The Impact of Infrastructure on Mexican Manufacturing Growth

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Abstract: This paper analyses the impact of infrastructure on the growth rate of the Mexican manufacturing sector. For such purpose, two measures of infrastructure are used: highways and electricity. Further, we also estimate the degree of returns to scale and the markup. We pooled two digit industries to obtain the estimates of the whole manufacturing sector. For the entire manufacturing sector, our results do not show evidence of increasing returns but the existence of market power cannot be rejected. We find that both types of public infrastructure have a significant effect on manufacturing growth and its inclusion reduces the estimated values of returns to scale and market power. Once we use sectoral data, we obtain mixed results: public infrastructure affects significantly only some sectors.

Resumen: Este trabajo analiza el impacto de la infraestructura en la tasa de crecimiento del sector manufacturero mexicano. Con tal fin, se utilizan dos medidas de infraestructura: carreteras y electricidad. Adicionalmente, se estima el nivel de retornos a escala y el *markup*. Se agrupan las industrias a nivel de dos dígitos para poder obtener estimaciones para todo el sector manufacturero. Para el total del sector manufacturero, nuestros resultados no muestran evidencia de retornos crecientes, pero la existencia de poder de mercado no puede ser rechazada. Se encuentra que ambos tipos de infraestructura tienen un impacto significativo sobre el crecimiento manufacturero y su inclusión en las regresiones reduce el nivel de estimación del índice de retornos a escala y el nivel de poder de mercado. Al utilizar datos sectoriales, se obtienen resultados mixtos: la infraestructura afecta de manera significativa sólo a algunos sectores.

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I. Introduction

There are several papers in the economic literature that emphasize the impact of infrastructure on economic growth. On the theoretical side, Barro (1990) and Barro and Sala i Martin (1990) developed a theoretical framework that is useful to understand the links between fiscal variables, public goods, and economic growth. On the empirical side, on the other hand, most of these papers concentrate their efforts in calculating the impact of infrastructure on growth at very high levels of aggregation. In this regard, the papers by Aschauer (1989) and Holtz-Eakin (1988) are good examples of such literature.

In our paper we use data on Mexican manufacturing sector for the period 1971 to 1991 to simultaneously calculate the elasticity of manufacturing output with respect to public infrastructure, the degree of returns to scale and the degree of market power.[1] Nadiri and Mamuneas (1994) calculated the impact of infrastructure on industrial factor productivity using data on twelve two-digit industries. These authors device an analytical framework that allows them to quantify the contribution of output demand, relative input prices, technical change and publicly financed capital on total factor productivity growth. The technique used by these authors required an estimation process for output demand and cost functions. Also, they imposed an assumption of constant returns to scale in private inputs.

In this paper we propose a framework that allows the simultaneous estimation of the impact of infrastructure on industrial growth, the degree of market power and of returns to scale. In contrast to Nadiri and Mamuneas (1994), we do not need to estimate a demand function to account for market power effects or assume constant returns to scale in private inputs.

Recent literature uses instrumental variables to estimate the degree of returns to scale and the degree of market power. In an influential paper, Hall (1988a) estimates the markup for the U.S. manufacturing sector. He assumes that the Solow residual in levels follows a random walk with drift and uses aggregate instruments correlated with business fluctuations not known to be correlated with productivity shocks. In a related paper, Hall (1988b) applies his idea to estimate the degree of returns to scale for the U.S. manufacturing sector. Caballero

[1] Feltenstein and Ha (1995) estimate (using a translog function) the role of infrastructure on several two digit industries. However, their statistical fit was not completely satisfactory.

and Lyons (1989) changed Hall's (1988b) estimate by including an external index factor in the production function. These latter authors use both instrumental variable and SUR techniques to calculate its estimates.

This paper aims to capture the impact of public infrastructure on industrial growth in a context where returns to scale and market power are simultaneously estimated. For such purpose, we use data on the Mexican manufacturing sector. The approach followed here uses a production function framework in which the infrastructure stock is included as input for production. The addition of infrastructure stock as an input, renders an estimating equation that allows us to estimate the degree of returns to scale and the degree of market power. The methodology used in this paper implies that previous work, aimed at estimating the degree of market power or the returns to scale index, may have yield biased estimates of these measures, since infrastructure stocks may be correlated with the instruments used for obtaining the estimates.[2]

II. Methodology

Let us assume a technology with degree of homogeneity *r* in labor and capital and no intermediate inputs:

$$Y(t) = F\big(L(t), K(t), A(t), G(t)\big) \tag{1}$$

$A(t)$ represents technical progress, $K(t)$ is the stock of capital, $L(t)$ represents labor input, $G(t)$ is the stock of public infrastructure and $Y(t)$ is output. Differentiating the last equation with respect to time and rearranging:

$$\frac{\dot{Y}}{Y} = \left(\frac{F_K K}{Y}\right)\frac{\dot{K}}{K}\left(\frac{F_L L}{Y}\right)\frac{\dot{L}}{L} + \left(\frac{F_G G}{Y}\right)\frac{\dot{G}}{G} + \left(\frac{F_A A}{Y}\right)\frac{\dot{A}}{A} \tag{2}$$

We assume homogeneity of degree 1 in the technical progress index:

[2] Using Mexican data, Jarque (1988) run several regressions of the Solow residuals on infrastructure stocks. However, he did not control for market power effects or returns to scale. Thus, his results may be imprecise.

$$\left(\frac{F_A A}{Y}\right) = 1$$

Given the homogeneity of degree *r* in labor and capital:

$$\left(\frac{F_K K}{Y} + \frac{F_L L}{Y}\right) = r$$

We can express condition (2) as follows:

$$\frac{\dot{Y}}{Y} = r\frac{\dot{K}}{K} + \left(\frac{F_L L}{Y}\right)\left(\frac{\dot{L}}{L} - \frac{\dot{K}}{K}\right) + \left(\frac{F_G G}{Y}\right)\frac{\dot{G}}{G} + \frac{\dot{A}}{A} \qquad (3)$$

Given the first order conditions of a profit maximizing firm with some degree of market power –see appendix B–, the marginal product of labor can be expressed in the following way: $F_L = \beta(w/p)$.

With *w* representing nominal wage, *p* the price of output and β the markup (price over marginal cost). Using this last expression, equation (3) can be expressed in the following way:

$$\frac{\dot{Y}}{Y} = r\frac{\dot{K}}{K} + \beta\frac{wL}{pY}\left(\frac{\dot{L}}{L} - \frac{\dot{K}}{K}\right) + \left(\frac{F_G G}{Y}\right)\frac{\dot{G}}{G} + \frac{\dot{A}}{A} \qquad (4)$$

The coefficient multiplying the growth of the stock of public infrastructure represents the elasticity of output growth with respect to the growth of public infrastructure.

If infrastructure has no impact on growth and we assume constant returns to scale, equation (4) corresponds to Hall's formulation. On the other hand, if infrastructure has an impact on economic growth and it is not considered in the set of explanatory variables, the estimation of β will be biased. The direction of the bias will depend on the sign of the correlation between infrastructure and the weighted change in the labor capital ratio.[3,4] Furthermore, note also that proceeding as in Jarque (1988) and imposing the assumptions of β and *r* equal to one will generate an erroneous measurement of the impact of infrastructure.

[3] Notice that the imposition of constant returns to scale will also bias our estimate of β.

[4] For the instrumental variable case, the direction of the bias may depend on the sign of the correlation between infrastructure and the projection of the labor-capital ratio on the space spanned by the instruments.

Hall (1988b) used the first order conditions for cost minimization and Euler's theorem to obtain a relationship between market power and returns to scale. Specifically, he found that $\beta\alpha = r\eta$, where a represents the share of labor in total income and η measures its share in total costs. He then obtained an estimating equation that does not include the coefficient β. Caballero and Lyons (1989) used Hall's (1988b) formulation and included an externality index instrumented by a measurement of aggregate manufacturing input (labor and capital weighted by their shares in manufacturing total costs) to adjust the estimate of the index of returns to scale. Castañeda and Garduño (1999) did not find significant evidence for the existence of an external economy index for the Mexican manufacturing sector. However, as we will later show, the inclusion of infrastructure in the production function appears to have an important impact on the Mexican manufacturing sector.

III. Results

In order to have a better understanding of the impact that public infrastructure has on manufacturing growth, we first estimate the impact of public infrastructure, the size of market power and the index of returns to scale under the assumption of identical parameters across industrial sectors and fixed effects for each industry. We use data belonging to 42 Mexican industries for the period 1970-1991[5] –see appendix A for an explanation of the data. Next, we assume a common impact of infrastructure and heterogeneous coefficients for both market power and returns to scale. Finally, we pool industries into sectors (see the appendix for the definitions of sectors) and estimate the impact of infrastructure for these sectors. For all our estimates we assume fixed effects for each two digit industry.

The estimation of equation (4) may entail difficulties because technical progress may be correlated with private inputs yielding a classical case of simultaneous equation bias in the estimation process.[6] To eliminate such bias, we followed Caballero and Lyons (1989) and Hall (1988b) and use instrumental variables. However, as is well known, instrumental variable techniques may be ineffective if the instruments

[5] We use this period span because we could not get data on infrastructure for later years.

[6] In the estimation procedure, technical progress is incorporated in the constant and the econometric error by Caballero and Lyons (1989) and Hall (1988a) followed similar procedures.

are poorly correlated with the inputs. In this case, as Nelson and Starz (1988a and 1988b) have shown we may have significant biases in our estimates because we have a small sample. Thus, we may have a tradeoff while using this technique: results may be biased in small samples but are asymptotically correct. On the other hand, non-instrumental estimates are asymptotically biased but behave better for small samples.

For these reasons, in Tables 1a and 1b, we show the results of using least squares and two stage least squares.[7] Table 1a reports the size of market power, degree of returns and impact of public infrastructure under the assumption of common coefficients across industrial sectors and fixed effects for each industry. It shows that there is no evidence of increasing returns but the existence of market power cannot be rejected. Note that the inclusion of public infrastructure provokes a small reduction in the size of both parameters. For the entire sample and with the use of the two stage least squares procedure, such reduction makes impossible to reject the hypothesis of no market power. In the meantime, both types of infrastructure (highways and electricity) appear to have significant impact on the manufacturing sector.

There are two results that are worth mentioning in Table 1a. First, the least squares method suggests that the manufacturing sector has a mark-up that is statistically less than one –a result that is inconsistent with economic principles. Such inconsistency is grounded on the existence of some outliers' estimates in a few industrial sectors.[8] Thus, as we will see later, with the exception of industries 11, 22, 26, 27, 38, 42, and 49, the estimates of the markup are statistically larger than one or the hypothesis of β equal to one cannot be rejected. Once these seven sectors are not considered, the markup estimate is no longer less than one –as Table1b shows.

Second, the two stage least square procedure suggests that the size of the estimated parameters of market power and returns to scale changes in an important manner once public infrastructure is introduced. This last assertion is also true for Table 1b. Thus, it may be the case that its exclusion brings about an important bias. Regardless of techniques and the number of industries considered, highways have a

[7] We used the current and lagged growth rates of gross domestic product, the rate of growth of oil price and the growth rate of terms of trade as instruments.

[8] Later, in the sectoral analysis we will advance an hypothesis that pretends to explain these abnormal results.

Table 1a. Estimations using the Entire Sample
(Dependent Variable: Output Growth)

	Least Squares	*Least Squares*	*Two Stage Least Squares*	*Two Stage Least Squares*
Degree of Returns (*r*)	0.307	0.287	0.663	0.449
	(0.02)	(0.02)	(0.05)	(0.04)
Market Power (β)	0.739	0.698	1.285	0.931
	(0.04)	(0.04)	(0.11)	(0.08)
Elasticity of Highways	—	0.096	—	0.078
Infrastructure		(0.02)		(0.02)
Elasticity of Electricity	—	0.288	—	0.226
Infrastructure		(0.07)		(0.07)

Notes:
1 We imposed as restriction that all industrial sectors had the same degree of returns, the same market power and that infrastructure had an identical impact over industrial growth. We also assume fixed effects for individual industries.
2 The numbers in parenthesis are the standard errors.

Table 1b. Estimations with Restricted Sample
(Dependent Variable: Output Growth)

	Least Squares	*Least Squares*	*Two Stage Least Squares*	*Two Stage Least Squares*
Degree of Returns (*r*)	0.548	0.524	0.835	0.733
	(0.02)	(0.02)	(0.05)	(0.05)
Market Power (β)	1.519	1.463	2.334	2.006
	(0.07)	(0.07)	(0.15)	(0.13)
Elasticity of Highways	—	0.081	—	0.062
Infrastructure		(0.02)		(0.02)
Elasticity of Electricity	—	0.192	—	0.095
Infrastructure		(0.07)		(0.08)

Notes:
1 We imposed as restriction that all industrial sectors had the same degree of returns, the same market power and that infrastructure had an identical impact over industrial growth. We estimate a fixed effects model.
2 The numbers in parenthesis are the standard errors.

significant impact on manufacturing growth; a 10% increase in highways infrastructure leads to an increase of manufacturing output that ranges between 0.62 and 0.96%. With respect to electricity, it is only for the restricted sample and with two stage least square that its impact is not statistically significant –see Table 1b. An increase of 10% in electricity brings about an increase of manufacturing output that lies between 1.92 and 2.88 percent.

Table 2. (Dependent Variable: Output Growth)

	Non-Instrumental Variables	*Instrumental Variables*
Highways	0.072^{s}	0.067^{s}
	0.021	0.030
Electricity	0.120^{s}	0.013
	0.062	0.086

	Non-Instrumental Variables		*Instrumental Variables*			*Non-Instrumental Variables*		*Instrumental Variables*	
Industry	*r*	β	*r*	β	*Industry*	*r*	β	*r*	β
11	0.294^{s}_{dr}	0.090	0.44^{s}_{dr}	0.293_{pc}	37	0.61^{s}_{dr}	1.848_{pc}	0.695	2.435_{pc}
	0.117	0.302	0.249	0.506		0.219	1.024	0.428	2.355
12	0.430^{s}_{dr}	1.589_{pc}	0.489	0.727_{pc}	38	0.138	0.277	–0.715	–1.180
	0.195	0.434	0.407	0.826		0.155	0.284	0.653	1.126
13	0.851_{cr}	2.066_{pc}	1.050	2.444_{pc}	39	0.901^{s}_{cr}	2.706_{pc}	1.658^{s}_{cr}	2.661_{pc}
	0.554	1.422	1.016	2.647		0.469	1.282	0.887	2.090
14	0.967^{s}_{cr}	9.523_{mp}	1.44^{s}_{cr}	17.628_{pc}	40	0.685^{s}_{cr}	2.281_{pc}	1.077^{s}_{cr}	2.342_{pc}
	0.170	3.104	0.589	10.590		0.214	0.873	0.357	1.242
15	1.099^{s}_{cr}	8.082_{mp}	0.894	9.625_{pc}	41	1.248^{s}_{cr}	2.549_{mp}	1.356^{s}_{cr}	3.756_{mp}
	0.302	3.209	0.622	7.761		0.376	0.845	0.529	1.665
16	0.584^{s}_{dr}	2.322_{mp}	1.533	4.411_{pc}	42	0.39^{s}_{dr}	0.140	0.782^{s}_{cr}	0.314_{pc}
	0.222	0.602	1.320	3.583		0.168	0.127	0.452	0.526
17	0.126	–0.053	0.684	11.578_{pc}	43	0.668^{s}_{cr}	2.100_{mp}	0.972^{s}_{cr}	2.762_{pc}
	0.245	2.533	0.513	7.037		0.295	0.645	0.495	1.195
18	0.840^{s}_{cr}	2.210_{mp}	1.22^{s}_{cr}	1.633_{pc}	44	0.58^{s}_{dr}	1.526_{pc}	0.817^{s}_{cr}	1.921_{pc}
	0.263	0.694	0.448	1.792		0.248	0.786	0.467	1.661
19	0.686^{s}_{cr}	2.888_{pc}	0.911	3.427_{pc}	45	0.814^{s}_{cr}	2.414_{pc}	1.111^{s}_{cr}	3.263_{pc}
	0.385	1.429	0.708	2.739		0.135	0.956	0.289	1.693
20	0.744^{s}_{cr}	4.989_{mp}	0.712	4.609_{pc}	46	0.716^{s}_{cr}	1.833_{pc}	0.720	3.680_{mp}
	0.390	1.707	0.738	3.219		0.275	0.739	0.460	1.238
21	0.436^{s}_{dr}	1.761_{pc}	0.188	0.149	47	0.004	1.333_{pc}	–0.762	1.228_{pc}
	0.186	0.694	0.333	1.425		0.188	0.414	0.380	0.878
22	0.316^{s}_{dr}	0.380	0.537	0.287	48	1.023^{s}_{cr}	2.460_{mp}	1.550^{s}_{ir}	3.160_{mp}
	0.176	0.122	0.303	0.195		0.166	0.368	0.315	0.750
25	0.763^{s}_{cr}	3.993_{mp}	0.72^{s}_{cr}	1.852_{pc}	49	0.58^{s}_{dr}	0.796_{pc}	0.548^{s}_{cr}	1.022_{pc}
	0.168	0.322	0.305	1.097		0.193	0.316	0.306	0.585
26	0.326^{s}_{dr}	–0.012	0.56^{s}_{dr}	–0.056	50	0.624^{s}_{cr}	2.325_{mp}	0.574	2.715_{mp}
	0.143	0.160	0.227	0.317		0.305	0.617	0.481	0.951
27	-0.020	0.241	0.153	0.732_{pc}	51	0.859^{s}_{cr}	2.872_{mp}	1.011^{s}_{cr}	2.944_{mp}
	0.053	0.354	0.200	0.676		0.216	0.437	0.315	0.852
28	0.759^{s}_{cr}	1.383_{pc}	1.01^{s}_{cr}	1.754_{pc}	52	0.968^{s}_{cr}	2.829_{mp}	1.322^{s}_{cr}	3.588_{mp}
	0.206	0.522	0.311	1.454		0.197	0.481	0.306	0.883
29	0.638^{s}_{dr}	1.530_{pc}	0.71^{s}_{cr}	1.806_{pc}	54	0.48^{s}_{dr}	1.310_{pc}	0.848^{s}_{cr}	2.258_{mp}
	0.197	0.497	0.334	1.031		0.124	0.336	0.207	0.561
30	0.491^{s}_{dr}	2.217_{mp}	0.55^{s}_{dr}	1.927_{pc}	55	1.264^{s}_{cr}	2.913_{mp}	1.540^{s}_{cr}	3.349_{mp}
	0.159	0.712	0.256	1.395		0.289	0.474	0.480	0.736
31	0.269	0.781_{pc}	0.357	3.014_{pc}	56	0.67^{s}_{dr}	3.088_{mp}	0.814^{s}_{cr}	3.958_{mp}
	0.309	0.727	0.739	1.716		0.161	0.234	0.274	0.407

Table 2. (Dependent Variable: Output Growth) (conclusion)

	Non-Instrumental Variables		*Instrumental Variables*			*Non-Instrumental Variables*		*Instrumental Variables*	
Industry	*r*	β	*r*	β	*Industry*	*r*	β	*r*	β
32	0.281	0.589_{pc}	1.10^{s}_{cr}	2.539_{pc}	57	0.788^{s}_{cr}	2.546_{mp}	0.840^{s}_{cr}	2.919_{mp}
	0.228	0.596	0.508	1.369		0.146	0.360	0.203	0.541
35	0.398	1.298_{pc}	0.538	1.935_{pc}	58	0.37^{s}_{dr}	0.709_{pc}	0.527^{s}_{dr}	1.070_{pc}
	0.259	0.677	0.386	1.365		0.078	0.126	0.160	0.250

Notes:

Numbers below parameters are standard errors.

s means that the estimated parameter is statistically significant at 10% level.

mp denotes that the coefficient is significantly higher than 1 at the 10% level.

pc denotes that we cannot reject the hypothesis of β = 1 at the 10% level.

cr denotes that we cannot reject the hypothesis of constant returns to scale.

dr and *ir* denote that we reject the hypothesis of constant returns in favor to decreasing and increasing returns to scales respectively.

Next we allow our estimates of degree of returns and market power not to be constant across sectors. We show in Table 2 the results imposing a common coefficient on infrastructure and individual estimates of *r* and β for each industry. As can be seen, highways have a small but significant impact on manufacturing growth: a 10% increase in highways assets increases manufacturing output in approximately 0.7%. In the meantime, according to our least square estimates, electricity has an important impact on manufacturing growth. Thus, this methodology suggests that a 10% increase in this type of capital will lead to an increase in manufacturing output of 1.2%. The non-instrumental variable results on the estimates of β and *r* show that 8 industries have statistically insignificant coefficients on *r*, no single industry shows evidence of increasing returns to scale and 16 show evidence of market power. The instrumental variable results show that our estimates of β and *r* are different from those reported in previous work. Only one industry shows evidence of increasing returns to scale and 10 show evidence of market power.[9] Previous works have found much more evidence on market power and increasing returns.[10]

Finally, we pool industries into sectors (see the appendix for the definitions of sectors) and estimate the impact of infrastructure for these sectors. As explained before, the estimation of equation (4) is

[9] We use instrumental variable results to make the comparisons, because previous work used instrumental variables to obtain its market power measures.

[10] See Castañeda (1998) and Castañeda and Garduño (1999).

difficult because technical progress may be correlated with private inputs. To solve this problem we follow Caballero and Lyons (1989) and Hall (1988). However, instrumental variable techniques may be ineffective if the instruments are poorly correlated with the inputs. In this case, we may have significant biases in our estimates (Nelson and Starz, 1988a, b) because we have a small sample.

We implemented specification tests to examine the endogeneity of the industrial stock of capital and the weighted change in the labor-capital ratio. The chi-square statistics with its marginal significance are reported in Table 3. At the 10% level, we reject the hypothesis of no endogeneity in 34 industries and we do not reject the hypothesis in the 8 remaining industries. At the 5% level we reject the hypothesis of no endogeneity in 28 industries and we do not reject the hypothesis in the remaining 14. These results justify the use of instrumental variable models. However, the number of industries in which the non-instrumental variable can be used is significant. Besides, the arguments by Nelson and Starz commend us to use non-instrumental techniques. For these reasons, we decided to report the three stage least squares results and the seemingly unrelated regression estimates.[11] The instruments used were the current rate of growth of gross domestic product and its lagged value, the rate of growth of oil price and the rate of growth of the terms of trade. The stock of highways and electricity infrastructure is treated as exogenous, since no single industry is able to control its availability.

We followed two procedures to test the constraint that restricts all industrial coefficients to be equal inside a sector. In the first one, we tested whether the coefficients r and β can be restricted to be equal across all the industries included in the sectors. In the second one, we tested whether the infrastructure coefficients can be restricted to be equal inside the sector.[12] We followed this procedure for both sets of estimates (SUR and 3SLS). For most pooled sectors we cannot reject the hypothesis of a common impact of infrastructure. For the markup and the coefficient of returns to scale, the results are less definitive. In several sectors we reject the hypothesis of common coefficients. Therefore, in Table 4 we report single industrial coefficients for those cases in which we rejected the hypothesis of a common markup and a common index of returns to scale.

[11] For the whole manufacturing sector we were not able to obtain SUR and 3SLS estimates. For this reason, we report in Tables 1a, 1b and 2 the OLS and 2SLS estimates.

[12] We realized standard F and Wald tests.

Table 3

Industry Digit	*Chi-Square*	*Probab.*	*Industry Digit*	*Chi-Square*	*Probab.*	*Industry Digit*	*Chi-Square*	*Probab.*
11	5.133	0.076	26	17.430	0.000	46	32.428	0.000
12	35.057	0.000	27	17.786	0.000	47	35.260	0.000
13	5.730	0.056	28	11.985	0.002	48	8.032	0.018
14	3.966	0.137	29,30	8.161	0.016	49	7.178	0.027
15	7.964	0.018	31,32	12.215	0.002	50	4.924	0.085
16	1.105	0.575	35	3.469	0.176	51	7.069	0.029
17	22.986	0.000	36	7.950	0.018	52	21.599	0.000
18	12.724	0.001	38	5.790	0.055	54	9.647	0.008
19	4.962	0.083	39	6.411	0.040	55	12.824	0.001
20	1.733	0.420	40	18.934	0.000	56	12.777	0.001
21	3.960	0.138	41	0.283	0.867	57	1.244	0.536
22	4.675	0.096	42	7.014	0.029	58	3.726	0.155
25	9.614	0.008	43,44,45	6.823	0.032			

As can be seen in Table 4, almost all of the estimates of degree of returns (r) and market power (β) are very precise[13] –on average the SUR estimates are more precise than the 3SLS estimates. In 90% of the industries listed in such table, the ratio of the markup to the returns to scale index implies that firms are consistently obtaining benefits $(\beta > r)$. In contrast to what happened at the pooled level, the impact of infrastructure on industrial growth is mixed. When we observe the SUR and the 3SLS estimates, we note that either one of these techniques of estimation show that highways infrastructure affects positively –and statistically significant– the rate of growth of several sectors: textiles, paper, chemicals, glass, and cement and metal products, with the elasticity ranging between 0.07 and 0.21. For other sectors, the impact –according to this estimation-process is not significant, although there are some cases (such as wood, metals and transport sector) where the marginal significance level is only slightly below 10%. For electricity, our estimates suggest that it has a positive and statistical significance for three sectors: wood, chemicals and transport equipment; with the elasticity ranging between 0.230 and 0.471.

When we analyze the results of Table 4, we notice that most of them are consistent with economic principles. With the exception of indus-

[13] Our metric of precision is given by the ratio of the parameter estimated to the standard deviation.

Table 4. (Dependent Variable: Output Growth)

Food, Beverage and Tobacco

	SUR		3SLS	
Highways	0.009 (0.014)		0.030 (0.028)	
Electricity	0.005 (0.041)		–0.002 (0.082)	
Industry	*r*	β	*r*	β
11	0.295^{s}_{dr} (0.058)	0.134 (0.164)	0.477^{s}_{dr} (0.129)	0.538 (0.270)
12	0.483^{s}_{dr} (0.103)	1.631_{mp} (0.246)	0.254 (0.278)	0.534_{pc} (0.501)
13	0.798^{s}_{cr} (0.163)	1.841_{mp} (0.412)	1.214^{s}_{cr} (0.297)	2.785_{mp} (0.761)
14	0.978^{s}_{cr} (0.043)	9.354^{mp} (0.828)	1.418^{s}_{cr} (0.299)	17.187_{mp} (5.644)
15	1.119^{s}_{cr} (0.104)	8.837_{mp} (1.125)	0.782^{s}_{cr} (0.270)	9.204_{mp} (3.209)
16	0.605^{s}_{dr} (0.163)	2.305_{mp} (0.442)	2.376^{s}_{cr} (1.063)	6.647_{mp} (2.846)
17	0.172 (0.185)	0.709_{pc} (1.906)	0.488 (0.432)	8.142_{pc} (6.393)
18	0.898^{s}_{cr} (0.154)	2.292_{mp} (0.373)	1.608^{s}_{ir} (0.282)	0.993_{pc} (0.928)
19	0.856^{s}_{cr} (0.136)	3.521_{mp} (0.508)	0.950^{s}_{cr} (0.297)	3.863_{mp} (1.175)
20	0.688^{s}_{cr} (0.293)	4.662_{mp} (1.234)	0.354 (0.519)	3.402_{pc} (2.196)
21	0.547^{s}_{dr} (0.156)	2.106_{mp} (0.575)	0.357 (0.286)	0.797_{pc} (1.237)
22	0.434^{s}_{dr} (0.169)	0.409 (0.129)	0.560^{s}_{cr} (0.291)	0.335 (0.185)

Glass and Cement

	SUR		3SLS	
Highways	0.119^{s} (0.065)		0.082 (0.072)	
Electricity	0.224 (0.191)		0.092 (0.217)	
Industry	*r*	β	*r*	β
43,44,45	0.717^{s}_{dr} (0.071)	2.128_{mp} (0.205)	0.919^{s}_{cr} (0.144)	2.286_{mp} (0.439)

Textiles

	SUR		3SLS	
Highways	0.038 (0.209)		0.072^{s} (0.000)	
Electricity	0.066 (0.189)		0.084 (0.197)	
Industry	*r*	β	*r*	β
25	0.776^{s}_{cr} (0.186)	3.979_{mp} (0.341)	0.842^{s}_{cr} (0.455)	2.160_{pc} (1.533)
26	0.171^{s}_{dr} (0.084)	–0.041 (0.090)	0.530^{s}_{dr} (0.155)	–0.172 (0.188)
27	–0.037 (0.034)	0.019 (0.230)	0.165 (0.164)	0.737_{pc} (0.554)
28	0.584^{s}_{dr} (0.151)	1.060_{pc} (0.370)	1.004^{s}_{cr} (0.216)	1.668_{pc} (0.986)

Chemicals

	SUR		3SLS	
Highways	0.176^{s} (0.040)		0.213^{s} (0.049)	
Electricity	0.230^{s} (0.111)		0.193 (0.129)	
Industry	*r*	β	*r*	β
35	0.228^{s}_{dr} (0.107)	1.095_{pc} (0.254)	0.110_{dr} (0.183)	1.345_{pc} (0.489)
37	0.520^{s}_{dr} (0.124)	2.060_{mp} (0.548)	0.364_{dr} (0.225)	1.774_{pc} (1.144)
38	0.024 (0.101)	0.067 (0.185)	–0.110 (0.439)	–0.166 (0.755)
39	0.804^{s}_{cr} (0.224)	3.007_{mp} (0.624)	1.227^{s}_{cr} (0.394)	3.122_{mp} (1.010)
40	0.610^{s}_{dr} (0.107)	2.146_{mp} (0.432)	0.972^{s}_{cr} (0.197)	2.461_{mp} (0.677)
41	0.973^{s}_{cr} (0.344)	2.263_{mp} (0.759)	0.905^{s}_{cr} (0.495)	4.425_{mp} (1.451)
42	0.302^{s}_{dr} (0.155)	0.154 (0.115)	0.849^{s}_{cr} (0.468)	0.579_{pc} (0.548)

Table 4. (Dependent Variable: Output Growth) (conclusion)

	SUR		*3SLS*			*SUR*		*3SLS*	
	Wood					*Paper*			
High-ways	0.069		0.039		*High-ways*	0.128		0.201^{s}	
	(0.043)		(0.042)			(0.084)		(0.117)	
Electri-city	0.298^{s}		0.187		*Electri-city*	0.316		–0.018	
	(0.141)		(0.146)			(0.273)		(0.405)	
Indus-try	*r*	β	*r*	β	*Indus-try*	*r*	β	*r*	β
29,30	0.439^{s}_{dr}	1.328_{mp}	0.619^{s}_{dr}	1.810_{mp}	31,32	0.281^{s}_{dr}	0.616_{pc}	1.002^{s}_{cr}	2.366_{pc}
	(0.065)	(0.188)	(0.092)	(0.306)		(0.165)	(0.393)	(0.417)	(1.016)
	Metal Products					*Basic Metals*			
High-ways	0.152^{s}		0.090		*High-ways*	0.126		0.103	
	(0.076)		(0.086)			(0.100)		(0.177)	
Electri-city	–0.311		$–0.618^{s}$		*Electri-city*	0.041		0.216	
	(0.226)		(0.219)			(0.306)		(0.542)	
Indus-try	*r*	β	*r*	β	*Indus-try*	*r*	β	*r*	β
48	0.993^{s}_{cr}	2.443_{mp}	1.508^{s}_{cr}	3.018_{mp}	46	0.665^{s}_{cr}	1.585_{pc}	0.527_{dr}	3.392_{pc}
	(0.195)	(0.427)	(0.365)	(0.895)		(0.221)	(0.600)	(0.744)	(1.823)
49	0.633^{s}_{dr}	0.386	0.806^{s}_{cr}	0.883_{pc}	47	0.153	1.274_{pc}	-0.799^{s}	0.833_{pc}
	(0.187)	(0.302)	(0.276)	(0.535)		(0.174)	(0.388)	(0.470)	(1.310)
50	0.419^{s}_{dr}	2.344_{mp}	0.502^{s}_{dr}	3.294_{mp}					
	(0.175)	(0.366)	(0.252)	(0.570)					
	Transport					*Machinery and Equipment*			
High-ways	0.133		0.109		*High-ways*	0.029		–0.055	
	(0.090)		(0.098)			(0.065)		(0.073)	
Electri-city	0.471^{s}		0.499		*Electri-city*	–0.140		–0.433	
	(0.272)		(0.308)			(0.211)		(0.263)	
Indus-try	*r*	β	*r*	β	*Indus-try*	*r*	β	*r*	β
56	0.589^{s}_{cr}	2.832_{mp}	0.783^{s}_{cr}	3.754_{mp}	51	0.803^{s}_{cr}	2.465_{mp}	1.242^{s}_{cr}	3.196_{mp}
	(0.267)	(0.389)	(0.446)	(0.650)		(0.214)	(0.412)	(0.278)	(0.724)
57	0.731^{s}_{dr}	2.292_{mp}	0.745^{s}_{cr}	2.673_{mp}	52	0.862^{s}_{cr}	2.390_{mp}	1.561^{s}_{ir}	3.944_{mp}
	(0.162)	(0.386)	(0.212)	(0.538)		(0.176)	(0.414)	(0.286)	(0.805)
58	0.347^{s}_{dr}	0.716	0.417^{s}_{dr}	1.037_{pc}	54	0.447^{s}_{dr}	1.199_{pc}	0.996^{s}_{cr}	2.702_{mp}
	(0.096)	(0.151)	(0.187)	(0.281)		(0.138)	(0.373)	(0.254)	(0.691)
					55	1.308^{s}_{cr}	2.727_{mp}	1.895^{s}_{ir}	3.639_{mp}
						(0.171)	(0.263)	(0.306)	(0.408)

Notes:

Numbers below parameters are standard errors.

s means that the estimated parameter is statistically significant at 10% level.

mp denotes that the coefficient is significantly higher than 1 at the 10% level.

pc denotes that we can not reject the hypothesis of β = 1 at the 10% level.

cr denotes that we cannot reject the hypothesis of constant returns to scale.

dr and *ir* denote that we reject the hypothesis of constant returns in favor to decreasing and increasing returns to scales respectively.

tries 11, 22, 26, 27, 38, 42, and 49[14] the estimates of the markup are statistically larger than 1 or either we cannot reject the hypothesis of β equal to 1.[15] With the use of instrumental variables, Castañeda (1998) found that 44 industries rejected the hypothesis of price equal to marginal cost. In contrast, our 3SLS estimates suggest that only in 21 industries this hypothesis is rejected. In addition, we find that the hypothesis of increasing returns to scale is rejected in all but 3 industries. This result also contrasts with previous work that estimated the increasing returns to scale index by calculating the share of labor costs on total costs. In those estimates, 21 industries were reported as having increasing returns. These important differences suggest that omitting infrastructure from the explanatory variables set may create biases in the estimate of the index of increasing returns and the index on market power.

Before we analyze each manufacturing industry in detail, in Table 5 we describe the aggregate impact that infrastructure has on manufacturing output. This table reports the output share of each industry within the manufacturing sector for 1991 and the estimated value of the elasticity of infrastructure that was statistically significant –as shown in Table 4. According to the SUR procedure, highways has a statistically impact in industries that accounted for 27% of all manufacturing output. Meanwhile, electricity has an impact in industries that account for 31% of all manufacturing output. These figures suggest that a 10% increase –for example– in the stock of electricity would lead to an increase of 1.06% of manufacturing output.[16]

For food and beverages, only one individual industry estimate shows evidence of increasing returns to scale. In general, the SUR estimates are more precise. In eleven industries of these estimates (SUR), the coefficient for *r* is significantly different from zero. For six industries, we are not able to reject the hypothesis of constant returns to scale. In the other five, we reject the hypothesis of constant returns to scale in favor of the hypothesis of decreasing returns. For the 3SLS procedure we obtain more imprecise estimates: in 4 industries the estimated coefficients of *r* are not statistically significant. This is a by prod-

[14] Below we advance a potential explanation for these results.

[15] For some of these industries the markup is statistically smaller than one for only one technique of estimation.

[16] This figure was obtained by weighting the elasticity of electricity –in each of the three sectors where this investment had a statistical impact– with the relative importance of these sectors in manufacturing output.

Table 5

	% Manu-facturing	SUR		3SLS	
		Highways	Electricity	Highways	Electricity
Chemicals	14.1	0.176	0.230	0.213	
Glass and Cement	8.1	0.119			
Metal Products	4.7	0.152			–0.618
Transport	13.3		0.471		
Wood	3.8		0.298		
Textiles	8.0			0.072	
Paper	5.7			0.201	
Food, Beverage and Tobacco	27.4				
Machinery and Equipment	9.1				
Basic Metals	5.8				

uct of the imprecision that accompanies instrumental variable estimates. For six industries in these estimates (3SLS), we do not reject the hypothesis of constant returns to scale, one industry shows evidence of increasing returns and another one of decreasing returns.

With regard to the market power measures, the SUR coefficients show that 9 industries reject the hypothesis of perfect competition –for the 3SLS estimates there are 5 industries with such characteristic. For two industries, the markup coefficient is significantly less than one, which demands an intuitive explanation. For the instrumental variable case, a possible explanation for such awkward result is that the instrument is relatively more correlated with output growth than with the shifts in the growth of the weighted labor-capital ratio.[17] For the SUR estimates, we may have a symmetric explanation: the covariance between the weighted labor capital ratio and output may be low, which may be a signal of labor hoarding.[18] Firms hoard labor because it may be costly for them to train labor each time there is a boom. Under labor hoarding, labor becomes something closer to a fixed cost.

Finally, with regard to the infrastructure measures, we note that highways and electricity are not significant.

[17] We must remember that the formula for the coefficient (in this multiple regression case).

[18] Among other things, the formula for this SUR estimate is an increasing function of the covariance between the weighted change in the labor-capital ratio and output growth.

Note that textiles have, for the SUR estimates, two industries that yield an unreasonably low estimate of the markup (industries 26 and 27). For industry 27 we also have a non-significant estimate of the coefficient *r*.[19] The explanation is similar to the one advanced before for the food and beverages sector, labor hoarding may be playing a role. For the SUR procedure, 1 industry shows evidence of market power. No industry has a markup statistically larger than 1 for the 3SLS estimate. With regard to the SUR estimates, three estimates of *r* are significantly different from zero and for one we cannot reject the hypothesis of constant returns to scale. For the 3SLS procedure, we have the same number of significant industries, with two industries not statistically different from 1. In the 3SLS estimates, highways are statistically significant and electricity is not. For the SUR technique, none of our measures of infrastructure is significant.

In the case of wood, we find for the SUR procedure that electricity has a significant impact on industry growth. Highways show a null statistical impact (highways gets closer to a significant impact with a marginal significance level of 12%). The estimate of *r* is significantly different from zero and statistically lower than 1. The estimate of the coefficient on market power is statistically larger than 1. For the 3SLS estimates we have similar results except for the fact that none of our measures of infrastructure have a significant impact (electricity gets close to have a significant impact, marginal significance level of 14 percent).

For the paper sector, we find for the 3SLS procedure that highways have a significant impact on industry growth. There is no significant impact for electricity. The estimate of *r* is significantly different from zero for both procedures. We cannot reject the hypothesis of constant returns for the 3SLS procedure. With regard to market power we do not reject the hypothesis of perfect competition.

Highways and electricity have a significant positive impact on chemicals for the SUR procedure (only highways are significant for 3SLS). With regard to the SUR estimates, in 6 industries we have an estimate of *r* that is significantly different from zero. For 4 industries, we reject the hypothesis of constant returns to scale in favor of the hypothesis of decreasing returns to scale. The 3SLS estimates of *r* show 4 industries with a coefficient statistically different from zero. For 4

[19] Caballero and Lyons (1988) found similar results for the U.S. industry, using an index of external economy as a regressor instead of the stock of infrastructure.

industries we do not reject the hypothesis of constant returns to scale. For the 3SLS estimates, 3 industries have a non-significant estimate. With regard to the β estimates, the SUR procedure shows 4 industries with evidence on market power. For 2 industries we have estimates of β that are statistically smaller than 1. The 3SLS results show that three industries reject the hypothesis of perfect competition, for two we have an estimate of β statistically smaller than one. As mentioned above, a possible explanation for these unreasonably low measures of the markup is that the instrument is relatively more correlated with output growth than with the shifts in the growth of the weighted labor-capital ratio. For the SUR estimates, we may have a symmetric explanation, the covariance between the weighted labor capital ratio and output may be low, which may be a signal of labor hoarding.

We notice that highways have a significant impact on glass and cement when we look at the SUR results. None of our measures of infrastructure show a significant impact in the 3SLS results. We reject the hypothesis of perfect competition for the three pooled industries under both procedures of estimation. We reject the hypothesis of constant returns to scale (for the three pooled industries) in favor of the hypothesis of decreasing returns when we estimate by SUR. The estimate of *r* under 3SLS does not reject the hypothesis of constant returns to scale.

For basic metals, none of our measurements of infrastructure have a significant impact on the sector (highways have a marginal significance level of 15% for the SUR estimates). The SUR and 3SLS estimates indicate that perfect competition cannot be rejected for the two industries included in this sector. With regard to the estimates of *r*, the SUR estimates show that for one industry the coefficient does not reject the hypothesis of constant returns to scale. For industry 47, the estimate of *r* is not statistically significant. The 3SLS estimates indicate a non-significant coefficient for industry 46 and a negative coefficient for industry 47 this may be indication of the poor performance of the instruments in relation with the industry. We must notice also that the estimates of β are also very imprecise.

Highways have a significant impact on the behavior of the metal products sector under the SUR procedure. Electricity has a negative (significant) impact in the 3SLS results. The SUR estimates show that two industries have evidence of decreasing returns to scale and for one we cannot reject the hypothesis of constant returns to scale. For two industries we reject the hypothesis of perfect competition and for one we cannot. The 3SLS estimates show that one industry has evidence of decreasing returns to scale with two industries not rejecting the hypothesis of constant returns to scale. In two of the industries included in the sector, the 3SLS estimates reject the hypothesis of perfect competition.

In the machinery and equipment sector none of our measures of infrastructure have a significant impact on sector growth. Highways have a marginal significance level of 24% for the SUR estimates, and much lower for the 3SLS calculations. In the SUR estimates, three industries do not reject the hypothesis of constant returns and for one industry there is significant evidence of decreasing returns, three industries show significant evidence on market power. The 3SLS estimates show that two industries have significant evidence of increasing returns to scale, for the other two we cannot reject the hypothesis of constant returns to scale. In all four industries included in the sector we have evidence on market power. Not surprisingly, the industries that show significant evidence of increasing returns also show significant evidence of market power.[20]

For transport equipment, the SUR results show that electricity has a significant impact on industrial growth. The 3SLS estimates do not show evidence of a significant impact of infrastructure. The SUR estimates show significant evidence on decreasing returns for two industries and significant evidence on market power for two industries. For industry 58 we also have an estimate of β statistically smaller than one. The intuitive explanation is similar to the one advanced above. The 3SLS estimates show one industry with an estimate of r statistically lower than one and two other industries in which we cannot reject the hypothesis of constant returns to scale. The market power estimates indicate that for 2 industries we have market power evidence, and for one we cannot reject the hypothesis of perfect competition.

Concluding Remarks

In this paper we attempted to estimate the impact of infrastructure on the Mexican manufacturing sector. Our results show that, irrespective of our estimation method, highways and electricity have a

[20] An industry with increasing returns must necessarily exhibit a markup larger than one to avoid losses.

significant impact on the Mexican manufacturing growth. Also, the evidence on market power and increasing returns is less evident than in previous work. Using the results of the sectoral estimates, we find only 3 sectors that show evidence of increasing returns and 21 industries with market power results. Previous work found 44 industries with a markup larger than 1[21] and 21 industries with evidence of increasing returns to scale.[22]

For the whole manufacturing sector, a ten percent growth in the assets of highways contributes to an increase in manufacturing output that lies in the range between .62 and .96%. An increase of 10% in the stock of capital in electricity leads to an increase of manufacturing output in the range of 1.92 to 2.88%. The sectoral estimates vary with regard to the impact of highways and electricity.

Finally, in previous work by Castañeda and Garduño (1999), the authors followed the methodology proposed by Caballero and Lyons (1988). They concluded that there is no substantial evidence of an externality in the Mexican manufacturing sector. In contrast, in this study we found other measures of external effects to individual industries that show significant evidence and that make us recalculate our estimates of market power and increasing returns.

Appendix A

Food and beverages are industries 11 to 22 in the National Account Systems of INEGI (Meat and Dairy, Fruit and Vegetables, Wheat Grinding, Corn Grinding, Coffee, Sugar, Oil and Fat, Animal Food, Other Food Products, Alcoholic Beverages, Beer and Beverages).

Wood includes industries 29 and 30 (Wood and Wood Products).

Machinery and Equipment includes industries 51, 52, 54, and 55 (Non- Electrical Machinery, Electrical Machinery, Electronic Instruments, and Electric Instruments).

Basic Metals includes industries 46 and 47 (Primary Iron Metals and Primary Non-Iron Metals).

Glass and Cement includes industries 43 and 44 (Glass and Glass Products and Cement).

Chemical includes industries 35, 37, 38, 39, 40, 41, and 42 (Basic

[21] See Castañeda (1988)
[22] See Castañeda and Garduño (1999).

Chemicals, Synthetic Resins, Pharmaceutical Products, Soaps and Detergents, Other Chemical Products, Rubber Products, and Plastic Products).

Paper includes industries 31 and 32 (Paper Products and Printing/Publishing).

Textiles includes industries 24, 25, 26, 27, and 28 (Soft Fiber Textiles, Resilient Fiber Textiles, Other Textile Products, and Apparel).

Metal products includes industries 48, 49, and 50 (Metal Furniture, Fabricated Metals, and Other Metal Products).

Transport equipment includes industries 56, 57, and 58 (Automobiles, Autoparts, and Transport Equipment).

Appendix B

The profits for a firm with market power are given by the following expression

$$\Pi = P\big(F(K,L)\big)F(K,L) - wL - rK,$$

where $P(\bullet)$ represents the inverse demand function.

The necessary first order condition is

$$P'F_L F + PF_L - w = 0,$$

with P' representing the derivative of the inverse demand function and F_L the partial derivative of the production function with respect to labor input.

Rearranging the last expression we get

$$PF_L\left(1 - \frac{1}{\varepsilon}\right) = w,$$

with ε representing the absolute value of the firm's elasticity of demand. Thus

$$F_L = \frac{w}{P}\left(\frac{\varepsilon}{\varepsilon - 1}\right).$$

Being C' the firm's marginal cost, it's well known that

$$\frac{P}{C'} = \left(\frac{\varepsilon}{\varepsilon - 1} \right)$$

denoting the markup as β, it follows that

$$F_L = \frac{w}{P}\left(\frac{P}{C'} \right) = \frac{w}{P}\beta$$

which is the expression in the text.

Appendix C

Output was obtained from the statistics for sectoral GDP published by INEGI in the National System Accounts for the period of 1971 to 1991. We used data at constant and nominal prices. These data were adjusted for indirect taxation and subsidies. The sectoral price deflator (p) was obtained by combining the real and nominal data. The sources for labor data were the statistics on employment published by INEGI. From the sectoral employment data we inferred the yearly hours by assuming that each worker would work 40 hours per week with two weeks of holidays per year. This methodology appears arbitrary, however it appears to be the only available methodology. Labor income was obtained from the National Accounts System published by INEGI. The average wage (W) is calculated from the ratio of labor income to yearly hours. The data on capital assets were taken from the publications by Banco de México. In its estimates, the Central Bank uses the methodology of perpetual inventories, which appears to be a reasonable way of estimating the capital assets.

The sources for public capital assets –highways and electricity– were the Presidential Report (several years), the Mexican Historic Statistics published by INEGI, and the Federal Electricity Commission's annual report (several years). We used the total kilometers in federal and local highways –including rural ways and toll ways– to calculate the assets of highways infrastructure. Regarding the infrastructure in electricity the data was built considering the annual installed capacity in generation, distribution and transmission.

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