.

Munnell, A. H. (1992) “Policy Watch: Infrastructure Investment and Economic Growth” *Journal of Economic Perspectives* **6**, 189-198.

Noriega, A. and M. Fontenla (2007) “La infraestructura y el crecimiento económico en México” *El Trimestre Económico* **74**(4), 885-900.

Ocegueda-Hernández, J. M. and G. Plascencia-López (2004) “Crecimiento económico en la región fronteriza de México y Estados Unidos: una contrastación empírica de la hipótesis de convergencia” *Frontera Norte* **16**(31), 7-31.

OECD (2013) *Getting It Right. Strategic Agenda for Reforms in Mexico*, OECD Publishing: Paris.

Pereira, A. M. and J. M. Andraz (2012) “On the Regional Incidence of Highway Investments in the USA” *The Annals of Regional Science* **48**, 819-838.

Sánchez-Robles, B. (1998) “Infrastructure Investment and Growth: Some Empirical Evidence” *Contemporary Economic Policy* **16**(1), 98-108.

Sedesol (2014) *Fondo de Aportaciones para la Infraestructura social: Reforma a la Ley de Coordinación fiscal*, Sedesol: México. July 2.

Viesti, G. (2015) *Diagnóstico de desarrollo regional: México*, Colección Estudios No. 13, Eurosocial: Madrid.

Zhang, X. (2008) “Transport Infrastructure, Spatial Spillover and Economic Growth: Evidence from China” *Frontiers of Economics in China* **3**(4), 585-597.

Annex. Source and typology of variables.

Typology	Description	Source	Measurement unit
		Economic variables	
YPC	Per capita gross county product	INEGI: Economics censuses, several years.	Thousands of pesos of 2003
YL	gross county product per worker	INEGI: Economics censuses, several years.	Thousands of pesos of 2003
Y15	gross county product per adult (older than 15 years)	INEGI: Economics censuses, several years.	Thousands of pesos of 2003
L	Labor: occupied personnel.	INEGI: Economics censuses, several years.	Number of remunered persons in the economic activity.
K	Physical capital stock: gross formation of fixed capital	INEGI: Economics censuses, several years.	Thousands of pesos of 2003
		Indexes obtained through Biehl methodology.	
SII	Social infrastructure index: integrated by electricity, water and drainage, normalized	INEGI: Statistical yearbooks by federal	Sinthetic index
RII	Road infrastructure index: is integrated by highways as synthetic index.	INEGI: Statistical yearbooks by federal	Sinthetic index
GII	Global infrastructure index: calculated as geometric mean of SII and RII, such as is suggested by Biehl (1998).	INEGI: Statistical yearbooks by federal entity, several years	Sinthetic index
ROAD	Index of roads: a combination of paved and unpaved roads in squared-kilometers.	INEGI: Statistical yearbooks by federal entity, several years	Sinthetic index
		Indexes obtained as proportion	
DRA	Drainage: number of houses with drainage system per thousand inhabitants older than 15 years.	INEGI: Statistical yearbooks by federal entity, several years	Rescheduling of the indicator between 0 and 100, where 0 is the lowest amount and 100 the highest.
WAT	Water: number of houses with drinking water system per thousand inhabitants older than 15 years.	INEGI: Statistical yearbooks by federal entity, several years	Rescheduling of the indicator between 0 and 100, where 0 is the lowest amount and 100 the highest.
ELE	Electricity: number of houses with electricity system per thousand inhabitants older than 15 years.	INEGI: Statistical yearbooks by federal entity, several years	Rescheduling of the indicator between 0 and 100, where 0 is the lowest amount and 100 the highest.
VD	Vehicle density: number of vehicles per thousand habitants older than 15 years.	INEGI: Statistical yearbooks by federal entity, several years	Rescheduling of the indicator between 0 and 100, where 0 is the lowest amount and 100 the highest.
HC	Human capital: matriculated students in secondary school as proportion of the population of 12 to 15 years old.	Population censuses by INEGI and Conapo.	Rescheduling of the indicator per each thousand of persons.

Source: own elaboration.