Public Infrastructure and Economic Growth in Mexico

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Abstract

We develop a model where investment in infrastructure complements private investment. We then provide time series evidence for Mexico on both the impact of public infrastructure on output, and on the optimality with which levels of infrastructure have been set. In particular, we look at the long-run effects of shocks to infrastructure on real output. We compute Long-Run Derivatives for kilowatts of electricity, roads and phone lines, and find that shocks to infrastructure have positive and significant effects on real output for all three measures of infrastructure. For electricity and roads, the effect becomes significant after 8 years are included, whereas for phones, the effect on growth is significant only after 13 years. These effects of infrastructure on output are in agreement with growth models where long-run growth is driven by endogenous factors of production.

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Abstracto

Desarrollamos un modelo teórico donde inversión en infraestructura complementa inversión privada. Luego proporcionamos evidencia de series de tiempo en México del impacto de infraestructura pública sobre producción, y sobre si estos niveles han sido fijados de manera óptima. En particular, estudiamos los efectos de largo plazo de shocks en infraestructura sobre producción real. Calculamos derivadas de largo plazo para kilowatios de electricidad, kilómetros de caminos y número de líneas telefónicas instaladas. Encontramos que shocks en infraestructura tienen efectos positivos y significativos sobre producción para las tres medidas utilizadas. Para electricidad y caminos, el efecto se vuelve significativo después de incluir 8 años de rezagos. Para teléfonos, el efecto sobre producción se vuelve significativo luego de 13 años. Nuestros resultados respaldan los modelos donde el crecimiento de largo plazo es causado por factores de producción endógenos.

1 Introduction

The role of public infrastructure on output has received wide attention since the contributions of Aschauer (1989), who showed that public investment has had a significant effect on growth for the United States, and the theoretical model of Barro (1990). These seminal papers induced further research with mixed results[1]. For example, Barro (1991), using a cross section for 98 countries in the period 1960-85, finds no significant effect of public investment on growth rates. Given that there is no clear cross-country empirical consensus, it becomes interesting to study individual countries. We do so for Mexico.[2]

We develop a theoretical model based on Barro (1990), where investment in infrastructure complements private investment. We then adapt Fischer and Seater (1993) notion of a long-run derivative to provide time series evidence for Mexico[3]. We study both the long-run impact of public infrastructure on output, and the optimality with which levels of infrastructure have been set. Mexico is a particularly interesting case, since it is a country that has implemented severe stabilization and structural adjustment programs as a response to the crises of the eighties and nineties. Aschauer (1998) reports that for some variables, growth rates of public capital became negative for that period.

We use annual data from 1950 to 1994 on real GDP and public infrastructure variables. As in Canning and Pedroni (1999), our variables comprise kilowatts of electricity, kilometers of roads, and number of telephone lines. Using long-run derivatives over a horizon of twenty years, we find that shocks to infrastructure have positive and significant effects on real output for all three measures of infrastructure. Thus, these effects of infrastructure on output are in agreement with growth models where long-run growth is driven by endogenous factors of production. The effect becomes significant for electricity and roads after 8 years are included in the long-run derivatives. For phones, the effect on growth is significant only after 13 years are included. The fact that these effects come to light only after a

[1] See Gramlich (1994) for a survey of the literature.

[2] A recent work on the Mexican case is Ramirez (2004), who finds positive and significant effects of public infrastructure spending on the rate of output growth, using a vector error correction approach and aggregate data on public infrastructure. Our approach differs in that we develop a theoretical model of growth, use disaggregated infrastructure data, and apply a novel methodology for assessing the impact of public infrastructure on growth.

[3] Fisher and Seater (1993) first developed their methodology to look at neutrality and superneutrality of money. We apply it to study long-run effects of infrastructure on output.

number of years are included in the long-run derivatives may indicate the time it takes for investments in infrastructure to have an effect on actual output.

As for growth maximizing levels, electricity seems to have been set at growth maximizing levels after 8 years are included. Roads does not seem to be set at growth maximizing levels, while the results for telephones are less clear.

The remainder of this paper proceeds as follows: Section 2 presents the theoretical model. Section 3 discusses the data and econometric methodology, while section 4 discusses the empirical results. Section 5 concludes.

2 Model

We develop a simple growth model adapted from Barro (1990), where public infrastructure is an input in the production of final output, and is financed by taxes on output. The production function has the Cobb-Douglas form

$$y_t = A_t k_t^{\alpha} g_t^{\beta} \tag{1}$$

where $\alpha + \beta \leq 1$, y_t and k_t are output and capital per worker, respectively, A_t is an index of technology, and g_t is the quantity of infrastructure services provided to each producer. Infrastructure expenditures are financed by an income tax according to

$$g_t = \tau_t \; y_t \tag{2}$$

where

$$\tau_t = \bar{\tau} + \eta_t \tag{3}$$

and

$$\eta_t = \phi \eta_{t-1} + \varepsilon_t. \tag{4}$$

Combining (3) and (4) we have that

$$\tau_t = \bar{\tau} + \phi^k \eta_{t-k} + \sum_{j=1}^{k} \phi^{j-1} \varepsilon_{t-(j-1)} \tag{5}$$

Equation (3) models the erratic behavior of Mexico's share of infrastructure to GDP: it fluctuates around a fixed value $\bar{\tau}$, the fluctuations being governed by the AR process (4). The closer ϕ to 1, the more persistent are shocks to infrastructure. We assume that ε_t a zero-mean stationary random variable.

There is an infinite-lived representative household whose utility function is given by

$$\int_0^{\infty} \frac{c_t^{1-\theta} - 1}{1-\theta} e^{-\rho t} dt, \tag{6}$$

where c_t is consumption, $\theta > 0$ is the intertemporal elasticity of substitution between consumption, and $\rho > 0$ is the constant rate of time preference. When there is no population growth and depreciation is zero, capital evolves according to

$$\dot{k}_t = (1 - \tau_t) A_t k_t^{\alpha} g_t^{\beta} - c_t. \tag{7}$$

The competitive equilibrium solution when $\alpha + \beta = 1$ has the growth rate of the economy

$$\gamma_y = \frac{1}{\theta} \left[(1 - \tau_t) \, \alpha A_t k_t^{\alpha - 1} g_t^{\beta} - \rho \right]. \tag{8}$$

When τ_t is constant, then the economy is on a balanced growth path, and there is endogenous growth driven by constant return to scale in both private capital and infrastructure. However, when $\alpha + \beta < 1$, then there are diminishing returns in both inputs, and long-run growth will be driven exogenously by technological progress, captured by A_t.

From (2) we know that $\tau_t = g_t / y_t$, substituting it in (8), and maximizing with respect to g_t we get

$$\frac{\partial \gamma_y}{\partial g} = \frac{1}{\theta} \frac{\alpha}{k_t} \left[\frac{\beta}{\tau_t} - 1 \right]. \tag{9}$$

Now we can equal this derivative to zero, which implies from the term in brackets that the optimal tax rate for the economy is $\tau_t^* = \beta$. This is our version of Barro's famous result, mainly that in order to maximize growth, the tax rate of the economy should be set equal to the share of income that belongs to infrastructure.

Combining (1), (2), (5) and taking derivatives we arrive at the long-run derivative – the effect of an infrastructure disturbance on real output relative to that disturbance's ultimate effect on infrastructure –

$$\frac{\partial y_t / \partial \eta_{t-k}}{\partial g_t / \partial \eta_{t-k}} = \frac{\beta}{\bar{\tau} + \phi^k \eta_{t-k} + \sum_{j=1}^{k} \phi^{j-1} \varepsilon_{t-(j-1)}} \tag{10}$$

where the denominator is τ_t. Given that $\tau_t^* = \beta$ at it's growth maximizing level, then (10) is optimal at one. Further, if we find the long-run derivative (LRD from now on) to be statistically different from zero, then shocks to infrastructure are persistent. Therefore this would provide support for models of endogenous growth.

3 Data and Econometric Methodology

The objective in this section is to provide time series evidence for Mexico on both the impact of public infrastructure on income, and on the optimality with which levels of infrastructure have been set, using annual data from 1950 to 1994. We utilize real gross domestic product divided by the labour force, to approximate real income per worker. The public infrastructure variables comprise kilowatts of electricity, kilometers of roads, and number of telephones. The source of the data is Comisión Federal de Electricidad, Secretaría de Comunicaciones y Transportes, and Teléfonos de Mexico. In many cases, data were collected from these federal agencies in quite an artisan way, drawing from different sources of internal statistical reports. The series for real income per worker was constructed using the data set in Alzati (1997). The sample size is the longest homogeneous data set possible, given the available information.

In particular, we are interested in the long-run effects on real output, of stochastic shocks to the level and trend of infrastructure. Fisher and Seater (1993) develop an econometric methodology to measure the long-run effect of money on output. We adapt their notion of a long-run derivative to measure the ultimate effect of an infrastructure shock on the level of real (per capita) output, relative to the effect of that same shock on the level (or trend) of public provision of infrastructure (per capita), based on a bivariate VAR. If the long-run effect is not significantly different from zero, then public investment in infrastructure is neutral. If the effect departs away from zero significantly, then public infrastructure investment has permanent effects on real output, positive or negative, and is, therefore, non neutral. Finally, if the long-run effect approaches 1, then impacts to infrastructure move the economy towards its growth maximizing level. In terms of our growth model, if $\frac{\beta}{\tau_t} \rightarrow 1$ in (10), then the derivative in (9) will equal zero.

To fix ideas, consider the following stationary invertible bivariate Vector Autoregression (VAR) in per capita infrastructure provision by the government, g_t, and real per capita output, y_t:

$$\begin{aligned} a(L)\Delta^{\langle g\rangle} g_t &= b(L)\Delta^{\langle y\rangle} y_t + \eta_t \\ d(L)\Delta^{\langle y\rangle} y_t &= c(L)\Delta^{\langle g\rangle} g_t + w_t \end{aligned} \tag{11}$$

where $a(L)$, $b(L)$, $c(L)$ and $d(L)$ are polynomials in the lag operator L, with $a_0 = d_0 = 1$, $\Delta = (1 - L)$, and the symbol $\langle x\rangle$ stands for the order of integration of x; i.e. $\langle x\rangle = 1$, means that x is integrated of order one ($I(1)$). The errors vector (η_t, w_t) is assumed to be *iid*, zero mean with covariance matrix Σ, with elements $\sigma_{\eta\eta}$, $\sigma_{\eta w}\sigma_{ww}$. The solution, or impulse-response representation of system (11) is given by:

$$\begin{aligned} g_t &= \Delta^{\langle -g\rangle} \left[\alpha(L)\eta_t + \beta(L)w_t\right] \\ y_t &= \Delta^{\langle -y\rangle} \left[\gamma(L)\eta_t + \delta(L)w_t\right] \end{aligned}$$

where $\alpha(L) = d(L)/A$, $\beta(L) = b(L)/A$, $\gamma(L) = c(L)/A$, $\delta(L) = a(L)/A$, with $A = a(L)d(L) - c(L)b(L)$. Then the effect of public infrastructure is measured through the long-run derivative of output with respect to permanent stochastic exogenous changes in public infrastructure:

$$LRD_{y,g} \equiv \lim_{k\to\infty} \frac{\partial y_{t+k}/\partial \eta_t}{\partial g_{t+k}/\partial \eta_t} \tag{12}$$

The limit of the ratio in (12) measures the ultimate effect of a (stochastic) infrastructure disturbance on real output relative to that disturbance's ultimate effect on the infrastructure variable. g is said to be neutral (superneutral) when, following a permanent shock to the level (trend) of infrastructure, $LRD_{y,g}$ is equal to zero ($LRD_{y,\Delta g}$ is equal to zero). One can show that the computation of the LRD depends on the order of integration of each variable, according to the formula,

$$LRD_{y,g} = \frac{(1-L)^{\langle g\rangle - \langle y\rangle}\gamma(L)\mid_{L=1}}{\alpha(1)} \tag{13}$$

from which one can obtain values for the LRD under different empirically relevant orders of integration of the variables. The LRD for superneutrality is derived from the same formula by replacing g with Δg.

First of all, the order of integration of infrastructure should be at least equal to one ($\langle g\rangle \geq 1$), otherwise there are no stochastic permanent changes in infrastructure that can affect real output. When $\langle g\rangle - \langle y\rangle > 0$ the long-run derivative is zero, providing direct evidence of no long-run effect of infrastructure on output. When $\langle g\rangle = \langle y\rangle \geq 1$, $LRD_{y,g} = \gamma(1)/\alpha(1) = c(1)/d(1)$, and the significance of the impact of a permanent change in the level of infrastructure on output is measurable. For testing superneutrality, the relevant long-run derivative is given by $LRD_{y,\Delta g} = \gamma(1)/\alpha(1) = c(1)/d(1)$. Superneutrality, however, is not addressable when there are no permanent changes in the growth rate of infrastructure. In other words, superneutrality requires $\langle g\rangle \geq 2$. Table 1 summarizes the various possibilities.

Table 1

	$LRD_{y,g}$			$LRD_{y,\Delta g}$		
$\langle y\rangle$	$\langle g\rangle = 0$	$\langle g\rangle = 1$	$\langle g\rangle = 2$	$\langle g\rangle = 0$	$\langle g\rangle = 1$	$\langle g\rangle = 2$
0	undefined	$\equiv 0$	$\equiv 0$	undefined	undefined	$\equiv 0$
1	undefined	$c(1)/d(1)$	$\equiv 0$	undefined	undefined	$c(1)/d(1)$

Source: Adapted from Fisher and Seater (1993).

For the cases where $LRD = \gamma(1)/\alpha(1) = c(1)/d(1)$, and assuming $b(1) = \sigma_{\eta w} = 0$, an estimate of $c(1)/d(1)$ is given by $\lim_{k\to\infty} b_k$, where b_k is the coefficient from the OLS long-horizon regression

$$\left[\sum_{j=0}^{k} \Delta^{\langle y\rangle} y_{t-j}\right] = a_k + b_k \left[\sum_{j=0}^{k} \Delta^{\langle g\rangle} g_{t-j}\right] + \varepsilon_{kt}. \tag{14}$$

In terms of our growth model, the LRD can be expressed as:

$$LRD_{y,g} = \lim_{k\to\infty} \frac{\beta}{\tau_t} \tag{15}$$

where τ_t is given by (5). Furthermore, it was found the optimal tax rate for the economy to be $\tau_t^* = \beta$. Hence, in a growth maximizing setting, LRD should be equal to one. In other words, infrastructure has to be non neutral and $\frac{\beta}{\tau_t} \to 1$, for the economy to approach maximum growth. The significance of the limit of $\frac{\beta}{\tau_t}$ is measured through a sequence of OLS estimates of b_k in (14) for $k = 1, ..., 20$, together with 95-percent confidence bands around the parameter estimates, using the Newey-West covariance matrix estimator. The non neutrality of an infrastructure variable implies that growth is endogenous.

4 Empirical Results

As noted above, the order of integration of the variables is a crucial first step in calculating the *LRD*. To this end, we apply augmented Dickey-Fuller (ADF) tests for a unit root for each of the four variables. In Dickey and Pantula (1987), it was observed empirically that the probability of rejecting the null hypothesis of one unit root (denoted H_1) against the alternative of stationarity (H_0) increases with the number of unit roots present. In Pantula (1989), two asymptotically consistent sequential procedures for testing the null hypothesis H_r against the alternative H_{r-1} are presented. We assume that it is known a priori that the maximum possible number of unit roots present in the data is s =3. Based on Pantula's results, the hypotheses must be tested sequentially in the order H_3, H_2 and H_1. Table 2 summarizes the time series properties of the variables for Mexico.

We perform unit root tests downwards, starting with a test of the null hypothesis H_3: exactly three unit roots (or a unit root in the second differences of the data). If the null H_3 is rejected, then we test the null H_2: exactly two unit roots, against the alternative H_1: one unit root in the autoregressive representation of the series. If both H_3 and H_2 are rejected, we test H_1 against H_0.

Table 2

Order of Integration of real income and infrastructure variables, Mexico, (1950 – 1994)

Regression: $\Delta^r X_t = \mu + \beta t + a_r^* \Delta^{r-1} X_{t-1} + \sum_{j=1}^{l} b_j^* \Delta^r X_{t-j} + \varepsilon_t$

$r = 1, 2, 3.$

Variable	$H_3(\mu = \beta = 0)$	$H_2(\beta = 0)$	H_1
Real GDP	-9.31** (1)	-6.08^{a,**} (0)	-0.69 (0)
Electricity	-6.61** (4)	-5.06** (3)	-3.07^{b} (0)
Roads	-8.54** (0)	-4.49** (0)	-2.02 (1)
Telephones	-7.52** (1)	-3.26* (0)	-3.22 (3)

Notes:

*, and ** stand for significant at the 5%, and 1% level, respectively.

a: this regression includes a constant and a linear trend

b: for this regression, the fourth lag resulted significant, however neither the constant nor the linear trend are significant. There were no other significant values for l. We report results for $l = 0$, for which both constant and trend are highly significant, and the AIC and the standard error of regression indicate a better fit.

In Table 2, the second column reports augmented Dickey-Fuller (ADF) statistics for testing the null H_3 against the alternative H_2 where no constant nor linear trend are allowed in the auxiliary regression. Columns 3 and 4 have a similar interpretation. The numbers in parenthesis correspond to the order of the autoregressive approximation, following Perron's $l - \max$ criterion.[4] As can be seen, the ADF tests strongly reject the presence of three and two unit roots for all variables. The last column indicated that it is not possible to reject one unit root in the AR representation for each series, implying that our vector of series is integrated of order one. We also applied four additional test statistics, advocated in Ng and Perron (2001), and obtained the same results.[5]

Once we have established that $\langle y \rangle = \langle g_i \rangle = 1$, $i = e, r, p$, it is now possible to compute the LRD_{y,g_i} to test whether our infrastructure variables are long-run neutral or not. That is, using the LRD we investigate the extent to which each infrastructure variable and real income per worker are ultimately changed by an exogenous infrastructure disturbance. If the respective infrastructure variable happens to be non neutral (neutral), then exogenous shocks to this variable should (not) increase per capita income[6].

Figures 1 to 3 present estimates of the LRD for each pair of real output and an infrastructure variable for a horizon of 20 years, with 95% confidence interval bands.

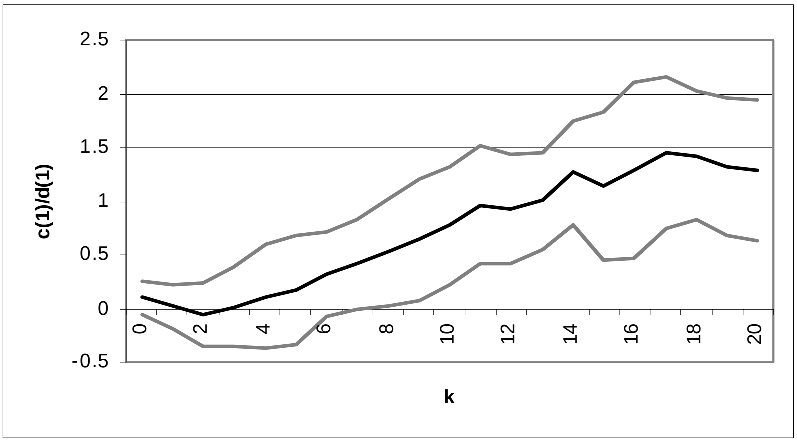
Figure 1 suggests that the effect of investing in electricity for Mexico becomes positive after 3 year lags are present, significantly different from zero after 8 year lags, and remains significant for the remainder of the years computed. This suggests that public investment in electricity has a permanent effect on output, supporting the notion of endogenous growth. Investment in electricity is close to its optimal effect on output growth for $11 \leq k \leq 13$. Further, we cannot reject electricity to be set at growth maximizing levels after 8 years are included.

[4] We start with a maximun value for the autoregressive component, $l\max$, of 5, and reduce the length of lag if the t-statistic on $\widehat{b}^*$ was significant at the 5% level (instead of the 10% level used by Perron). In all cases we check the resulting correlogram to verify there is no remaining autocorrelation in the residuals using the estimated $\widehat{l}$, reported in the Table.

[5] These tests are extensions of the M tests of Perron and Ng (1996) that use GLS detrending of the data, together with a modified information criterion for the selection of the truncation lag parameter. These tests are the MZ_t^{GLS}, ADF_{MAIC}^{GLS}, MZ_α^{GLS}, and the MSB^{GLS}. In applying these tests, we also used the procedure of Pantula (1989).

[6] Since the neutrality tests of Fischer and Seater (1993) are based on how *changes* in the infrastructure variable are ultimately related to *changes* in output, cointegration is neither necessary nor sufficient for long-run neutrality.

Figure 1
Kilowatts of Electricity



For roads, figure 2 indicates that a permanent shock to infrastructure has positive and significant effect on real output after 8 years are included, and remains significantly different from zero thereafter. Although the LRD becomes significant after 8 years, it does not reach the optimal provision level even after a period of 20 years. That is, investment in roads does not appear to have been set at growth maximizing levels for Mexico.

Figure 2
Kilometers of Roads

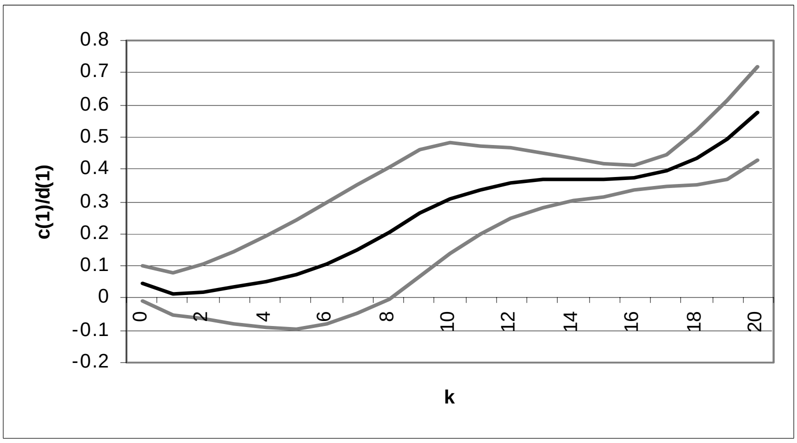
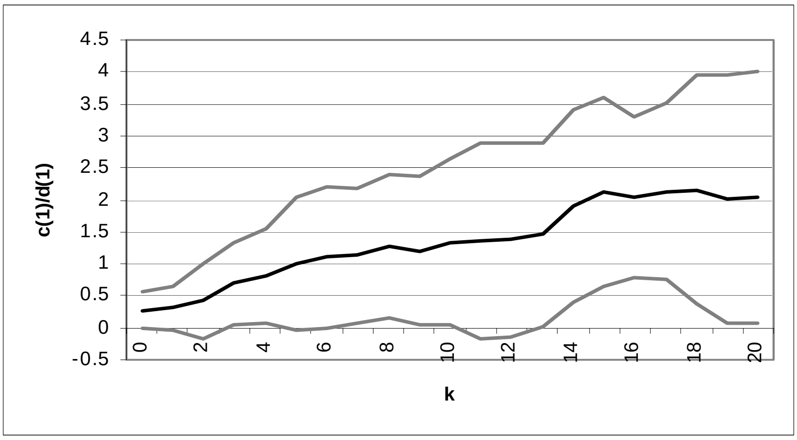


Figure 3 depicts the effect of telephone lines provision on output. The effect is always positive and crosses the optimal level of one around year 5, but continues to increase after that. Finally, it becomes only significantly different from zero after 13 years are included in the *LRD*. Although the upper confidence interval crosses 1 after 2-3 years are included, the fact that the lower confidence interval fluctuates around zero for most of the years included, induces us to be cautious about this result.

Figure 3
Telephones



5 Conclusion

This paper developed a theoretical model based on Barro (1990), where investment in infrastructure complements private investment. We then provide time series evidence for Mexico on both the impact of public infrastructure on output, and on the optimality with which levels of infrastructure have been set. Using Fischer and Seater (1993) notion of a Long-Run Derivative over a horizon of twenty years, we found that shocks to infrastructure have positive and significant effects on real output for all three measures of infrastructure. For electricity and roads, the effect becomes significant after 8 years, whereas for phones, the effect on growth is significant only after 13 years. Thus, these effects of infrastructure on output are in agreement with growth models where long-run growth is driven by endogenous factors of production. Electricity seems to have been set at growth maximizing levels, while road provision has not. For phone lines the results are less clear.

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