AN ANALYSIS OF THE IMPACT OF PUBLIC INFRASTRUCTURE ON PRODUCTIVITY PERFORMANCE OF MEXICAN INDUSTRY

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Abstract

It has been frequently quoted in the literature that one decisive cause of the productive performance of an economy might be infrastructure investment. This paper provides a dual profit theoretical framework of measuring the effects of infrastructure on economic performance in terms of gains in profits, cost savings, as well as in terms of productivity growth enhancement. In an empirical application, we opt for Mexican industry data. The results show that returns to infrastructure capital are significant and positive, though some variability across time exists. Moreover, the decomposition of total factor productivity growth reveals that the economic performance could be enhanced by investing in infrastructure capital.

JEL Code: D21, D24, H54, E62.

Keywords: profit function, productivity growth, public infrastructure, Mexican manufacturing.

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1. Introduction

Measuring productivity growth has always been central in discussions regarding the development of an economy (Barro, 1989, Shah, 1992, Morrison and Schwartz, 1994). But what we imply by productivity growth, Jorgenson (1997) defines productivity growth as "*the part of output growth that can not be explained by an increase in the use of inputs*". Moreover, productivity growth is attributed to improvements in technology, scale effects and an increase in the efficiency of resource use (see Capalbo and Antle, 1988). However, given the complexities involved in accurately measuring productivity growth it is not surprising that much controversy has been generated around this issue.

A rather neglected determinant of productivity growth for a prolonged period of time is infrastructure, though its importance has been unequivocal. The spark of recent research papers could be traced to Aschauer (1989) following the early work of Meade (1952). Ashauer's paper argued that public infrastructure explained some of the productivity growth slowdown in US economy in the late seventies and it triggered a plethora of papers thereafter (for a review see Gramlich, 1994 and Vijverberg et al., 1997). Despite the evidence provided by Aschauer (1989) and Munnel (1992), some research provided estimates of an insignificant return to public infrastructure in US (Evans and Karras, 1994 and Holtz-Eakin, 1994). Moreover, the high output elasticities of infrastructure reported by Aschauer (1989) and Munnel (1992) raised criticism on issues such as the lack of flexibility of their underlying production function specification, the aggregation bias in the macroeconomic data sets used, and the possible endogeneity of output (see Vijverberg et al. (1997)).

Using duality theory, Nadiri and Mamouneas (1994) and Morrisson and Schwartz (1996) addressed some of these issues to find that public infrastructure was enhancing productivity in US.

A country in which the role of public infrastructure may be seen as particularly influential is Mexico, in light also of the fact that public investment in infrastructure fell from 12% in the early eighties to bellow 5% in the nineties, at a period that growth of output in parallel dramatically declined and major macroeconomic instabilities occurred. This trend is not unique as it has been observed to other OECD countries (see Sturm, 1998), though in case of Mexico becomes even more apparent as productivity growth severely deteriorated over the years. This parallel development of low infrastructure investment and sluggish growth could indicate some correlation between the two, hence the numerous studies investigating the returns to public infrastructure (see Gramlich, 1994 and Vijverberg et al., 1997).

Of course, other factors could be held accountable for the observed underperformance of the Mexican economy. In particular in the nineties, the economy faced a major financial crisis that led to severe macroeconomic imbalances, which coupled with rising world uncertainties posed by high volatility in oil prices and high interest rates curbed economic activity. Another factor could be the globalization that appears to have stressed the economy triggered by the intensified competition of low labour cost countries, such as China (see OECD, 2003 a). However, globalization should not be seen as posing threats to the economy. Indeed in the case of Mexico, globalization could have been beneficial if producers and policy makers alike had swiftly responded towards restructuring traditional labour intensive production procedures and adopting the necessary policy reforms, in particular in labour markets (see Bergoeing et al. 2002). Moreover, the low skilled manufacturing sector of Mexico is difficult to compete against China or with other low income countries, including in Central America. Based on data reported in the IMD World Competitiveness Yearbook (2004) the hourly compensation in the manufacturing sector in Mexico is $2.45 compared to $0.66 in China.

Besides the idiosyncratic characteristics of the Mexican economy and the uncertainties linked to the external economic environment, OECD (2005) emphasizes the importance of infrastructure. This emphasis is based on the recent literature of productivity growth that widely, yet not universally, argues that infrastructure investment could contribute to total factor productivity (TFP), regardless of the technical change and the returns to scale (Gelauff et al. 2004). However, few studies have attempted to measure this return in the case of Mexican economy, though Shah (1992), Feltestain and Ha (1995) and Feltestein and Shah (1995) report that indeed public infrastructure investment is a productive input.

The theoretical framework of this paper complements studies that use duality theory (see Vijverberg et al., 1997) as it also opts for a flexible functional form, and therefore it departs from the primal analysis proposed by Aschauer (1989). Moreover, we derive a solution to the profit maximization problem that a firm is facing. The choice of profit function is based on the earlier research of Vijverberg et al. (1997), arguing that the profit function approach, in general, performs better than either the production function or cost function approach. The profit function provides additional flexibility as the hypothesis of the exogeneity of output, found within a cost function framework, is relaxed and the supply function is considered endogenous (see Shah, 1992). In turn, this optimization provides a theoretical framework that allows the identification of profit gains due to public infrastructure, as well as it allows measuring the effects of infrastructure on total factor productivity. In addition, this framework provides also measurement of the cost savings due to infrastructure.

The remainder of the paper is organised as follows; section 2 presents the theoretical framework of the profit function, while section 3 discusses the data set. Section 4 provides the empirical specification, the estimation procedure, and the empirical findings, whereas the last section highlights some concluding remarks and economic policy implications derived from the empirical findings.

2. A theoretical specification of profit function

Consider the following production function, where *X, G, t* denotes production inputs, public infrastructure, and technological change respectively.

$$Y = f(X, G, t) \tag{1}$$

The firm's objective is to maximise profits given the production function (1) and it can be written as:

$$\pi_{\pi}(P,w, G, t) = \max_{X} \; [P\, f(X, G, t) - w\, X] \tag{2}$$

, where P is the output price, *w* is as nx1 vector of the price of private inputs. The profit function is strictly convex in *P* and *w*.

By applying the envelope theorem we get:

$$\pi_{\pi G}(P, w, G, t) = P\, f_G(X, G, t) \quad (3)$$

$$\pi_{\pi t}(P, w, G, t) = P\, f_t\ (X, G, t) \quad (4)$$

, where subscripts denote first partial derivatives.

Equation (3) shows that the profit marginal shadow value of public infrastructure equals the marginal product value of public infrastructure, while equation (4) the profit marginal shadow value of technology as depicted by a time trend equals its marginal product value.

Similarly, the above optimisation could be expressed in terms of maximising the difference between total revenues and the cost of producing the output level *Y*.

$$\pi_c\ (P,w, G, t) = \max_{w}\ [P\ Y - C(w, Y, G, t)] \quad (5)$$

This profit function is convex and linear homogenous in *P* and *w*.

We apply envelope theorem in equation (5) and obtain:

$$\pi_{cG}\ (P, w,G, t) = -C_G\ (w, Y, G, t) \quad (6)$$

$$\pi_{ct}\ (P,w, G, t) = -\ C_t\ (w, Y, G, t) \quad (7)$$

Equation (6) shows that the marginal shadow value of public infrastructure as measured by the profit function is equal to the negative of the marginal shadow value of public infrastructure as measured from the cost function, *C*. Similarly, equation (7) describes the effect of the technological change.

2.1 Profit gains due to public infrastructure

Next, we use the above theoretical specification to quantify the effects of public infrastructure on economic performance. In the case that infrastructure capital is indeed a productive input, then it would induce profit gains. To measure these profit gains we start our analysis by total differentiating the profit function of equation (2):

$$\dot{\pi}(P,w,G,t) = \frac{\pi_P(P,w,G,t)P}{\pi(P,w,G,t)}\dot{P} + \Sigma\frac{\pi_{wi}(P,w,G,t)w_i}{\pi(P,w,G,t)}\dot{w}_i + \frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}\dot{G} + \frac{\pi_t(P,w,G,t)}{\pi(P,w,G,t)} \quad (8)$$

, where dots above the variables denote percentage growth rates.

The effect of public infrastructure on profit is derived as the difference between the total derivative of the profit function of equation (8) and the weighted average of the growth rates of output price and input prices:

$$\eta_{\pi G} = \dot{\pi}(P,w,G,t) - \xi(\dot{P},\dot{w}) \quad (9)$$

, where ξ is a function of the growth rate of *P* and *w*. For practical reasons ξ is taken as the weighted average of the growth rates of output price and input prices with weights being the elasticities of the profit function with respect to *P* and *w* (see Ray and Segerson, 1990 and Fousekis and Pantzios, 2000). Thus, we derive:

$$\eta_{\pi G} = \dot{\pi}(P,w,G,t) - \left[\frac{\pi_P(P,w,G,t)P}{\pi(P,w,G,t)}\dot{P} + \Sigma\frac{\pi_{Wi}(P,w,G,t)w_i}{\pi(P,w,G,t)}\dot{w_i}\right] \qquad (10)$$

Combining equation (10) with (8) we get:

$$\eta_{\pi G} = \frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}\dot{G} + \frac{\pi_t(P,w,G,t)}{\pi(P,w,G,t)} \qquad (11)$$

In effect the $\eta_{\pi G}$ measures the impact of public infrastructure and technological change on profit over time.

2.2 Cost savings due to public infrastructure

Similarly, in a parallel exercise the cost saving impact of public infrastructure is derived as in Morrison and Schwartz (1994) by total differentiating the cost function *C(w, Y, G, t)* in equation (5) that gives:

$$\dot{C}(w,Y,G,t) = \Sigma\frac{C_{wi}(w,Y,G,t)w_i}{C(w,Y,G,t)}\dot{w_i} + \frac{C_Y(w,Y,G,t)Y}{C(w,Y,G,t)}\dot{Y} + \frac{C_G(w,Y,G,t)G}{C(w,Y,G,t)}\dot{G} + \frac{C_t(w,Y,G,t)}{C(w,Y,G,t)} \qquad (12)$$

The effect of public infrastructure on cost is derived as the difference between the total derivative of the cost function of equation (12) and the weighted average of the growth rates of input prices:

$$\eta_{CG} = \dot{C}(w,Y,G,t) - \theta(\dot{w}) \qquad (13)$$

, where θ is a function of the growth rate of w.

For practical reasons θ is taken as the weighted growth rates of input prices with weights being the elasticities of the cost function with respect to w. Thus, we derive:

$$\eta_{CG} = \dot{C}(w,Y,G,t) - \left[\Sigma \frac{C_{w_i}(w,Y,G,t)w_i}{C(w,Y,G,t)} \dot{w}_i \right] \qquad (14)$$

Next, by combining equation (14) with (12) we get:

$$\eta_{CG} = \sigma \dot{Y} + \frac{C_G(w,Y,G,t)G}{C(w,Y,G,t)} \dot{G} + \frac{C_t(w,Y,G,t)}{C(w,Y,G,t)} \qquad (15)$$

, where $\sigma = \frac{C_Y \dot{Y}}{C}$, the cost elasticity with respect to output.

Given the assumption of cost minimization, the equation (15) decomposes the cost savings into the scale effect, the effect of public infrastructure, and the technical change effect.

However, notice that the growth rate of output in equation (15) is affected by price changes as well as by public infrastructure and technology changes. This is due to the underlying profit maximization theoretical specification of the present analysis. Therefore, output is endogenous and we should remove any effect stemming of changes in prices. To this end, equation (15) should include an adjusted supply net of changes in prices.

To derive the adjusted output we take the total derivative of the supply function, $Y = f(P, w, G, t)$[1]:

$$\dot{Y}(P,w,G,t) = \frac{Y_P(P,w,G,t)P}{Y(P,w,G,t)}\dot{P} + \Sigma\frac{Y_{wi}(P,w,G,t)w_i}{Y(P,w,G,t)}\dot{w}_i + \frac{Y_G(P,w,G,t)G}{Y(P,w,G,t)}\dot{G} + \frac{Y_t(P,w,G,t)}{Y(P,w,G,t)} \qquad (16)$$

The adjusted growth rate of output is the difference between equation (16) and the weighted average of the growth rates of output price and input prices, with weights being the elasticities of the output function with respect to *P* and *w*:

$$\dot{Y}_\alpha = \dot{Y}(P,w,G,t) - \left[\frac{Y_P(P,w,G,t)P}{Y(P,w,G,t)}\dot{P} + \Sigma\frac{Y_{wi}(P,w,G,t)w_i}{Y(P,w,G,t)}\dot{w}_i\right] \qquad (17)$$

, where subscript α counts for the adjusted profit maximized growth of output.

By combining (16) and (17) we get:

$$\dot{Y}_\alpha = \frac{Y_G(P,w,G,t)G}{Y(P,w,G,t)}\dot{G} + \frac{Y_t(P,w,G,t)}{Y(P,w,G,t)} \qquad (18)$$

, that is the corrected growth rate of output net of changes in prices.[2]

Thus, the adjusted cost savings are:

$$\eta_{CG\alpha} = \sigma\dot{Y}_\alpha + \frac{C_G(w,Y,G,t)G}{C(w,Y,G,t)}\dot{G} + \frac{C_t(w,Y,G,t)}{C(w,Y,G,t)} \qquad (19)$$

[1] Note that the supply function is given as $Y= f(X, G, t)$, while $X = X(P, w, G, t)$ as it is determined by the optimization of Π. Then, the supply function becomes $Y= f(P, w, G, t)$.

[2] This adjustment is necessary so as to isolate, and therefore be able to identify, the supply side impact of public infrastructure. Thus, any demand side effects are purged of.

The cost saving rate in equation (19) is decomposed into: (a) the scale effect induced by the response of production to changes both in public infrastructure and technology, (b) the direct cost impact of public infrastructure, that is the contribution of public infrastructure to the firm's cost savings over time holding production constant, and (c) the dual technical change effect.

Now, by substituting equations (6) and (7) into (19), multiplying and dividing the last two terms on the right hand side of equation (19) by profit, and using $\frac{\Pi}{C} = \frac{(R-C)}{C} = \sigma - 1$, where R is total revenue, we get the cost savings due to scale effects, public infrastructure, and technology:

$$\eta_{CG\alpha} = \sigma \dot{Y}_{\alpha} + (1\text{-}\sigma)\, \eta_{\pi G} \tag{20a}$$

$$\eta_{CG\alpha} = \sigma \dot{Y}_{\alpha} + (1\text{-}\sigma) \left(\frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)} \dot{G} + \frac{\pi_t(P,w,G,t)}{\pi(P,w,G,t)} \right) \tag{20b}$$

2.3 The impact of public infrastructure on productivity growth

Next we derive the impact of public infrastructure on total factor productivity. As in Vijverbeg et al. (1997) given production function (1) the decomposition of total factor productivity is:

$$\dot{TFP}_{\mathrm{G}} = \frac{f_G(X,G,t)G}{f(X,G,t)} \dot{G} + \frac{f_t(X,G,t)}{f(X,G,t)} \tag{21}$$

The first term is the product of the output elasticity with respect to public infrastructure, which is the primal rate of return to public infrastructure, and the growth rate of public infrastructure. The second term is the primal rate of technical change. Note that if the growth rate of infrastructure is zero or the output elasticity with respect to infrastructure is zero then equation (21) reduces to the traditional Sollow's residual measure of total factor productivity.

Now, substituting (3) and (4) into (21), and multiplying and dividing the right hand side of (21) by profit we get:

$$\dot{TFP}_G = \left(1 - \frac{1}{\sigma}\right)\eta_{\pi G} \tag{22}$$

or

$$\dot{TFP}_G = \left(1 - \frac{1}{\sigma}\right)\left(\frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}\dot{G} + \frac{\pi_t(P,w,G,t)}{\pi(P,w,G,t)}\right) \tag{23}$$

Equation (23) shows that the total factor productivity depends on the scale economies, $1-\frac{1}{\sigma}$, and the profit impact of public infrastructure and of technological change. Low economies of scale in parallel with small profit impact of public infrastructure and technological change would result to low levels of productivity growth.

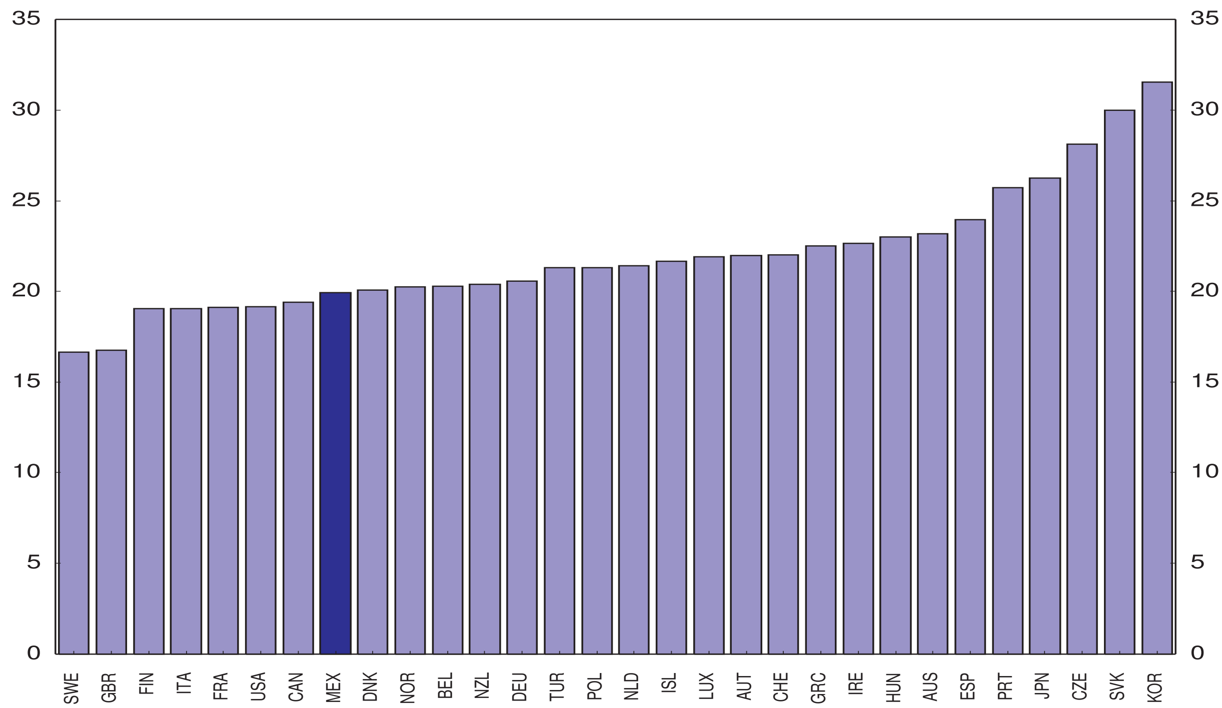
3. The Mexican economy and the Data set

The case of Mexico is of some interest as investment in core public infrastructure, defined as capital stock in electricity, transport and communication, has been one of the lowest among OECD countries (see OECD Economic Outlook, 2002). OECD (2005) argues that there has been a chronic underinvestment of infrastructure investment caused mainly by the lack of fiscal consolidation and prioritisation of public expenditure towards investment rather than consumption expenditure. One of the latest episodes of heavy curtailment in infrastructure investment took place during the financial crisis in the mid-1990s followed by fiscal consolidation efforts that heavily relied on reducing public investment expenditures. In addition, public investment projects were crucially dependent on changes in oil revenue and thus subject to the high volatility of oil markets. In a parallel process, and despite the economic recovery in the second half of the nineties brought by the fiscal consolidation, the productivity growth followed a declining path. Over the sample period, the growth of Mexican total factor productivity (TFP thereafter) relative to the growth in US TFP followed a downward trend, falling from 1.21% in 1970, 1.17 in 1980, 0.8% in 1990, to all time low 0.67% in 1995, while partly recovering thereafter to reach 0.74% in 2000 (see OECD, 2003 a). Evidently, the average rate of Mexican TFP growth lagged behind US TFP growth since early in the 1980s, underlining the magnitude of the Mexican economy's task of converging to the living standards of its northern neighbour.

An answer to this underperformance could be found in the low levels of infrastructure investment, despite the investment boom of the late 1990s as it largely focused on building consumption related facilities, such as shopping malls and fast food chains, rather than enhancing the production capabilities of the economy. Based on the country economic review of OECD (2003 a), the inadequate public investment has created shortages in core infrastructure such as communications, transportation, electricity, sanitation and water.[3] In addition, the business climate in Mexico has not been at all supportive to private investment due to heavy regulations and legislative restrictions, which is all more striking as these are part of the institutional infrastructure that also appears to be rather inadequate to enhance potential growth.

[3]According to OECD Environmental Performance Review (2003b) in Mexico the water and waste water sector would require $2.2 billion of investment funds, twice the annual budget of the National Water Commission (CNA), which is responsible for producing and regulating water.

Diagram 1, Nominal fixed investment as % of GDP, annual averages, 1996-2003



Source: OECD 2005, Economic Outlook.

In turn, an inadequate provision of infrastructure deters further investment and acts as an impediment to business (Feltestain and Ha, 1995). In particular, weakness in transportation and communication infrastructure prevents Mexico from getting the most out of its proximity to the US. Besides the strategic location of Mexico, fixed investment as percent of GDP in Mexico takes low values if compared to other OECD countries. The investment ratio averaged merely 20% in the latest expansion phase during the period 1996-2001, including residential construction and investment by large state-owned companies. This ratio is lower than its level in the early eighties or in previous decades, and it is quite low compared to the OECD average (see Diagram 1). It is worth mentioning that following the extensive privatization operations of the early 1990s, the public sector share of investment declined. However, and despite the significant share of private investment, the private sector has appeared not willing to cover the shortage of infrastructure created by the public underinvestment as it has mainly directed resources to the commercial sector. In addition, there is also evidence of inadequate quality of investment (OECD, 2005).

The above descriptive analysis poses a question regarding the importance of infrastructure investment. To answer this question, we next provide an empirical application concerning Mexican industries over the period 1970-2000. The data set is mainly derived from the Annual Industrial Survey (AIS) from the Mexican Institute for Statistics, Geography and Informatics (INEGI), which provides adequate information regarding: output measured as value added, that is net of intermediate inputs, employment measured as number of employees, wages, investment, capital stocks, and expenditures in electricity, communications, and transport.

The focus on micro data allows employing some disaggregation into our empirical application justifying the theoretical specification of the present analysis that focus on the firm's profit optimization and thus departs from a demand side analysis.[4] In detail, the following ten Mexican two-digit industries are included in our sample: mining, food, beverages & tobacco, wood and wood products, paper, chemicals, plastics & rubber, metal products, machinery & equipment, construction.

Time series for infrastructure and industry capital stocks is constructed using series for total Gross Fixed Capital Formation (GFCF) and investment. The capital stock series for both totals and disaggregated components were built up via a Perpetual Inventory Method (PIM) applied to a

[4] It is worth noting that a demand side analysis is warranted at an aggregate macroeconomic as in Aschauer (1999) or a general equilibrium framework and it would have, therefore, assisted the identification of the impact of public infrastructure. However, such an analysis is beyond the scope of the present study that relies on profit optimization and industry data.

benchmark capital stock for the year 1970, which is the standard OECD method. A PIM adds GFCF to benchmark capital and subtracts the depreciated capital in each year. The depreciation pattern can be linear or non linear. We used a linear depreciation pattern, which is the normal choice when information about actual depreciation is not available (see Albala-Bertrand, 2003). The benchmark for total capital stock was based on Hofman (2000 a, b). The proportion of core infrastructure of the total stock is based on the methodology proposed by Arellano and Braun (1999). In turn, the proportion of infrastructure components of total infrastructure was based on actual investment patterns. The depreciation rates used were the ones suggested in these sources. The price indexes used to deflate the nominal series came mostly from the GDP deflator, but we also used PPI and CPI as deflators when the former were unavailable. These series were available from the National Income and Product Accoutns (NIPA) of the Banco de Mexico. All series are expressed in constant 1993 pesos.

4. Empirical model

To estimate the effects of infrastructure capital on productivity and on the production structure of Mexican industries, we specify a restricted translog profit function:

$$ln\pi = \alpha_{0s} + \sum_{i=1}^{n} \alpha_i \ln w_i + \beta_p \ln P + \alpha_t t + \beta_G \ln G + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij} \ln w_i \ln w_j + \frac{1}{2}\beta_{GG} \ln G^2 + \frac{1}{2}\beta_{pp} \ln P^2$$
$$+ \sum_{i=1}^{n} \gamma_{ip} \ln w_i \ln P + \sum_{i=1}^{n} \gamma_{iG} \ln w_i \ln G + \beta_{pG} \ln P \ln G + \beta_t t + \frac{1}{2}\beta_{tt} \ln t^2 + \sum_{i=1}^{n} \gamma_{it} \ln w_i t + \gamma_{pt} \ln Pt +$$
$$\gamma_{Gt} \ln Gt \qquad (24)$$

Applying Hotelling's Lemma to equation (24), we obtain the following equations for the shares of profit attributed to output, inputs, and infrastructure:

$$R_P = \frac{d\ln\Pi}{d\ln P} = \beta_p + \beta_{PP}lnP + \sum_{i=1}^{n}\gamma_{iP}\ln w_i + \beta_{PG}\ln G + \gamma_{Pt}\, t \qquad (25)$$

$$S_i = \frac{d\ln\Pi}{d\ln w_i} = \alpha_i + \sum_{i=1}^{n}\alpha_{i\xi}\ln w_j + \sum_{i=1}^{n}\gamma_{ip}lnP + \sum_{i=1}^{n}\gamma_{iG}lnG + \sum_{i=1}^{n}\gamma_{it}t \qquad (26)$$

$$R_G = \frac{d\ln\Pi}{d\ln G} = \beta_G + \beta_{GG}lnG + \sum_{i=1}^{n}\beta_{iG}\ln w_i + \beta_{pG}lnP + \gamma_{Gt}t \qquad (27)$$

Equation (27) is of our interest as it shows the shadow share of public infrastructure, and is considered as a measure of the return to public infrastructure.

The monotonicity condition on the profit function requires that it is, respectively, non decreasing and non increasing in prices of output and inputs and is non decreasing in infrastructure capital. At the point of approximation, equations (25)-(26) imply that the profit shares of output and inputs are, respectively, positive and negative. Sufficient conditions for these inequalities are that $\beta_p \geq 0$, $\beta_t \geq 0$, and $\alpha_i \leq 0$, for all i, respectively. We impose linear homogeneity restrictions on profit function equation (24) with respect to output and input prices, namely $\sum_{i=1}^{n}\alpha_i + \beta_p = 1$, $\sum_{i=1}^{n}\gamma_{it} + \gamma_{pt} = 0$, and $\sum_{i=1}^{n}\alpha_{ij} + \sum_{i=1}^{n}\gamma_{ip} = 0$. We also impose the symmetry condition $\alpha_{ij} = a_{ji}$. In addition, convexity with respect to price is tested in terms of the positive semi definiteness of the Hessian matrix of second-order partial derivatives of the restricted profit function. Also, the profit function needs to be concave with respect to the quasi fixed capital infrastructure stock, so that the Hessian matrix of the profit function should be negative semi-definite with respect to this stock.

4.1 Empirical results

The system of equations (24) - (26) is estimated with iterative SUR to account for contemporaneous correlations of error terms. In the estimation, we exclude the private capital's profit share equation to avoid singularity of the variance co-variance matrix. Also, in order to estimate the parameters of the profit function equation we pooled the inter industry time series data. By doing so we deal with the problem of multicolinearity frequently associated with data of a single industry. The interindustry data set provides the necessary variability, and therefore allows a more rigorous statistically analysis of the parameter estimates and the correspondent elasticities.[5]

As a way to capture these interindustry differences we introduce dummy variables on the constant term of the profit function for each industry. We have assumed that $\alpha_{0s} = \alpha_0 + \sum_s \alpha_{0s} D_s$, where D_s refers to the industry dummies taking values 1 and 0, s is the industry identification index, and the α_{js} are normalised with respect to the k industry ($\alpha_{jk} = 0$).

Parameter estimates of the profit function are reported in Table 1. Overall, the results suggest that the estimated translog profit function is well behaved, as the signs on the coefficients of the profit function are reported to be consistent with curvature conditions, while the magnitudes of the estimated elasticities are plausible and statistically significant for most industries.

Moreover, the fitted profit function satisfies the motonicity property at all data points as the output shares are found to be positive and the variable input shares negative, while the profit shares of infrastructure capital is estimated to be positive. Also the Hessian matrix reports that the profit function is convex in prices and concave in infrastructure capital.

[5] Given that our data set has time series dimension, in addition to the cross section dimension across industries, it could be the case that there exist unit-roots and stochastic trends. Preliminary tests show that the despite some non-stationary variables into our sample the residuals from the estimated equations were found to be stationary indicating the existence of long-run relationships in terms of cointegration (results are available under request).

Table 1: parameter estimates of translog profit function.

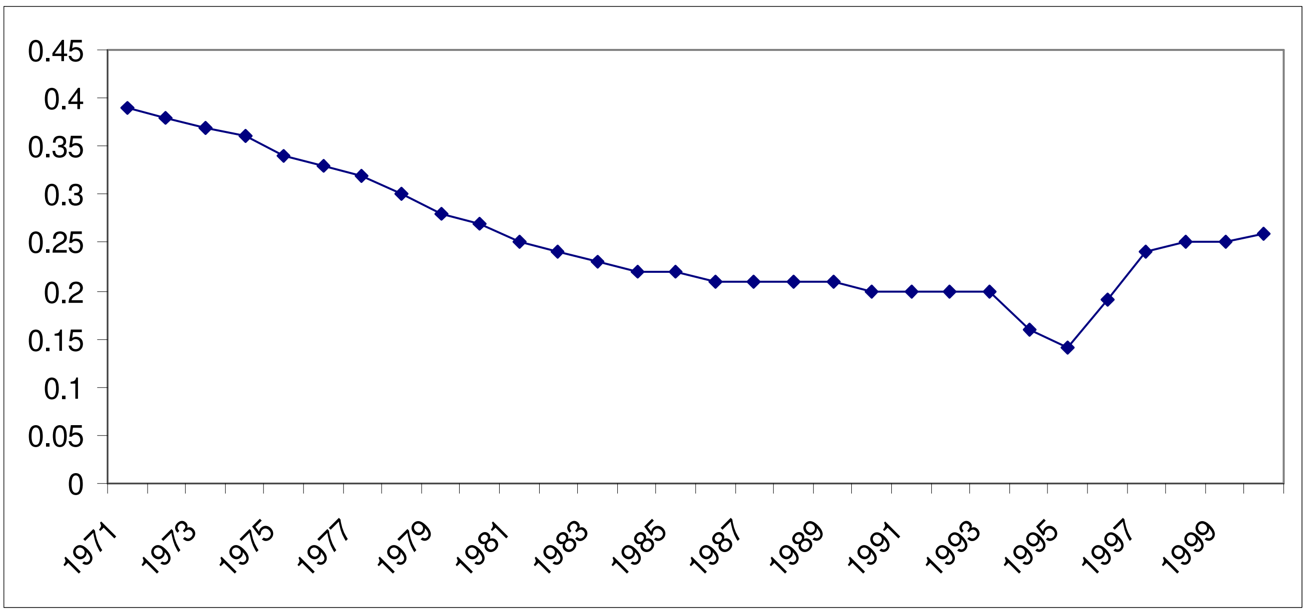
parameter	estimated value	t-stat
α_K	-1.17	-2.05*
α_L	-0.14	-8.03**
β_P	0.28	3.83**
β_{PP}	0.01	2.56*
β_G	0.22	3.80**
γ_{LG}	0.001	0.154
γ_{PK}	0.067	0.758
γ_{PL}	0.070	5.48**
β_{PP}	-.0109	-2.56*
α_{KL}	-1.155	-1.35
α_{KK}	-0.007	-6.80**
β_t	0.779	4.34**
β_{tt}	0.001	1.232
β_{GG}	0.26	2.88*
γ_{tP}	0.23	4.22**
γ_{tL}	0.61	0.81
γ_{tG}	-0.019	-2.01*
D_{95}	-0.18	-4.108**
R^2-*profit*	0.975	
R^2-*output*	0.986	
R^2-*labour*	0.966	

Source: Author's estimations, ** statistically significant at 1% level, while * at 5% level.

Note that the previous section discusses a major macroeconomic instability caused by financial crisis in the mid-1990s that could potentially bias our empirical estimation of the system of equations. To take into account this event, we include a dummy-variable for the year of pesos crisis, 1995, in the translog profit function specification. The dummy variable is found to be significant and carries a negative sign, insinuating the detrimental effect the pesos crisis on the profitability of the Mexican industry.

Diagram 2 presents the elasticity of profit with respect to public infrastructure. It is positive across all sample points. This finding implies that public infrastructure asserts a positive externality to the Mexican industry. However, note that it follows a negative trend till mid nineties, whereas in 1995 the financial crisis led to major macroeconomic instability that resulted to a negative spill over effect on the return to public infrastructure as measured by the elasticity of profits with respect to public infrastructure.

Diagram 2, The elasticity of profit with respect to infrastructure



4.2 Profit gains, cost savings, TFP contribution of public infrastructure

The profit gains of public infrastructure depend crucially on the elasticity of profits with respect to public infrastructure, but also the actual growth rate of public infrastructure (see equation 11). Despite the promising above 6.5% average growth in infrastructure investment in the 1970s, investment followed a negative trend from the early 1980s until the crash in 1995 due to the financial crisis. Moreover, the average growth rate of infrastructure capital, which was slightly above 2.5% in the 1980s, less than half of the growth rate in the 1970s, dropped to -1.65% in the 1995. A recovery in infrastructure investment is reported in the second half of the 1990s, reaching an average 5%, as the outcome of an improvement in the general economic climate.

Table 2 presents the contribution of public infrastructure to profit as derived from equation (11), augmented with the technical change effect, over the sample period 1970-2000. The results show that the effect of infrastructure is positive in all years (see 3rd column in Table 2). The average value of the profit gains over the period due to infrastructure is around 1.14%. The technical change, 4th column in Table 2, is also positive every year but 1995, insinuating that technical change was progressive with an average value of 1.1%. However, in contrast with the impact of infrastructure, the contribution of technology, though declines over time, it exhibits a stable contribution to profit gains compared to public infrastructure. Note that in the 1970s, the impact of public infrastructure was higher than 2.0%, and higher than the impact of technical change. Alas, it rapidly diminished in the 1980s and 1990s as investment in infrastructure investment was fainting away during a prolonged period of economic instability. As a result, and despite the significant magnitude of profit gains due to infrastructure and technology in the 1970s, over time the $\boldsymbol{\eta_{\pi G}}$ exhibits a clear downward trend.

TABLE 2, estimate of rate of gains in profit due to infrastructure

	$\frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}$	$\dot{G}$	$\frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}\dot{G}$	$\frac{\pi_t(P,w,G,t)}{\pi(P,w,G,t)}$	$\eta_{\pi G}$
1970-75	0.33	6.99	2.32	1.36	3.68
1975-80	0.31	6.40	1.96	1.17	3.13
1980-85	0.24	5.58	1.33	1.14	2.47
1985-90	0.21	2.62	0.55	0.93	1.48
1990-95	0.18	1.30	0.24	0.92	1.16
1995-00	0.22	2.01	0.45	1.21	1.66
1970-00	0.25	4.15	1.14	1.12	2.26

The average $\eta_{\pi G}$ during the period 1970-80 is around 3.3%, whereas considerable decline is observed in the 1980s, followed by a sharp decline thereafter reaching an all time low at around 1.1% in the first half of the 1990s. This development is explained by both the decline in the profit elasticity with respect to public infrastructure but also by the downward trend observed in the growth rate of public infrastructure since the mid 1980s. In particular, due to the dramatic collapse of infrastructure investment in the 1990s the profit gains due to infrastructure lacked persistently behind the profit gains due to technology, halving the value of $\eta_{\pi G}$ compared to the 1970s.

Table 3 presents the cost savings due to scale effects (1st column), infrastructure capital (2nd column) and technology (3rd column). The average cost saving due to infrastructure is -0.25% over the sample period, though it steadily declines over time to reach its lowest value in the period 1991-95 of -0.02% from around -0.31% during the 1980s and -0.4% in the 1970s, confirming the findings of the profit gains. Moreover, given that the scale and the technological effect remain relatively stable over the sample period, despite some observed decline in the 1990s, it is the infrastructure effect that determines the magnitude of cost savings. Note, that during the period of financial crisis in 1991-95, $\eta_{CG\alpha}$ takes a positive value of 0.01%. This result implies that the Mexican industry faced negative externalities that raise costs, mainly due to the underinvestment in public infrastructure, while some recovery occurred in the late 1990s.

TABLE 3, cost savings due to infrastructure

	$\sigma\dot{Y}_{\alpha}$	$(1\text{-}\sigma)\left(\frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}\dot{G}\right)$	$(1\text{-}\sigma)\left(\frac{\pi(P,w,G,t)}{\pi(P,w,G,t)}\right)$	$\eta_{CG\alpha}$
1970-75	1.19	-0.47	-1.05	-0.33
1976-80	1.17	-0.36	-1.05	-0.24
1981-85	1.20	-0.31	-1.04	-0.15
1986-90	1.23	-0.27	-1.05	-0.09
1991-95	0.97	-0.02	-0.94	0.01
1996-00	0.90	-0.05	-0.87	-0.02
1970-00	1.11	-0.25	-1.00	-0.14

In a recent study, Cole et al (2005) show that Latin America in general has been less productive than main industrialised economies with the average TFP levels in Mexico corresponded to roughly 50% of US productivity between 1950 and 2000. There are many arguments put forward as possible explanations for this trend among others; macroeconomic instability due to widespread governmental economic intervention, corruption, income inequality, and lack of competition due to monopolies and barriers to entry (see Cole et al, 2005). Equation (23) provides a specification of TFP decomposition into the direct impact of public infrastructure and the primal rate of technical change so as to investigate whether these two factors could explain the decline of TFP over the years.

Table 4 reports the dramatic decline of TFP in manufacturing that more than halved over the sample period from above 2.8% in the 1970s to around 1.26% in the 1990s. The low level of TFP in the 1990s is also demonstrated by Lopez-Cordova (2003). Moreover, as in the case of $\eta_{\pi G}$ and $\eta_{CG\alpha}$, the contribution of public infrastructure to TFP exhibits a downward trend. The average contribution of the effect of public infrastructure on TFP growth is slightly above 1.0%, but it falls from around

1.8% in the 1970s to 1.2% in 1981-85, to 0.62 in 1986-90, and, then, further declines to 0.25% in the period 1991-95, recording some recovery thereafter. As a result, the observed decline in TFP is mainly due to the sharp drop in infrastructure investment in the second half of the 1980s and the 1990s that resulted to shortages in infrastructure capital in line with the discussion of OECD (2005). Note, that the contribution of technological change remains stable over the sample period, further emphasizing that the driving source behind the sluggish economic performance of Mexican industry since the mid 1980s is the low infrastructure investment.

TABLE 4, average values of the effect of public infrastructure on productivity Growth

	$\left(1-\frac{1}{\sigma}\right)\left(\frac{\pi_G(P,w,G,t)G}{\pi(P,w,G,t)}\dot{G}\right)$	$\left(1-\frac{1}{\sigma}\right)\left(\frac{\pi_t(P,w,G,t)}{\pi(P,w,G,t)}\right)$	$\dot{TFP}_G$
1970-75	1.87	1.1	2.97
1976-80	1.78	1.06	2.84
1981-85	1.23	1.05	2.28
1986-90	0.62	1.05	1.67
1991-95	0.25	0.97	1.22
1996-00	0.31	0.98	1.29
1970-00	1.01	1.03	2.05

6. CONCLUSION

This paper develops a theoretical framework based on a flexible profit function that allows measuring the returns of public infrastructure in terms of higher (lower) profits (costs). It also provides a theoretical specification of TFP decomposition. The empirical estimates show that infrastructure capital is a productive input for the Mexican industry, as it generates profit gains and cost savings, though over time its impact declines. In addition, the TFP decomposition demonstrates that infrastructure investment could be responsible for the observed slow down in economic performance since the mid eighties. This finding suggests that productivity growth cannot be attributed to technical change and scale economies alone.

In most respects, Mexico's economic performance improved since the financial crisis of the mid 1990s. However, Mexico's productivity growth performance, despite the efforts to achieve macroeconomic stability, has been rather unsatisfactory. Our estimates of TFP show a clear negative trend over time and in particular in the 1990s, that have act as an impediment to potential growth. Indeed, OECD (2005) revised downwards the potential GDP growth estimates to below 4%. This performance does not assist attempts to narrow the gap in living standards with the other OECD countries, and it can not be judged as satisfactory for a country with large income disparities and high rates of population growth. The present empirical findings shed some light to what is often characterized as one of the pathogenic causes of the low economic performance of the Mexican economy; that is the chronic shortage in infrastructure capital in roads, electricity system, water supply and water treatment. In terms of economic policy, the findings emphasize the necessity to address this shortage, also in line with the recent policy guidelines of OECD (2005).

However, an issue that the current paper has not tackled, and it is of importance, concerns the issue of raising the appropriate financial resources to build infrastructure. OECD (2005) argues that in Mexico *"the fiscal revenues under the existing tax system are insufficient to finance infrastructure spending by federal, state and local governments at an adequate level"*. In addition, it is more than often the case that fiscal consolidation efforts weigh much on the public investment rather than on the public consumption expenditures. As a result, building up the much needed infrastructure capital should also necessarily involve the private sector, while prioritizing public expenditure away from consumption expenditure and into infrastructure investment projects could also play a positive role.

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