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NAFTA'S IMPACT ON THE MEXICAN AUTOMOTIVE SECTOR

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The findings discussed here are the outcome of continuing research on the Mexican automotive industry and include data for several years during which the NAFTA was in effect. Key results include strong evidence of constant returns to scale in both the automotive industry as a whole as well as the vehicle assembly industry and a finding that the period after NAFTA was implemented has been associated with lower production costs. In addition, these data support the conclusion that capital, labor, and foreign intermediate goods are all substitutes for one another, as are capital and domestic intermediate goods, but that labor and domestic intermediate goods are complements. While evidence was found to suggest some increased responsiveness in domestic markets to both foreign and domestic input prices, other results give reason for concern about continuing market impediments in Mexico.

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JEL classification: C22, C32, F14

1. INTRODUCTION

The Mexican automotive industry is a crucial part of the Mexican economy, in 1999 contributing over one percent of its gross domestic product, over six percent of its manufacturing output, nearly 50,000 jobs in the industry, and 300,000 employment opportunities indirectly connected with industry production.[1] In addition, the industry is an important exporter for Mexico, with about 87 percent of its output exported, of which approximately 90 percent goes to the United States. In 1999, industry exports were over $15 billion, accounting for more than 11% of Mexico's foreign sales.[2] In fact, as one

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[1] BANAMEX-ACCIVAL, March 2000, p. 117.

[2] See BANAMEX-ACCIVAL (April 2002, p. 146; and March 2000, p. 117). The historical importance of the Mexican motor vehicle industry as both a potential source as well as a user of foreign exchange is implied by the various "decretos" directed toward the goal of these firms exporting more of their output and/or being less

domestic source recently commented regarding the auto industry:

> *Its export potential and the nature of its product (high unit value and sensitivity to the credit costs) make this industry not just an object of analysis in itself but also a useful element as an indicator of economic activity, at both an aggregate and a regional level.*[3]

The publication goes on to state that at the national level, the correlation coefficient between auto sales and GDP between 1994 and 2002 was .9.[4] In Mexico, the motor vehicle industry consists of seven automobile and light truck manufacturers, including BMW, Daimler-Chrysler, Ford, General Motors, Honda, Nissan, and Volkswagen.[5] In early 2000, the industry had thirteen assembly plants for automobiles and light and commercial motor vehicles, as well as five plants for trucks and heavy-duty vehicles.[6]

In recent years, the Mexican automotive industry has been affected by globalization pressures and opportunities, particularly since the initial implementation of the North American Free Trade Agreement (NAFTA) in 1994. Ironically, while most of the Mexican domestic production is exported, the majority (by a small percentage) of domestic sales are *imported* vehicles.[7] Moreover, the impact of globalization initiatives is likely to increase as Mexican-based assembly plants can import parts duty-free from North America beginning in 2004 and from Europe in 2007.[8]

In an earlier paper (Truett and Truett (1996)), the authors estimated translog cost functions for the Mexican motor vehicle and autoparts industries, finding evidence of economies of scale for the motor vehicle industry but results consistent with diseconomies of scale for the autoparts industry.[9] They argued in that study that the findings with respect to the autoparts industry may have reflected X-inefficiency and also noted the conclusions of a Booz Allen & Hamilton and INFOTEC study (Booz Allen & Hamilton and INFOTEC (1987), p. 51; and Truett and Truett (1996), p. 441) that many of the exports of autoparts from Mexico were of low or outdated technology and internationally competitive only because of low-cost Mexican labor. However, the

dependent on imports. See *(Diario oficial* (1962, 1983, 1989, and 1990)), for example.

[3] Banco Nacional de México, S.A., June 2003, p. 244.

[4] *Ibid*, p. 245.

[5] BANAMEX-ACCIVAL, April 2002, p. 146.

[6] BANAMEX-ACCIVAL, March 2000, p. 117.

[7] In 2001, imported vehicles were 52% of wholesale and 51.5% of retail sales, respectively. See BANAMEX-ACCIVAL, April 2002, p. 148.

[8] See *North American Free Trade Agreement* (p. 3-A-4 to 3-A-12) and <www.mex-i-co.com/industries/autovrvu.htm>.

[9] In an earlier study using Mexican panel data from 1984-1990, Tybout and Westbrook (1995) found evidence of increasing returns to scale, although their estimated values of the returns to scale coefficient declined to approximately 1.02 as output increased in the transportation equipment industry.

exports of the smallest firms were in general of intermediate-level technology and world-class levels of competitiveness.

Data for 2001 and 2002 show that the vehicle assembly sector accounts for approximately fifty percent of the value added at current prices for the Mexican automotive industry. The valued added of the autoparts industry is approximately 46 percent of total value added, and rubber products make up the remaining approximately four percent. The largest output by value of the autoparts industry consists of motors and their parts, followed by parts for the electrical systems. Parts for suspension systems, brake systems, and bodies and trailers constitute much smaller segments of the autoparts industry. The production of tires and inner tubes accounts for the largest percentage of the rubber products branch of the industry.[10]

The earlier paper separated inputs into only three categories: capital, labor, and intermediate goods, and utilized data from 1970-1990. In contrast, sufficient data were available for this study to additionally divide the intermediate goods category into domestic and imported products and to extend the time period through 1997, thus including four years during which NAFTA was in effect. The impact of NAFTA in those later years was investigated through the use of a dummy variable with a value of one from 1994 onward. The economies of scale issue is revisited, along with the direct price and cross price elasticities of demand for the now four inputs included in the present study.[11] Another feature of the present work is the use of a bootstrap procedure to examine the statistical significance of the mean elasticity estimates as well as the possibility that these estimates changed by a statistically significant amount between the initial period and the final period in the study.[12] Because of the difficulty in obtaining all of the necessary data for the autoparts industry in isolation, cost functions were estimated for both the vehicle assembly industry by itself and the automotive industry as a whole, which includes the autoparts industry as a component.

The next section of the paper briefly summarizes the properties of the translog cost function. Section III examines the findings of the study, and Section IV concludes.

2. THE TRANSLOG COST FUNCTION

[10] Instituto Nacional de Estadística, Geografía e Informática, *La industria automotriz en México: edición 2003*, "Resumen," p. 1, and Cuadro 2.1.1.

[11] Other recent studies of economies of scale in the automotive industry in other countries include the Australian Industry Commission (1990, p. 19); Fuss and Waverman (1992, p. 122); Gros-Pietro and Rolfo (1989, p. 497-501); Tybout, de Melo, and Corbo (1991, p. 248); and Westbrook and Tybout (1993), p. 103-104).

[12] See (Eakin *et al*. (1990)) and (Kerkvliet and McMullen (1997)) for a discussion of the bootstrap procedure.

The production technology of the automobile industry is assumed to be representable by an implicit transformation function:

$$\tau(Y, K, L, D, F, T) = 0, \tag{1}$$

where Y is real output, K is capital, L is labor, D is domestically produced intermediate goods, F is imported intermediate goods, and T represents time-related components, including technological change.[13] If the transformation function in (1) has a strictly convex input structure, there exists a unique cost function

$$TC = f(Y, P_K, P_L, P_D, P_F, T), \tag{2}$$

where P_K is the price of capital, P_L is the price of labor, P_D is the price of domestically produced intermediate goods, and P_F is the price of imported intermediate goods.

The exact cost function specified in (2) can be approximated with the translog cost function[14]

$$\begin{aligned} \ln TC = \alpha_0 + \alpha_T T + \alpha_Y \ln Y + (1/2)^{\delta}{}_{YY} (\ln Y)^2 + \sum_i \beta_i \ln P_i \\ +1/2 \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \sum_i \rho_{yi} \ln Y \ln P_i \\ + \sum_i \gamma_{it} T \ln P_i + 1/2\, \gamma_{TT}\, T^2, \end{aligned} \tag{3}$$

where $i, j = K, L, D,$ and F.

This function has one neutral scale parameter, six first order parameters $(\alpha_{Tj}, \alpha_{\hat{y}}, \beta_{\hat{i}}),$ and twenty second order parameters.[15] The parameters of the translog cost function (3) can be estimated indirectly by estimating the coefficients of the cost share

[13] See Binswanger (1974a, p. 380; and 1974b, p. 967-969); Caves, Christensen, and Tretheway (1984, footnote 5, p. 473); and Kohli (1991, p. 103-106) for a discussion of the technological change variable.

[14] In the form of a Taylor series with an omitted remainder, translog cost functions can provide a local, second-order approximation to an arbitrary cost function. An advantage of the translog cost function is that it contains fewer parameters than some other flexible functional forms, such as the extended generalized Cobb-Douglas. (See Christensen, Jorgenson, and Lau (1973); Caves, Christensen, and Tretheway (1980); and Guilkey, Lovell, and Sickles (1983), for a discussion of the translog and other flexible functional forms.)

[15] Technically, the estimation of this cost function requires that input markets be perfectly competitive. Although many of the input markets relevant to this study are not perfectly competitive, administered or negotiated prices (such as union wage rates) that do not change frequently in response to volume changes can perform a similar role for estimation purposes.

equations, S_i, where

$$S_i = \beta_{\hat{i}} + \rho_{yI} \ln Y + \sum_i \gamma_{ij} \ln P_j + \gamma_{iT}\ T, \tag{4}$$

and $i, j = K, L, D, F$.[16]

The minimum requirements for the cost function to describe a "well-behaved" technology are that it be (1) linearly homogeneous in input prices, (2) positive and monotonically increasing in input prices and output, and (3) concave in input prices.[17] The restrictions imposed on the parameters by the requirement that the cost function be linearly homogeneous in factor prices allow the translog cost function to be written so that only twenty parameters must be estimated.[18]

[16] The principal advantages of using a translog cost function such as Equation (3) over a translog production function are found in the following features of the cost function: (1) the partial derivatives of a cost function with respect to input prices yield the corresponding input demand functions (Shephard's Lemma), (2) it follows from (1) and the definition of elasticity that the partial derivative of the cost function in logarithmic form with respect to factor prices yields the cost shares, and (3) the partial derivative of the cost function in logarithmic form with respect to output yields the cost elasticity with respect to output level. See Binswanger (1974a, p. 377) for a discussion of additional advantages of estimating a cost function rather than a production function.

[17] These assumptions require the following restrictions on its parameters:

(1) linearly homogeneous in input prices:

$\sum_i \beta_i = 1, \sum_i \rho_{\hat{i}j} = 0,\ \sum_i \gamma_{\hat{i}T} = 0,$ and $\sum_i \gamma_{ij} = 0$ for all j,

where $i, j = K, L, D, F$;

(2) monotonically increasing in input prices and output:

$\frac{\partial \ln TC}{\partial \ln P_i}$ and $\frac{\partial \ln TC}{\partial \ln y} > 0,$ and

(3) concavity in input prices.

A sufficient condition for concavity of the cost function is that the Hessian matrix of second partial derivatives with respect to factor prices is negative semidefinite.

Also, γ_{ij} must equal γ_{ji}.

[18] As a result of the linearly homogeneous in prices assumption,

$\beta_F = (1 - \beta_K - \beta_L - \beta_D),$

$\gamma_{FF} = [(1/2)\ \gamma_{KK} + (1/2)\ \gamma_{LL} + (1/2)\ \gamma_{DD} + \gamma_{KL} + \gamma_{KD} + \gamma_{LD}],$

$\gamma_{KF} = -(\gamma_{KK} + \gamma_{KL} + \gamma_{KD}),$

$\gamma_{LF} = -(\gamma_{KL} + \gamma_{LL} + \gamma_{LD}),$

$\gamma_{DF} = -(\gamma_{KD} + \gamma_{LD} + \gamma_{DD}),$

$\rho_{yF} = -(\rho_{yK} + \rho_{yL} + \rho_{yD}),$

$\gamma_{FT} = -(\gamma_{KT} + \gamma_{LT} + \gamma_{DT}).$

The additional assumption of a homothetic production function would require that the $\rho_{\hat{y}I}$ terms equal zero, and the more restrictive assumption of homogeneity would require that $\delta_{\hat{y}y}$ also equal zero.[19] The number of parameters to be estimated in the cost share equations can be similarly reduced.

Moreover, $S_F = 1 - S_L - S_K - S_D$. Only three of the factor share equations are linearly independent, since their sum must be equal to one. The assumption of a homogeneous production function was maintained in this study because of the limited number of available data points as well as the earlier finding that the null hypothesis that the additional restrictions corresponding to this functional form were appropriate was not rejected (Truett and Truett (1996), p. 434).

Given the homogeneity restrictions, the three factor share equations, S_K, S_L and S_D, have twelve free parameters. Inclusion of the translog cost function (3) in the model to be estimated would add four more parameters, $\alpha_{\hat{0}}, \alpha_{\hat{T}}, \alpha_{\hat{y}}$, and γ_{TT}.[20] Separate stochastic error terms, assumed to reflect errors in optimizing behavior, are implicitly added to the cost and share equations. Time series data from 1970 through 1997 were utilized in the study.[21]

[19] See Christensen and Greene (1976, p. 661). A cost function corresponds to a homothetic production function if and only if the former function is separable with respect to output and the input prices. A homogeneous production function also requires that the elasticity of cost with respect to output be constant.

[20] If the data are normalized so that total cost, the output quantities, and the input prices are equal to one in the base period and *if the translog cost function is exact*, the logarithm of $\alpha_{\hat{0}}$ is equal to zero. In this case, the addition of the translog cost function to the set of equations to be estimated increases the number of observations and adds only four parameters to be estimated. See Burgess (1975, p. 110). Although this normalization procedure was followed in the present study, the estimated translog cost function was not assumed to be exact. Thus $\alpha_{\hat{0}}$ is not necessarily equal to zero.

[21] The following data were used in estimating the total cost function. Total cost was equal to the value added of each industry (entire automotive industry and the vehicle assembly industry, respectively) plus payments for intermediate goods less (indirect taxes minus subsidies) in millions of current pesos. Labor cost was given by *remuneración de asalariados*, that of capital by *excedente bruto de operación*, the cost of imports by *valor de las importaciones*, and that of domestic intermediate goods as the difference between *consumo intermedio*, again all in millions of current pesos, for each respective industry. The price of intermediate goods was given by price indices (1993 = 100) for intermediate goods unique to each industry. The price of labor was given by the average annual remuneration of employees in each respective industry. The data series utilized for the price of capital is called the "costo porcentual promedio de captación en moneda nacional," or the average cost of capitalization. The price of imported intermediate goods was given by the price index for imported intermediate goods for the metal products, machinery, and equipment industry. The data for the output were the output of each respective industry in millions of 1993 pesos. The data were normalized, with 1970 as the base year. The data sources, Instituto Nacional de Estadística, Geografía e Informática, *La industria automotriz en México* and *Sistema de cuentas nacionales de México,* International Monetary Fund, are listed

Using the SHAZAM statistical program, the cost function and share equations are estimated by using the iterative Zellner-efficient (IZEF) method [Zellner (1962) and (1963)].[22]

3. ESTIMATION RESULTS

The model was estimated for both the vehicle industry as well as the automotive industry as a whole.[23] While both models were estimated with the nonneutral time trend variables included, these versions of the models violated the regularity conditions at a substantially greater number of points, especially for the vehicle industry. Thus, a model with only the neutral time trend variables was used as the final model. These estimates did not violate the monotonicity and concavity conditions at any data point for the automotive industry as a whole and did so at only one point for the vehicle industry.[24]

The estimates for the automotive industry and the vehicle industry cost functions are presented in Tables 1 and 2, respectively.[25]

in the bibliography.

[22] Barten (1969, p. 24-25) has shown that maximum-likelihood estimates of a set of share equations less one are invariant to which equation is omitted. Kmenta and Gilbert (1968) have demonstrated that iteration of the Zellner procedure until convergence yields maximum-likelihood estimates. Ruble (1968, p. 279-286) has also shown that the IZEF and maximum likelihood methods are computationally equivalent.

[23] The model was not estimated for the autoparts industry separately because of difficulty in obtaining some of the essential data, as noted earlier.

[24] Although the concavity condition was violated at the last data point for the vehicle industry, this fact does not preclude translog estimates of the elasticities from being acceptable. See Wales (1977) and Caves and Christensen (1980).

[25] The other model coefficients can be calculated from those reported in the table.

The conventional single-equation Durbin-Watson statistic for the total cost equation for the automotive model was 2.92, a value that was in the inconclusive range at the 5% level of significance. The coresponding Durbin-Watson statistic for the vehicle industry was 2.62, also in the inconclusive range at the 5% level of significance. See Durbin (1957), Malinvaud (1970, p. 509), and Berndt and Christensen (1973, p. 95) for a discussion of utilizing the Durbin-Watson statistic to check for serial correlation in the case of simultaneous equations.

A Lagrange multiplier test for serial correlation was also conducted on the total cost equation for each industry using lagged values of the error term ranging from one to 8 periods (see Godfrey (1988), p. 112-117; and Greene (2000), p. 540-541). The hypothesis of $\rho = 0$ could not be rejected at the 5% significance level for any of the lags for either model.

Finally, the Regression Specification Error Test (RESET) was also performed on the total cost equation for each industry using terms involving the dependent variable estimates up to the fourth power (see Maddala, p. 478). This procedure also did not indicate model misspecification at the 5% level of significance for the total cost function for either industry.

Table 1. Estimates of Automotive Industry Cost Function Parameters

Coefficient	Parameter (*t* values)
$\alpha_{\hat{0}}$	-0.042 (-0.981)
$\alpha_{\hat{T}}$	-0.026 (-3.033)
$\alpha_{\hat{T}T}$	0.005 (8.122)
$\alpha_{\hat{y}}$	1.081
$\beta_{\hat{K}}$	0.167 (12.709)
$\beta_{\hat{L}}$	0.139 (22.444)
$\beta_{\hat{D}}$	0.437 (20.933)
$\beta_{\hat{F}}$	0.257 (13.677)
$\gamma_{\hat{K}K}$	-0.004 (-1.166)
$\gamma_{\hat{L}L}$	0.049 (5.316)
$\gamma_{\hat{D}D}$	0.039 (0.548)
$\gamma_{\hat{K}L}$	0.008 (5.118)
$\gamma_{\hat{K}D}$	0.009 (1.819)
$\gamma_{\hat{L}D}$	-0.096 (-6.403)
DUM	-0.200 (-3.436)

Table 2. Estimates of Vehicle Cost Function Parameters

Coefficient	Parameter (*t* values)
$\alpha_{\hat{0}}$	0.026 (0.378)
$\alpha_{\hat{T}}$	-0.033 (-2.558)
$\alpha_{\hat{T}T}$	0.006 (6.321)
$\alpha_{\hat{y}}$	1.027
$\beta_{\hat{K}}$	0.131 (10.191)
$\beta_{\hat{L}}$	0.120 (26.815)
$\beta_{\hat{D}}$	0.697 (52.570)
$\beta_{\hat{F}}$	0.052 (7.172)
$\gamma_{\hat{K}K}$	-0.014 (-3.868)
$\gamma_{\hat{L}L}$	0.027 (5.292)
$\gamma_{\hat{D}D}$	0.009 (0.315)
γ_{KL}	0.015 (11.749)
γ_{KD}	0.005 (1.297)
γ_{LD}	-0.066 (-7.286)
DUM	-0.232 (-2.421)

The estimated coefficient of the dummy variable is negative and significantly less than zero for both industries, consistent with the hypothesis that NAFTA did have a favorable impact on industry costs. Productivity data for the industry are also consistent with this conclusion. For the automobile industry as a whole, the productivity index had risen to 127.0 (where 1993 = 100.0) by 2000. Moreover, the increase in the productivity index for the vehicle assembly sector is far more dramatic, having risen to 186.0 in 2000, again from 100.0 in 1993. However, the productivity index for the autoparts industry increased only slightly over this time period, to 112.1 (1993 = 100.0 also).[26] The automotive industry in Mexico has been experimenting with innovative production methods, including modular assembly and lean manufacturing, and $13.6 billion in foreign direct investment came to the Mexican automotive industry between 1994 and 2000. Moreover, the Mexican automotive industry can afford to train workers for longer periods because of the relatively low wage rates, compared with its counterpart in the United States.[27]

The estimated value of $\alpha_{\hat{y}}$, the cost elasticity (E_C) in this model, for the automotive industry was 1.08. Such a figure could be indicative of diseconomies of scale, since an estimate of the output elasticity or returns to scale coefficient can be obtained from ($1/E_C$). However, this value was not significantly greater than one at even the 10 percent level of significance, thus it is consistent with constant returns to scale.

The estimated value for $\alpha_{\hat{y}}$, for the vehicle industry was approximately 1.03, which was also not significantly greater than one. Thus, these results are consistent with constant returns to scale in both the automotive industry as a whole as well as the vehicle industry. It is interesting that these results with respect to the vehicle industry were particularly robust-the null hypothesis that E_C was greater than one could only be rejected at about the 75 percent level of significance, thereby providing very strong evidence in favor of constant returns to scale.

The direct price elasticity estimates for capital, labor, domestic materials, and imported materials are given in tables A1 and A2, in the appendix. All of these elasticity estimates were negative, with the estimated values for E_{KK} and E_{FF} being higher (in absolute value) than those for labor and domestic materials for both industries. The results of the bootstrap procedures were consistent with the hypothesis that all of the direct price elasticity estimates at their mean values were significantly less than zero at the one percent level of significance for the automotive industry, and all of those estimates *except for that of* E_{FF} were similarly significantly less than zero for the vehicle industry. The result that the mean estimate of E_{FF} for the vehicle industry was not significantly less than zero is somewhat surprising, given its large (in absolute value) negative estimates in the original model. However, the variation of the bootstrapped estimates was sufficiently large that the mean value of E_{FF} for the vehicle industry was significantly less than zero at only about the 17 percent level of significance.

The bootstrap procedures also yielded the rather interesting result that the direct price elasticity estimates for labor in the case of the entire automotive industry and for both capital and labor for the vehicle industry significantly (5 percent level of significance) decreased in absolute value between 1970 and 1997. The decrease was relatively small in the case of capital, but much more substantial for labor. The latter result may reflect movement of motor vehicle production from the United States and/or

[26] See *La industria automotriz en México: edición 2003*, Cuadro 2.1.12, and the accompanying graph.

[27] "Car Power," *Business Week*, October 23, 2003, p. 72-82.

other countries to Mexico, and, as a result, rising Mexican wage rates and the appearance of less sensitivity of employment to wage rates. It is interesting to note in tables A1 and A2 that the estimates for E_{LL}, particularly, dropped after 1994, the year the NAFTA was first (partially) implemented. Moreover, the Mexican labor market is still highly regulated so that responses to price signals are muted.[28]

Table A1. Mexican Automobile Industry Direct Price Elasticities

Year	E_{KK}	E_{LL}	E_{DD}	E_{FF}
1970	-0.859	-0.507	-0.474	-1.031
1971	-0.858	-0.509	-0.479	-1.021
1972	-0.857	-0.513	-0.482	-1.021
1973	-0.857	-0.514	-0.482	-1.022
1974	-0.856	-0.522	-0.493	-1.007
1975	-0.855	-0.521	-0.495	-1.002
1976	-0.855	-0.526	-0.496	-1.009
1977	-0.857	-0.530	-0.489	-1.033
1978	-0.858	-0.532	-0.485	-1.046
1979	-0.855	-0.522	-0.491	-1.015
1980	-0.856	-0.529	-0.493	-1.020
1981	-0.855	-0.530	-0.500	-1.007
1982	-0.858	-0.534	-0.486	-1.046
1983	-0.862	-0.528	-0.462	-1.096
1984	-0.858	-0.502	-0.462	-1.058
1985	-0.855	-0.505	-0.471	-1.041
1986	-0.856	-0.485	-0.454	-1.062
1987	-0.853	-0.463	-0.457	-1.039
1988	-0.846	-0.435	-0.474	-0.990
1989	-0.843	-0.427	-0.480	-0.975
1990	-0.840	-0.416	-0.488	-0.956
1991	-0.835	-0.416	-0.503	-0.928
1992	-0.833	-0.417	-0.509	-0.917
1993	-0.832	-0.412	-0.512	-0.909
1994	-0.830	-0.408	-0.516	-0.900
1995	-0.838	-0.317	-0.476	-0.950
1996	-0.835	-0.293	-0.480	-0.937
1997	-0.831	-0.292	-0.494	-0.913

[28] See, for example, "Decade after Nafta, Prospects for Mexico Seem to Be Dimming," *Wall Street Journal*, April 2, 2003, p. 1A, 2A.

Table A2. Mexican Vehicle Industry Direct Price Elasticities

Year	E_{KK}	E_{LL}	E_{DD}	E_{FF}
1970	-0.978	-0.654	-0.291	-2.297
1971	-0.974	-0.652	-0.296	-2.171
1972	-0.972	-0.656	-0.297	-2.260
1973	-0.973	-0.654	-0.291	-2.367
1974	-0.969	-0.657	-0.303	-2.212
1975	-0.967	-0.659	-0.308	-2.178
1976	-0.964	-0.661	-0.300	-2.515
1977	-0.959	-0.660	-0.295	-2.857
1978	-0.959	-0.662	-0.292	-3.180
1979	-0.957	-0.656	-0.297	-2.568
1980	-0.958	-0.656	-0.297	-2.517
1981	-0.956	-0.659	-0.311	-2.272
1982	-0.957	-0.660	-0.293	-2.981
1983	-0.956	-0.656	-0.267	-6.321
1984	-0.942	-0.633	-0.271	-3.444
1985	-0.932	-0.629	-0.278	-3.157
1986	-0.931	-0.622	-0.260	-5.313
1987	-0.914	-0.577	-0.262	-3.753
1988	-0.887	-0.558	-0.295	-2.511
1989	-0.875	-0.550	-0.300	-2.560
1990	-0.867	-0.528	-0.308	-2.348
1991	-0.853	-0.473	-0.317	-2.156
1992	-0.845	-0.490	-0.332	2.034
1993	-0.844	-0.481	-0.330	-2.044
1994	-0.839	-0.460	-0.335	-1.979
1995	-0.857	-0.375	-0.298	-2.302
1996	-0.848	-0.250	-0.294	-2.339
1997	-0.834	-0.166	-0.309	-2.128

The estimated input cross price elasticities of demand for the automotive and vehicle industries are presented in tables 3A and 4A, respectively. These results are generally consistent with the hypothesis that all of the input pairs are substitutes except for labor and domestic intermediate goods for both industries.[29] According to the bootstrap procedure results, all of the mean cross price elasticity estimates *except for E_{LD} and E_{DL}* were significantly greater than zero at about the 2.5 percent level of significance for the automotive industry as a whole. While the estimated values for E_{LD} and E_{DL} suggested a

[29] In the case of the vehicle industry, a few of the data points yielded negative estimates for E_{KF} and E_{FK} also.

complementary relationship between labor and domestic intermediate goods, they were significantly less than zero at only about the 17 percent level of significance.

Table A3. Mexican Automobile Industry Cross Price Elasticities

Year	E_{KL}	E_{LK}	E_{KD}	E_{DK}	E_{KF}	E_{FK}
1970	0.190	0.228	0.490	0.188	0.179	0.116
1971	0.190	0.228	0.483	0.189	0.184	0.118
1972	0.194	0.227	0.480	0.189	0.184	0.118
1973	0.200	0.227	0.480	0.189	0.183	0.118
1974	0.199	0.226	0.464	0.192	0.192	0.121
1975	0.203	0.227	0.462	0.192	0.194	0.122
1976	0.208	0.225	0.461	0.192	0.191	0.121
1977	0.210	0.222	0.471	0.190	0.178	0.118
1978	0.200	0.220	0.476	0.189	0.172	0.115
1979	0.206	0.227	0.468	0.192	0.188	0.121
1980	0.207	0.224	0.464	0.192	0.185	0.120
1981	0.212	0.225	0.456	0.193	0.192	0.122
1982	0.207	0.220	0.475	0.189	0.172	0.115
1983	0.186	0.219	0.507	0.184	0.148	0.107
1984	0.187	0.230	0.505	0.188	0.167	0.115
1985	0.187	0.232	0.492	0.191	0.175	0.119
1986	0.177	0.236	0.514	0.189	0.165	0.115
1987	0.166	0.245	0.509	0.192	0.177	0.121
1988	0.155	0.257	0.487	0.199	0.204	0.131
1989	0.152	0.262	0.478	0.202	0.213	0.135
1990	0.148	0.267	0.468	0.205	0.224	0.139
1991	0.147	0.271	0.447	0.211	0.241	0.146
1992	0.147	0.272	0.438	0.213	0.248	0.149
1993	0.145	0.275	0.434	0.214	0.253	0.150
1994	0.144	0.277	0.428	0.216	0.258	0.152
1995	0.127	0.289	0.483	0.206	0.228	0.142
1996	0.123	0.296	0.476	0.209	0.236	0.145
1997	0.122	0.300	0.458	0.214	0.251	0.151

Table A3 Con't. Mexican Automobile Industry Cross Price Elasticities

Year	E_{LD}	E_{DL}	E_{LF}	E_{FL}	E_{DF}	E_{FD}
1970	-0.257	-0.082	0.536	0.290	0.368	0.625
1971	-0.258	-0.084	0.538	0.288	0.374	0.614
1972	-0.246	-0.083	0.532	0.291	0.375	0.611
1973	-0.242	-0.082	0.530	0.292	0.374	0.611
1974	-0.232	-0.084	0.527	0.294	0.386	0.592
1975	-0.237	-0.086	0.531	0.292	0.389	0.588
1976	-0.218	-0.082	0.519	0.299	0.386	0.589
1977	-0.193	-0.073	0.501	0.309	0.372	0.606
1978	-0.180	-0.068	0.492	0.315	0.364	0.616
1979	-0.227	-0.082	0.523	0.296	0.381	0.598
1980	-0.206	-0.078	0.510	0.304	0.380	0.596
1981	-0.210	-0.082	0.515	0.301	0.389	0.583
1982	-0.177	-0.068	0.490	0.316	0.365	0.614
1983	-0.167	-0.058	0.477	0.326	0.335	0.664
1984	-0.257	-0.078	0.529	0.294	0.352	0.649
1985	-0.260	-0.081	0.533	0.291	0.362	0.631
1986	-0.299	-0.082	0.548	0.286	0.348	0.660
1987	-0.364	-0.094	0.583	0.270	0.359	0.648
1988	-0.460	-0.113	0.637	0.247	0.387	0.611
1989	-0.487	-0.120	0.653	0.241	0.398	0.598
1990	-0.525	-0.128	0.674	0.234	0.410	0.583
1991	-0.543	-0.139	0.689	0.227	0.431	0.555
1992	-0.550	-0.144	0.695	0.225	0.440	0.543
1993	-0.567	-0.148	0.705	0.222	0.446	0.538
1994	-0.581	-0.153	0.713	0.219	0.453	0.529
1995	-0.743	-0.140	0.771	0.212	0.410	0.596
1996	-0.804	-0.147	0.800	0.205	0.418	0.587
1997	-0.822	-0.156	0.814	0.200	0.436	0.563

Table A4. Mexican Vehicle Industry Cross Price Elasticities

Year	E_{KL}	E_{LK}	E_{KD}	E_{DK}	E_{KF}	E_{FK}
1970	0.232	0.254	0.733	0.138	0.013	0.033
1971	0.228	0.258	0.727	0.140	0.019	0.044
1972	0.231	0.255	0.725	0.141	0.016	0.039
1973	0.230	0.257	0.732	0.141	0.012	0.031
1974	0.232	0.255	0.719	0.143	0.018	0.044
1975	0.233	0.254	0.713	0.145	0.020	0.048
1976	0.235	0.253	0.721	0.146	0.008	0.025
1977	0.231	0.257	0.726	0.149	0.001	0.004
1978	0.234	0.255	0.729	0.149	-0.004	-0.019
1979	0.225	0.263	0.723	0.150	0.008	0.026
1980	0.225	0.263	0.723	0.150	0.009	0.029
1981	0.229	0.260	0.709	0.151	0.018	0.047
1982	0.230	0.259	0.728	0.150	-0.001	-0.004
1983	0.224	0.264	0.754	0.151	-0.023	-0.244
1984	0.199	0.295	0.748	0.159	-0.005	-0.028
1985	0.193	0.305	0.740	0.165	-0.000	-0.001
1986	0.189	0.312	0.758	0.166	-0.016	-0.156
1987	0.165	0.357	0.754	0.177	-0.005	-0.032
1988	0.151	0.389	0.717	0.196	0.018	0.076
1989	0.146	0.402	0.711	0.204	0.018	0.081
1990	0.139	0.423	0.702	0.211	0.025	0.102
1991	0.127	0.468	0.693	0.221	0.034	0.125
1992	0.127	0.464	0.677	0.228	0.041	0.140
1993	0.126	0.470	0.678	0.228	0.041	0.140
1994	0.121	0.487	0.672	0.232	0.045	0.149
1995	0.117	0.525	0.712	0.218	0.028	0.113
1996	0.106	0.604	0.715	0.225	0.027	0.117
1997	0.098	0.663	0.699	0.236	0.037	0.142

Table A4 Con't. Mexican Vehicle Industry Cross Price Elasticities

Year	E_{LD}	E_{DL}	E_{LF}	E_{FL}	E_{DF}	E_{FD}
1970	0.147	0.025	0.252	0.575	0.127	1.689
1971	0.133	0.023	0.260	0.532	0.133	1.594
1972	0.151	0.027	0.250	0.565	0.129	1.656
1973	0.149	0.026	0.249	0.598	0.125	1.738
1974	0.154	0.028	0.248	0.552	0.132	1.617
1975	0.159	0.030	0.246	0.543	0.134	1.587
1976	0.178	0.033	0.230	0.655	0.121	1.834
1977	0.179	0.033	0.224	0.767	0.112	2.086
1978	0.192	0.036	0.215	0.877	0.107	2.322
1979	0.154	0.027	0.238	0.666	0.119	1.876
1980	0.152	0.027	0.241	0.649	0.121	1.839
1981	0.157	0.029	0.242	0.574	0.130	1.651
1982	0.179	0.033	0.222	0.807	0.110	2.177
1983	0.183	0.031	0.209	1.921	0.085	4.644
1984	0.077	0.011	0.261	0.937	0.101	2.536
1985	0.053	0.007	0.271	0.838	0.106	2.319
1986	0.046	0.006	0.264	1.557	0.088	3.912
1987	-0.109	-0.012	0.328	1.016	0.097	2.769
1988	-0.201	-0.021	0.370	0.599	0.121	1.836
1989	-0.229	-0.024	0.377	0.613	0.120	1.866
1990	-0.303	-0.030	0.407	0.539	0.127	1.707
1991	-0.466	-0.040	0.471	0.468	0.136	1.563
1992	-0.433	-0.040	0.460	0.431	0.144	1.463
1993	-0.459	-0.041	0.469	0.432	0.143	1.471
1994	-0.520	-0.045	0.493	0.409	0.147	1.421
1995	-0.710	-0.048	0.560	0.504	0.128	1.685
1996	-1.032	-0.057	0.677	0.507	0.126	1.715
1997	-1.260	-0.063	0.763	0.435	0.136	1.552

For the vehicle industry, the mean cross price elasticity estimates of E_{KL}, E_{LK}, E_{KD}, and E_{DK} were significantly greater than zero at the one percent level of significance, while those for E_{LF} and E_{DF} were significantly greater than zero at about the 10 percent level of significance, and those for E_{FL} and E_{FD} at somewhat less that the 20 percent level of significance. The estimated values for E_{LD} and E_{DL} were negative from 1987 onward, consistent with a complementary relationship. However, given that these estimates decreased from positive to negative over the study period, it is not surprising that the mean estimated values of these cross price elasticities were not significantly different from zero at any reasonable level of significance. Similarly, the mean elasticity estimates for E_{KF} and E_{FK} were also not significantly different from zero for the vehicle industry.

The path of these cross price elasticity values over time is also interesting. The bootstrap procedure yielded the result that the estimated values of E_{KL} *decreased* while those of E_{LK} *increased* significantly at the one percent level of significance between 1970 and 1997 for both the entire automotive industry as well as the vehicle assembly industry. The estimated value of E_{DK} also increased significantly over the period for the vehicle assembly industry, but its value increased only at about the 13 percent level of significance for the automotive industry as a whole. These results would lend some support to the hypothesis that the quantities demanded of the domestic inputs of labor and nationally produced intermediate goods have become more sensitive to changes in the price of capital.

The values of E_{KF} and E_{FK} for the automotive industry also increased significantly over the study period, a finding that is consistent with the hypothesis that the quantities demanded of both domestic capital and foreign intermediate goods have become more responsive to a change in the other input's price. However, the value of E_{FK} increased significantly at only about the 17 percent level of significance for the vehicle assembly industry, and that of E_{KF} at a much lower level of significance. While casual observation would lead one to conclude that these values had increased over time for the assembly industry, the variation in the bootstrapped estimates was simply too high to lend statistical credibility to such a conclusion. Nevertheless, such an increasing responsiveness on the part of capital and foreign intermediate goods still may in fact be developing in the assembly industry as well as for the automotive industry as a whole.

On the other hand, the estimated values of E_{LD} and E_{DL} decreased significantly at the 0.5 percent level of significance between 1970 and 1997 for both industries, and E_{FL} did so for the entire automotive industry. These findings suggest that domestic labor and intermediate products are becoming less close substitutes for one another or, stated differently, developing a more complementary relationship. These results also are consistent with a hypothesis that a change in the price of labor is having a smaller impact on the demand for foreign intermediate goods for the automotive industry now than in 1970. If barriers to imported components are falling in Mexico, one would expect to see the opposite finding. Perhaps the relationship between foreign intermediate products and labor may also be becoming more complementary in nature over time or, alternatively, it may indirectly reflect some restrictions on adjusting domestic employment levels to changes in the price of labor (note the declining estimates of E_{LL} in the later years of the study).

In contrast, the estimated values of E_{LF} *increased* significantly for both industries as did the value of E_{DF} for the automotive industry.[30] These latter results suggest that a

[30] However, the level of significance for E_{LK} for the vehicle assembly industry was only about 9 percent as was that of E_{DF} for the automotive industry as a whole.

change in the price of foreign intermediate goods has a larger impact now on the demand for domestic inputs, particularly in the case of the automotive industry as a whole, than it did in 1970. These findings are consistent with what we would expect to find as Mexico reduces its protection of the domestic automotive industry from foreign competitors. However, the estimates of E_{FD} for both industries and that of E_{FL} for the assembly industry did not change by a statistically significant amount over the period of study. Thus, while there appears to be an increasing responsiveness on the part of the quantities demanded of domestic inputs to the price of foreign component parts during the period of study, especially for the automotive industry as a whole, the same cannot be said for the corresponding relationship between the demand for foreign intermediate products and the prices of domestic labor and intermediate goods.[31]

4. CONCLUSION

The findings of this study are consistent with the hypothesis that the implementation of NAFTA has resulted in a statistically significant decline in costs for both the entire automotive industry and the vehicle assembly industry. They also strongly support the hypothesis of constant returns to scale in both industries.

The mean estimates of the direct price elasticities of demand are significantly less than zero for all of the inputs for both industries, except for E_{FF} in the vehicle assembly industry. However, the estimates of E_{LL} for both industries and E_{KK} for the assembly industry increased significantly (decreased in absolute value) over the period of study, a finding that is certainly contrary to what one would expect if the domestic input markets are becoming more competitive. As discussed above, one possible explanation of these findings is that they reflect a shifting of motor vehicle production from the United States to Mexico in the wake of NAFTA. One result may be a corresponding positive impact on domestic input prices, and an appearance that the demand for domestic capital and labor was becoming less sensitive to domestic input prices. While a dummy variable was inserted for the years NAFTA was in effect, it may not have completely captured all of the effects of the agreement. An abundance of labor market restrictions and regulations may also have been at least partly responsible for these results.

The findings of this study are consistent with the conclusion that all of the inputs are substitutes for one another, with the exception of labor and domestic intermediate goods. These latter two inputs had a statistically significant complementary relationship throughout the study period in the automotive industry as a whole and an apparently complementary relationship in the later years for the assembly industry.

The result that E_{LK} and E_{DK} increased significantly between 1970 and 1997 lends some support to the hypothesis of greater flexibility in the domestic input markets, at

[31] E_{FL} actually decreased significantly in the case of the entire automotive industry.

least with respect to the price of capital.[32] The finding that E_{KF}, E_{FK}, E_{LF}, and E_{DF} also increased significantly for one or both industries suggests that the demand for domestic inputs may also be becoming more sensitive to the prices of foreign components. Although to some extent painful in the short run, especially with respect to labor, a reduction in the rigidities present in Mexico's domestic input markets would be expected to enhance its long-run international competitiveness and, therefore, its economic growth. While the international auto manufacturers have not yet indicated intentions to move production eastward, some industries in Mexico are currently feeling the pressure of competition from China. For example, in 2003, an assembly line worker from Guadalajara earned about five times as much as a similar employee in Guangdong, China, so Mexico clearly can no longer be internationally competitive based on low wage rates alone.[33] Still, there is reason to be concerned about remaining market impediments in Mexico, as illustrated by the finding that E_{KL} *decreased* over the study period. In fact, Delphi Corporation, one of the largest manufacturers of auto parts, announced in 2004 that it would shut down its wire-harness factory in Chihuahua because its labor costs were too high and it could not reach an agreement with the union to reduce wage rates.[34]

The complementary relationship between labor and domestic intermediate goods means that any stimulus to the demand for one of these inputs will also be a boon to the other. A complementary relationship between foreign component parts and domestic inputs would be very helpful to Mexico in the presence of falling foreign prices, but the data do not support such a finding.

The result that NAFTA has been correlated with lower costs in the automotive sector may mean that the agreement has pushed Mexico to become more internationally competitive just in time, before the pressures on its markets from other countries become even more intense. Nevertheless, warning signs are appearing on the horizon that Mexico dare not rest on past achievements and become complacent in its efforts to continually improve the flexibility of its domestic markets and its international competitiveness.

[32] However, E_{DK} increased significantly only at the 13 percent significance level for the entire automotive industry.

[33] "Wasting Away," *Business Week*, June 2, 2003, p. 42-43.

[34] See "GM's Delphi to Shut Mexican Plant," *San Antonio Express-News*, January 29, 2004, p. 2E. Also see "Decade After Nafta, Prospects for Mexico Seem to be Dimming," *op. cit.*

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