

Did NAFTA Really Cause Mexico's High Maquiladora Growth?

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I. Introduction

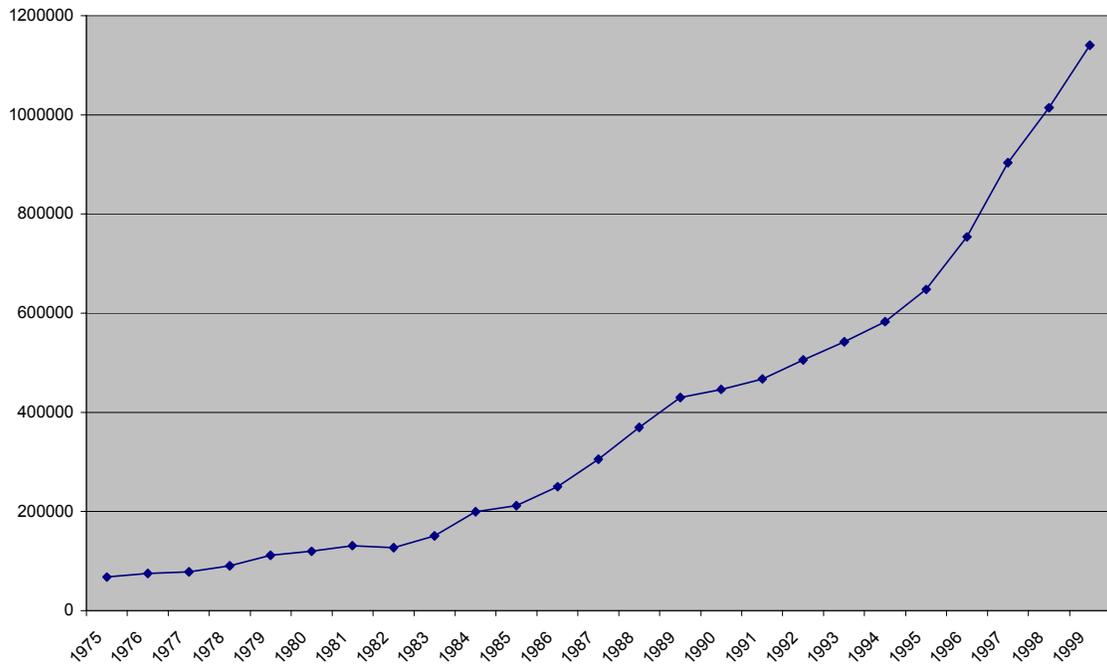
Among Mexico's most striking industrial phenomena in the wake of the North American Free Trade Agreement has been the rapid growth of in-bond plants that operate under the country's *maquiladora* program.¹ Under its simplest organizational form, a maquiladora plant imports inputs in-bond from the United States, processes them in some way, and then ships them back to the United States – perhaps for more processing. The maquiladora program itself permits the inputs and the machinery used to process them to enter Mexico without payment of import tariffs. On the return to the United States, the shipper pays only such U.S. import duties as are applicable to the value added by manufacture in Mexico.²

Although maquiladoras have been in operation in Mexico since the 1960s, their output and employment growth began to accelerate rapidly with the advent of NAFTA. Over the first five years after the onset of NAFTA, maquiladora employment grew 86 percent, compared with 47 percent growth over the five years previous. Seeing this sudden acceleration (Chart I), opponents, supporters and academic researchers of the North American Free Trade Agreement have argued that NAFTA was the cause. Balla (1998, 55), for example claims that “without doubt, NAFTA has resulted in a dramatic increase in activity in the maquiladora industry.” San Martin (2000, 32A) maintains that “NAFTA continues to drive the growth of the maquiladora industry.” Carrada-Bravo (1998, 8) argues that “the acceleration of foreign direct investment under NAFTA also

¹ Within the maquiladora industry and more generally along the U.S.-Mexico border, the terms *in-bond plant*, *maquila*, *maquiladora*, *maquiladora de exportación*, and *twin plant* are treated as synonymous. I accordingly bestow upon myself the right to use these terms interchangeably.

² Note that the return trip is not under the jurisdiction of the maquiladora program. The tariff arrangements involve U.S. law, not Mexican law, but treaties that affect both are an important focus of this paper.

Chart I
MAQUILADORA EMPLOYMENT



contributed to the creation of more than a half-million new employment opportunities in the U.S.-Mexico border region.... These new jobs, tied to the expansion of the maquiladora industry, (pay more) than those not related to international trade.” A post-NAFTA report produced jointly by the Economic Policy Institute and the United States Business and Industrial Council Educational Foundation (1997) claims that “as new and expanded plants are completed in the maquiladora zone..., the bilateral trade deficit should soar ever higher.” Even prior to NAFTA, Perot and Choate (1993) were positing that “the flow of U.S. companies voluntarily moving factories to Mexico under the Maquiladora Program threatens to become a flood under NAFTA.”³

II. Maquiladoras Are Not New, and Neither Is the Controversy Surrounding Them

Despite the concurrent opinions of commentators who otherwise typically disagree, there are at least as many reasons to suspect NAFTA did not cause the maquiladoras’ acceleration as there are to suspect it did.⁴ Certainly, Mexico’s maquiladoras have seen other episodes of sudden acceleration, even if they were not quite like the recent one.

Mexico developed the maquiladora program in response to the 1964 cancellation of a U.S. program that, starting during World War II, had admitted Mexican agricultural workers into the United States for temporary employment. Maquiladoras were supposed to provide an employment alternative in the manufacturing sector for *braceros*, the agricultural workers who had lost their jobs when the U.S. program ended.

³ Moreover, one of former presidential candidate Perot’s television props against NAFTA was a blowup of an advertisement that invited maquiladoras to locate in the southern Mexican state of the Yucatan. This, Mr. Perot said, was what NAFTA was going to bring us.

⁴ Balla and Carrada-Bravo are pro-NAFTA. Perot and Choate and the Economic Policy Institute and the United States Business and Industrial Council are anti-NAFTA.

Despite the program's history as a compensatory effort to offset job losses for Mexican agricultural workers who had been working in the United States, the maquiladora plants in Mexico became controversial in the United States as quickly as they appeared. Some commentators complained that while most of the braceros had been men, most of the newly hired maquiladora workers were women. However, the crux of the controversy was not so much jobs for women in Mexico, but jobs for anyone in Mexico.

Long before Balla (1998), Carrada-Bravo(1998), Perot and Choate (1993), and the Economic Policy Institute and the United States Business and Industrial Council Educational Foundation (1997), this controversy involved comparisons of Mexican wages with those in the United States and in developing countries. Maquiladora opponents argued that the maquiladora program facilitates efforts by U.S. and other firms to take advantage of low Mexican wages. As firms that had formerly employed low-skilled workers in the United States set up manufacturing and other operations in Mexico, maquiladora opponents argued that maquiladoras were “taking American jobs.”

Supporters of the maquiladoras argued that, regardless of where these plants actually located, the issue of where else they could have located was also relevant. According to this narrative, competitive pressures meant that if these assembly plants had not been able to locate in Mexico they would have been placed in other low-wage countries – in many cases in Asia. Indeed, it was pointed out, lower wage Asian countries had been serving as export platforms for U.S. manufacturing operations before the establishment of the maquiladoras in any case.^{5 6}

⁵ The Border Industrialization Program, under which Mexico's maquiladoras began, was introduced by Mexico's Secretary of Commerce and Industry after a trip he took to east Asia. The program was his

More to the point, the maquiladoras of Mexico reflected a broader phenomenon, the globalization of manufacturing. Although the maquiladoras were creatures of Mexican law, similar operations appeared across the globe. They were responses to reductions that have been occurring for decades in communications and transportation costs. These cost reductions facilitated the management of a far-flung network of assembly plants early on in Taiwan - later in Guatemala, Mauritius, Vietnam – whose products were to be marketed in the industrialized world in general and in the United States in particular (Grunwald and Flamm, 1985; Romer, 1992).

This globalization process was not a creature of NAFTA. If anything, NAFTA was a creature of this globalization process. If the reductions in transportation and communications costs that motivated globalization had not taken place, the political pressures that permitted NAFTA would not have been so strong.

III. If Maquiladoras Are Not New, Has Nafta Made Them Any Different?

There are reasons why NAFTA might have motivated companies starting or expanding operations in Mexico, but it is also possible that NAFTA might have discouraged maquiladora expansion or even discouraged maquiladora operations in general. On its own, NAFTA has begun to allow U.S.-Mexico production-sharing operations in the maquiladora mode, but without the maquiladora program.

By 1999 the majority of imports that used to be processed under the maquiladora program and then entered the United States could enter duty free without the reference to maquiladoras. For this majority, the Automotive Products Trade Act, and duty-free

policy response to what he saw on the trip – specifically, labor-intensive assembly operations involving east Asian workers employed in plants that belonged to U.S. corporations, and involving the same import tariff arrangements that later were applied to the maquiladoras. (See Fernandez-Kelly, 1987, p.151).

treatment of certain products from all most favored nation (MFN) suppliers, as well as regular or accelerated phase-ins of tariff eliminations under NAFTA could allow as easy entry as what took place via the maquiladora program (see Watkins, 1994a). To the extent that additional paperwork is involved for participation in the maquiladora program, membership in the maquiladora program in the age of NAFTA might seem unnecessarily costly.

Another disincentive to operate under the maquiladora program involves environmental restrictions. In some cases, waste handling and treatment regulations may be interpreted as stricter for maquiladoras than for other Mexican plants making the same products – even though under NAFTA some of these plants would have little difficulty exporting to the United States under levels of protectionism no higher than what the maquiladoras enjoy.⁷

Beginning January 1, 2001, moreover, NAFTA became the only premise for duty free treatment of imported inputs to Mexican maquiladoras – signaling the effective end of the old maquiladora program as it related to trade among North American countries. As of that date, NAFTA provisions phased out Mexico's temporary unconditional duty-free treatment for imported components and equipment for plants operating under the maquiladora program. Rules requiring certain North American content minimum (50 percent or, in some cases, more) apply to duty free movements of products between Mexico and the United States or Canada.

⁶ This controversy will be readdressed econometrically enroute to answering more recent questions relating NAFTA and the maquilas.

⁷ See Boyer (1997) for a detailed characterization of Mexican environmental law and its significance to the maquiladoras.

On the other hand, although NAFTA began lowering tariffs on the shipment of goods into the United States from Mexico immediately upon its inception on January 1, 1994, the full reductions were not instantaneous. To the extent that the Generalized System of Preferences or HTS 9802.00.60 or HTS 9802.00.80 (see footnote 6 for descriptions of all of these) result in lower tariffs for the import of Mexican goods than NAFTA does, then the maquiladora will continue to have its attractions, but they will not be attractions associated with NAFTA.⁸

Some NAFTA-related changes unequivocally encourage the expansion of maquiladora activities. As an example, Echeverri-Carroll (1999) notes that NAFTA eliminated all Mexican programs that favored specific industries. When these programs disappeared, some firms switched to the maquiladora program in order to continue importing inputs duty free to Mexico.

As a result of NAFTA an additional Harmonization Tariff Schedule was also created. This new schedule, HTS 9802.00.90, allows for the duty-free treatment of textile and apparel products assembled in Mexico from U.S.-formed and U.S.-cut fabric.⁹ More

⁸ Three general categories of U.S. tariff policy have historically applied to imports of maquiladora products into the United States. The first (Harmonization Tariff Schedule 9802.00.60) permits the importation of “fabricated” but unfinished metal products processed abroad. Duties are assessed on the value added in Mexico, rather than by levying an import tariff on the total value of the product. The products are required to have been processed in the United States before they were sent abroad. Products in this category must be further processed in the United States upon their return. The second (Harmonization Tariff Schedule 9802.00.80) of the three categories allows an article assembled in Mexico from U.S.-made components to be exempt from import duties on the value of these components. These products need not involve metal components. The third category is the most generous. If the value of the goods assembled or manufactured in Mexico contains at least 35 percent Mexican content upon import into the United States, they are eligible for treatment under the U.S. Generalized System of Preferences, or GSP. Mexican GSP-eligible items may enter the United States duty free.

⁹ Textile and apparel products have historically entered the United States under special trade restrictions and trade liberalizations of such trade have also had to be specific to such products. For apparel that had entered under 9800.00.80, only the value of U.S.-cut fabric pieces and U.S.-made fasteners such as buttons and zippers came in free of duty. Under 9802.00.90 the value added in Mexico in Mexico, including labor and overhead, also enters the United States free of duty. For additional discussion see United States International Trade Commission (1999).

generally, Echeverri-Carroll (1995) notes that some processed products that included inputs that still would enter Mexico under the maquiladora program post-NAFTA will be able to re-enter the United States more cheaply in the wake of NAFTA. Amongst this group would be products with particularly high percentages of North American content overall, including the textile and apparel products noted above. NAFTA's content rules are in some cases more restrictive than those under which some products entered the United States after having been processed in maquiladoras. For products that meet these rules, however, tariffs imposed upon returning to the United States are likely to be lower than before NAFTA. Maquiladoras that typically have high ratios of North American components on a percentage basis include textiles and apparel, scientific instruments, and chemical and related products.

In sum, some factors suggest that NAFTA may have affected maquiladora growth a great deal. Other factors offer reasons to suspect that NAFTA would have had little impact and still others suggest that NAFTA discouraged maquiladora growth. Whether NAFTA has made a significant contribution to the acceleration of maquiladora employment growth is not easy to divine without making an effort at econometric modeling. Nevertheless, the maquiladora expansion rate during the five post NAFTA years for which there is sufficient data to attempt to explain it is nearly twice as great as during the five pre-NAFTA years. This anomaly may explain (at least in the case of those writing post-NAFTA) why writers linking NAFTA to maquiladora growth are so easy to find.

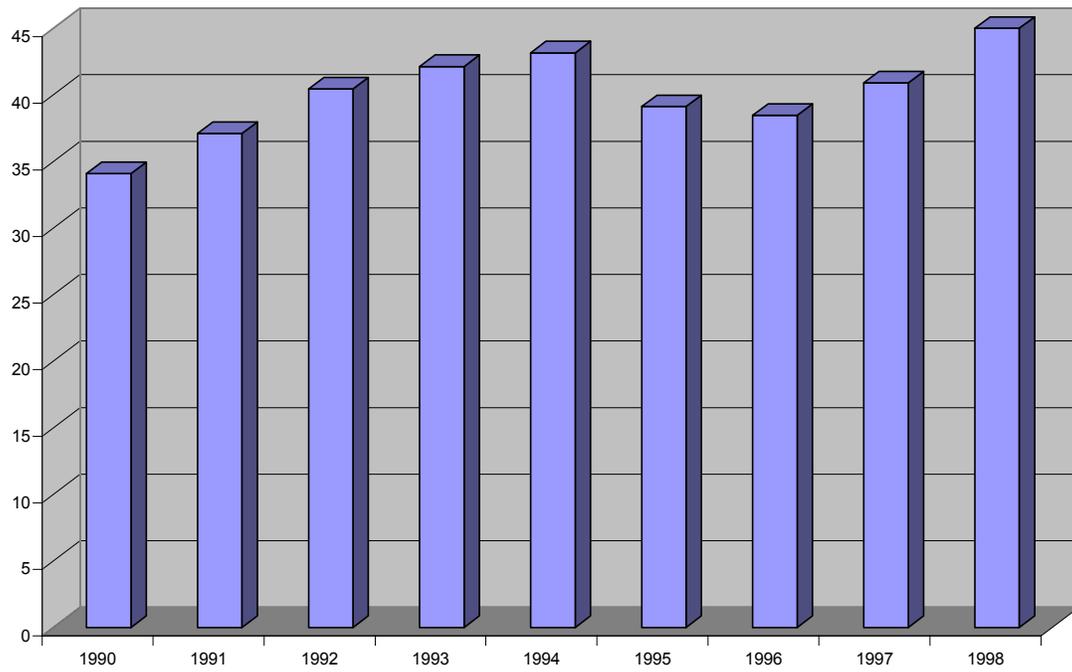
IV. If Maquiladoras Are Phased Out, Why Are These Questions Worth Asking?

Analysts writing on NAFTA-related topics commonly attribute all post-NAFTA changes in U.S.- Mexico trade to NAFTA. (See, for example, Council of the Americas, 1999 and Rothstein and Scott, 1999). In contrast, econometric evidence suggests that significant fluctuations in U.S.-Mexico trade since NAFTA's inception have been related to non-NAFTA factors (Gould, 1997). That is, variables that have nothing to do with NAFTA explain much of the recent overall fluctuations in U.S.-Mexico trade even though NAFTA also turns out to explain a significant portion of U.S.-Mexico trade.

Nevertheless, large blocs of economic activity related to U.S.-Mexico trade – such as maquiladora production – have not been specifically shown either to be connected or unconnected to NAFTA. Why is this important? If maquiladora production and trade were linked to NAFTA, the implications for modeling NAFTA's impacts would be markedly different than if NAFTA did not influence a large portion of U.S.-Mexico trade. For example, if maquiladora activity were not affected by NAFTA, then perhaps estimates of NAFTA's impact on U.S-Mexico trade ought to include only data for which maquiladora trade was deleted.

This issue becomes clearer if we consider the broader context of Mexico-U.S. trade. Mexican shipments of crude petroleum to the United States represent a significant portion of total Mexico-U.S. trade, but trade in crude petroleum is clearly unconnected to NAFTA. It may be possible to identify other such portions. If it turns out that the portion of Mexico-U.S. trade is rather limited, the research focus on NAFTA would also warrant greater limitations than are currently typical.

Chart II
MAQUILADORA EXPORTS AS A PERCENTAGE OF TOTAL EXPORTS



Suppose, however, that maquiladora activity is affected by NAFTA, as the authors cited previously seem to be saying. Another interesting aspect of examining the connections between maquiladoras and NAFTA would involve assessing not only whether NAFTA affected maquiladora activity, but how. For example, might NAFTA have only a direct influence on measures of maquiladora activity or might NAFTA turn out to have indirect effects, expressing itself through other factors related to maquiladora activity?

Finally, even though maquiladoras will be phased out as a phenomenon separate from NAFTA, the implications of such plants for trade liberalization related to NAFTA may deserve very different modeling and policy consideration if they measure out as linked to NAFTA. We can only measure these links while it is still statistically possible to consider maquiladoras as separate entities. Chart II, which delineates the ratio of maquiladora exports to total Mexican exports demonstrates how important these implications may be. Note that maquiladora exports have accounted for more than one-third of all Mexican exports in every year of the last decade.

V. Modeling Maquiladora Behavior: With or Without NAFTA

In order to test for the impact of NAFTA on maquiladora fluctuations, I apply a variant of a model (Gruben, 1990) designed to explain maquiladora employment variation. This model addresses influences on maquiladora employment fluctuations that would occur in the presence or absence of NAFTA. The model's construction includes adjustments for statistical problems inherent in examining such relationships (Navarrete Vargas and Hernandez, 1988; Gruben, 1990) and then adds a dummy variable for all observation periods from 1994 on.

The virtue of this model is that it is very parsimonious yet accommodates both demand side and supply-side explanations of maquiladora employment fluctuations. To account for the demand side, I use U.S. industrial production as Navarrete Vargas and Hernandez (1988) did. The rationale behind using industrial production is that maquiladoras are in large part simply a segment of the U.S. manufacturing sector. Since U.S. industrial production largely reflects output fluctuations in that sector, increases in U.S. industrial production may be seen as increasing demand for maquiladora products and to raise maquiladora employment. I also constructed a version of this model using U.S. real gross domestic product, since it is a broader measure of both supply and demand. I do not report the model results using that variable because, regardless of configuration of lag lengths or of the other variables in the model, U.S. GDP never offered as much explanatory power as U.S. industrial production.

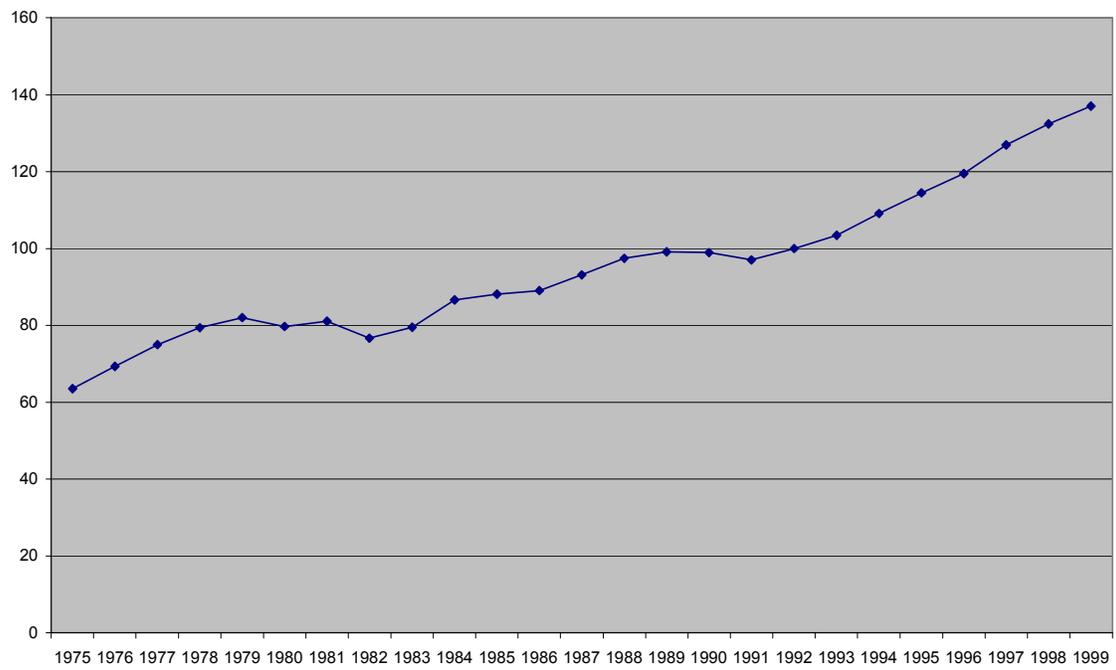
A second important category of explanatory variable for maquiladora models involves relative wages although, as will be seen, relative wage variables require some statistical adjustment before they become suitable for a regression equation. In any case, Mexican maquiladora employment may be expected to expand or contract inversely with the ratio of wages of production workers in Mexican manufacturing to comparable wages in countries that compete with Mexico in supplying products to the United States, including the United States itself. In the typical maquiladora model (Navarrete Vargas and Hernandez, 1988; Gruben, 1990; Truett and Truett, 1993), the maquiladoras' competitors are hypothesized to be plants in the United States and in newly industrializing Asian countries. *Ceteris paribus*, as Mexican manufacturing wages fall

relative to U.S. wages or to Asian wages, Mexican maquiladora employment is expected to grow.

I express all wages in dollars so as to characterize relative costs from the point of view of a U.S. producer or other U.S. customer. This detail is important. Why denominate foreign wages in dollars when the workers will in fact be paid in their national currency? The reason is, maquiladoras are operated chiefly by U.S. firms or by foreign firms that use maquiladora products as inputs for their U.S. operations. In either case, these firms are selling into the U.S. market. When they are attempting to hold down their product costs, they are attempting to hold them down in dollar terms, regardless of where the actual production takes place. Accordingly, even though workers in a company's foreign plants may be paid in the currency of their countries, the dollar value of these payments is what important to producers who are trying to decide whether to produce in Mexico, the United States or – for example – Hong Kong.

As an illustration, suppose workers in a particular country received 200 pesos per day yesterday and suddenly must receive 300 pesos per day today. However, suppose also that the increase in wages from 200 pesos per day to 300 pesos per day is accompanied by a currency devaluation such that while ten pesos purchased a dollar yesterday, twenty pesos must be exchanged for a dollar today. This would mean a reduction in the dollar cost of wages from \$20 per day yesterday to \$15 per day today. Naturally, U.S. firms selling in the United States will find operating in the peso-issuing country to be suddenly more cost-attractive – even though workers now receive 300 per day pesos instead of 200.

Chart III
U.S. INDUSTRIAL PRODUCTION 1992=100



The reader may wonder why I (and all other economists who econometrically model maquiladora behavior) use dollar-denominated relative wages rather than some measure of output per wage unit in dollar terms. From a maquiladora owner's perspective, the output per wage unit that an indigenous Mexican firm can generate without direct linkages back to U.S. operations and organizational procedures may not be a relevant benchmark for decision making. The reason is, maquiladora operators bring management skills and economies of scale that may offer opportunities for much higher worker productivity than an average Mexican manufacturing plant that employs workers of the same skill levels found in maquiladoras – but without paying wage differentials consistent with these productivity differentials.¹⁰ Despite shortages in some types of skilled labor, Mexico still has an abundance of low-skilled labor whose productivity can be increased through efficient management practices and plant design. It should be noted also that in models using relative unit labor costs rather than simple relative wages – the variables in question offered scarcely any explanatory power at all.

VI. Is Post-NAFTA Maquiladora Acceleration Tied to Non-NAFTA Variables?

An inspection of the three explanatory variables discussed so far offers insight as to why maquiladora employment accelerated in the years since NAFTA's inception on January 1, 1994. Chart III displays U.S. industrial production for the period 1976-1999. Note the acceleration in industrial production growth in 1992 and the re-acceleration in

¹⁰ On the issue of scale economies, note that the employment and output of the average Mexican manufacturing plant is smaller than that of the average maquiladora or of the average US plant. One issue of wages in deserves attention that , in the wake of Mexico's 1994 devaluation, real manufacturing wages adjusted downward and remained below pre-devaluation real wages for years. In dollar terms average overall manufacturing sector wages in Mexico remained below 1994 levels even as late as 1999, which is the latest year for which data are available.

Chart IV
RATIO OF MEXICAN TO U.S. MANUFACTURING WAGES

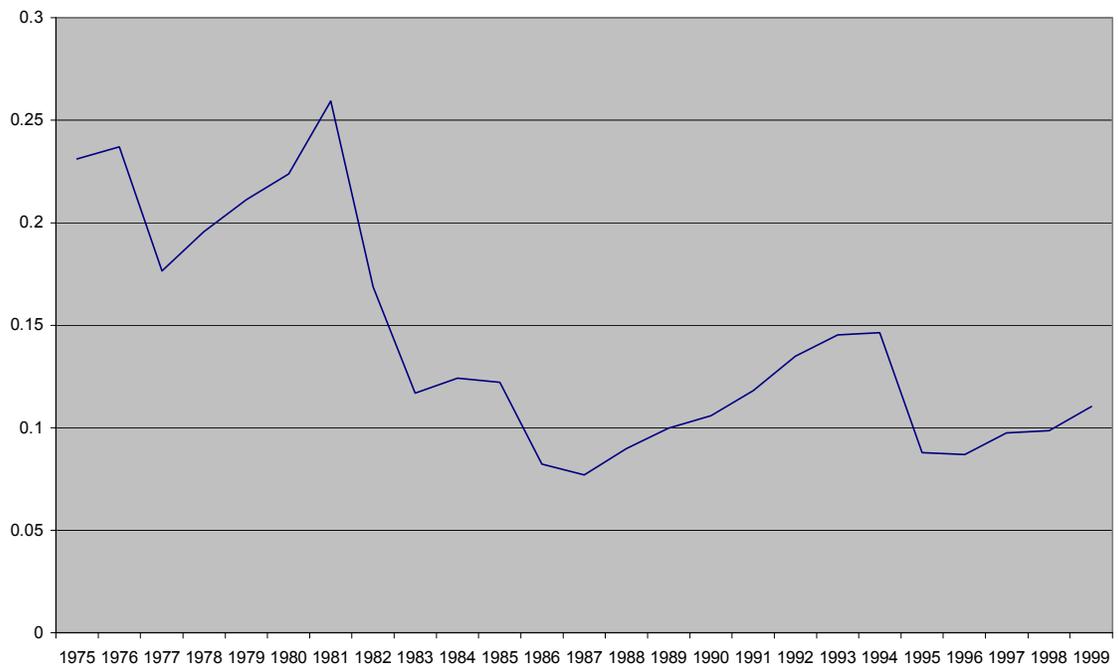
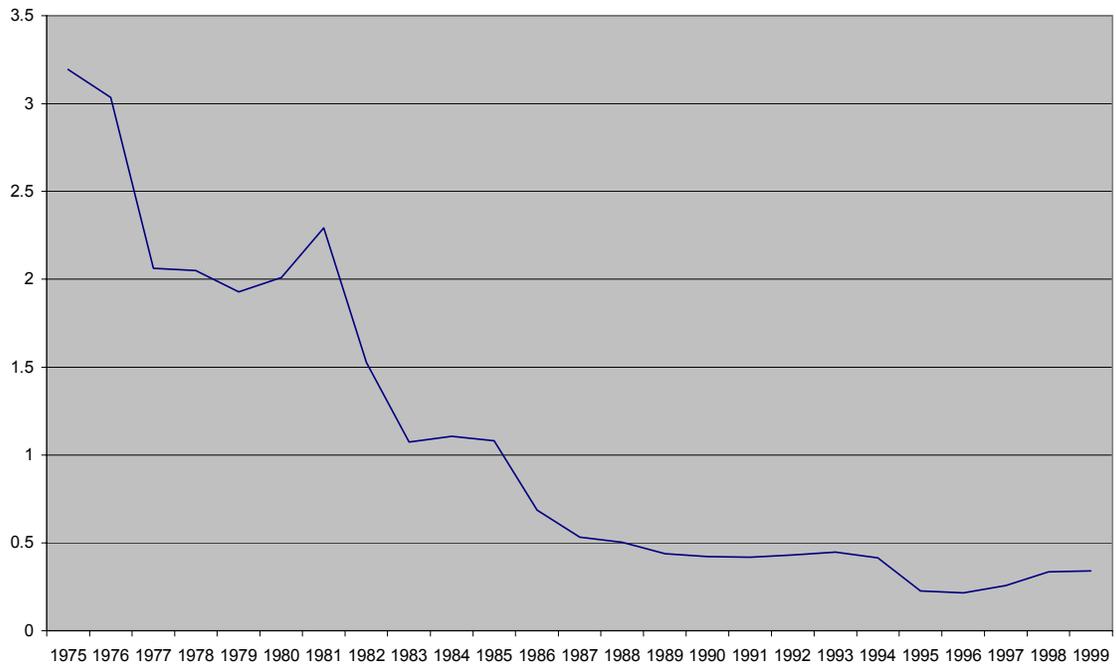


Chart V
RATIO OF MEXICAN TO ASIAN MANUFACTURING WAGES



1995. Over the first six years of NAFTA, U.S. industrial production grows 32 percent versus 11 percent growth over the six years previous to NAFTA.

Chart IV displays the ratio of hourly wages in Mexican manufacturing to hourly wages in U.S. manufacturing, both including benefits and both expressed in dollars. Note the sudden reduction in this ratio in 1995, the first year of NAFTA. Although this ratio edges up in succeeding years to its level of 1990, it never goes above it. In accordance with the literature on maquiladoras, these lower wage ratios may be associated with higher maquiladora employment

Similarly, the ratio of hourly wages in Mexican manufacturing to average hourly manufacturing wages (Chart V) in a sample of Asian countries (Hong Kong, Korea, Singapore and Taiwan) also falls suddenly in 1995. Like the Mexico/U.S. manufacturing wage ratio, the Mexico/Asia manufacturing wage ratio also increases slightly after 1995. Unlike the Mexico/U.S. manufacturing wage ratio, the Mexico/Asia manufacturing wage ratio never rises to any value ever reached in any year previous to 1995. As with the Mexico/U.S. manufacturing wage ratios, lower Mexico/Asia manufacturing wage ratios may be associated with higher maquiladora employment.¹¹

Nevertheless, the most recently published econometric models of maquiladora behavior use data series ending in 1988. Eleven years' data are available since the last model was estimated, so it is possible that relations between the independent variable and dependent variables could have changed since the last run of a maquiladora model.¹²

¹¹ Applying augmented Dickey-Fuller tests and Phillips-Perrone tests to each of the variables discussed above (including the dependent variable, maquiladora employment) all turned out to be unable reject the null hypothesis of a unit root. I accordingly took first differences of logarithms of all of these variables, this transformation allowing the rejection of the hypothesis of a unit root.

¹² All three econometric models of maquiladoras cited here, including Navarrete Vargas and Hernandez (1988), Gruben (1990), and Truett and Truett (1993) use a Mexico/U.S. wage variable, a Mexico/other industrializing country wage variable, and a U.S. output variable.

TABLE 1

CONSTANT	0.087811***	0.077245***	0.088691***	0.080133***	0.080674***
	(0.015193)	(0.015758)	(0.018936)	(0.011714)	(0.011988)
MEX/US (-1)	-0.132065**		-0.141554		
	(0.060174)		(0.131125)		
MEX/ASIA WAGE (-1)		-0.108876*	0.010268		
		(0.059248)	(0.125143)		
PRINCIPAL COMP. (-1)				-0.014589*	-0.019336*
				(0.007566)	(0.010012)
PRINCIPAL COMP. (-2)				-0.013934*	-0.016974
				(0.007305)	(0.012390)
INDUSTRIAL PROD.	1.049863**	1.131543**	1.051087**	1.278143***	1.200418**
	(0.395894)	(0.401794)	(0.406940)	(0.389837)	(0.484877)
NAFTA DUMMY	-0.019877	-0.010857	-0.020874	-0.025703	-0.025216
	(0.025985)	(0.027943)	(0.029329)	(0.022549)	(0.025341)
R-squared	0.534362	0.504401	0.534536	0.737014	0.747451
Adjusted R-squared	0.460840	0.426148	0.431100	0.675134	0.684314
S.E. of Regression	0.051558	0.053191	0.052961	0.040064	0.040354
Sum squared resid	0.050507	0.053757	0.050488	0.027287	0.026056
Log likelihood	37.75743	37.04029	37.76173	42.39968	
Mean dependent var.	0.118631	0.118631	0.118631	0.121682	0.120555
S.D. dependent var.	0.070217	0.070217	0.070217	0.070291	0.071823
Akaike info criterion	-2.935429	-2.873069	-2.848846	-3.399971	
Schwarz criterion	-2.737951	-2.675591	-2.602000	-3.152007	
Durbin-Watson stat	1.548164	1.434754	1.544536	2.027825	1.859293

Finally, to test for the impact of the North American Free Trade Agreement on fluctuations in maquiladora employment, I use a dummy variable with the value of 0 for pre-NAFTA years and the value of 1 for post-NAFTA years. This variable is the most important one in this modeling effort. If the model's estimated value for the NAFTA coefficient turns out to be positive and significant, that result would signify that San Martin (2000), Balla (1998), Carrada-Bravo(1998), the Economic Policy Institute and the United States Business and Industrial Council Educational Foundation (1997), and Perot and Choate (1993) are correct that NAFTA drives maquiladora growth. If the model's estimated value for the NAFTA coefficient turns out to be negative and significant the result would signify that NAFTA discourages maquiladora growth. This result would suggest that the maquiladora –discouraging aspects of NAFTA may dominate the maquiladora-encouraging aspects of NAFTA. If the model's estimate for the NAFTA coefficient turns out to be insignificant, that we cannot reject the null hypothesis that the actual value of the coefficient is zero, then perhaps NAFTA simply did not make any difference to the maquiladoras.

VII. Preliminary Statistical Examinations Suggest the Old Relations Still Hold

In Table 1, Columns I through III present the results of three very simple regression equations, each of which incorporates at least one Mexican wage ratio variable, plus the industrial production index variable, plus the NAFTA dummy variable. I use annual data beginning in 1975 and ending in 1999. With the exception of the NAFTA dummy variable, all data are transformed into first differences of their logarithmic forms, so that the data will be stationary.¹³ Column I reports a regression

¹³ All wage data for all countries, including Mexico, Hong Kong, Korea, Singapore, Taiwan and the United States come from the International Comparisons of Hourly Compensation Costs for Production Workers in

equation that includes the U.S. industrial production variable (Industrial Production) and (following Gruben, 1990) one lag of the Mexico-U.S. wage variable (Mex/US Wages) together with the NAFTA dummy variable (NAFTA Dummy). As expected, the Mexico-U.S. wage variable is negative and significant. The industrial production variable is positive and significant. Note that the NAFTA dummy variable is insignificant and negative, the implications of which will be discussed later.

Column II of Table 1 offers an equation with the same variables, except that the one-lagged Mexico-U.S. wage ratio is replaced by the Mexico-Asian wage ratio. The results are essentially the same, however, with the industrial production variable taking on a positive and significant sign, the Mexico-Asian wage ratio taking on a negative and weakly significant sign, and the NAFTA dummy variable once again negative and insignificant expected signs.¹⁴

Even though the common approach to the construction of econometric models of maquiladora models has been to account for both Mexico/U.S. wages and Mexico/industrializing country wages, an estimation problem commonly develops. If both wage variables are included in the same equation, not only will neither typically pass a significance test even if they do separately, but sign changes occur. This problem may be seen in Table 1, Column III, where both the ratio of Mexican wages to U.S. wages (Mex/US Wages, lagged once) and the ratio of Mexican wages to Asian wages (Mex/US wages, lagged once) are included in an equation that also includes U.S.

Manufacturing series that appears on the United States Bureau of Labor Statistics website. These data go back to 1975. Note again that the virtue of these data is that they account for benefits as well as salaries. All of the maquiladora employment data that I use come from the Mexican government's INEGI (Instituto Nacional de Estadística, Geografía e Informática) website. The U.S. industrial production data I use is produced by and is available from the Federal Reserve Board.

¹⁴ Although I do not report them here, the results are essentially the same with or without the NAFTA dummy variable. This variable does not affect the equation at all in the present configuration.

industrial production (Industrial Production) and the NAFTA dummy variable (NAFTA Dummy). As may be seen, the t-statistics for the lagged wage ratio variables fall below the typical benchmark levels of significance. Moreover, the coefficient on the Mexico/Asia wage ratio takes on a positive sign, even though it had taken on a negative sign in the absence of the Mexico/US wage ratio. Although this last result is inconsistent with expectations, these reductions in significance suggest an econometric problem that also appeared in a similar maquiladora-related modeling exercise by Hernandez and Navarrete Vargas(1988).¹⁵

This problem is “the existence of multicollinearity between the two variables that express relative costs.”¹⁶ That is, movements in the two wage variables are highly correlated with one another.¹⁷ This correlation substantially reduces the ability of regression analysis to separately attribute variations in maquiladora employment to each wage variable.

We have no direct method for correcting problems of multicollinearity in regression equations beyond increasing the number of observations. However, a procedure does exist that allows for the weighting of the wage variables in a context that avoids multicollinearity. This procedure is principal components analysis.

¹⁵ This problem was avoided by Truett and Truett (1993) by using a different dependent variable than other authors. However, the variable Truett and Truett (1993) applied has been criticized on other grounds.

¹⁶ Navarrete Vargas and Hernandez (1988, 225), my translation. Their model is quarterly, rather than annual, and uses wage data that are not corrected for international differences in worker benefits, as are the U.S. Bureau of Labor Statistics data used in the present model.

¹⁷ Even when the data are transformed into first differences of logarithms, representing growth rates of the Mexico/U.S. and Mexico/Asia wage variables, the coefficient of correlation between the two is .8852. This is substantive evidence of serious multicollinearity. In contrast, the coefficient of correlation between the transformed version of the Mexico/Asia wage ratio and the similarly transformed (first differences of logarithms) U.S. industrial production index variable is only .0935. The coefficient of correlation between the transformed version of the Mexico/US wage ratio and the transformed U.S. industrial production index is .1232. These last two low degrees of correlation suggest that the multicollinearity in the equations discussed are strictly in the wage ratio variables.

Through principal components analysis, the variation of several variables can be compressed into one or more index variables. The resulting index variable is known as a principal component. The principal component is a linear combination of some collection of variables such as – in the context of this model - the two wage ratios. A mathematical procedure is used to maximize the amount of variation of each of the two wage variables that can be captured in one index. This variance-maximization procedure suppresses the contaminating effects of one wage variable’s correlation with the other. Multicollinearity ceases to be a problem.

Through this maximization procedure, a coefficient becomes attached to each original variable. In the context of this study, the wage-ratio variables are the two original variables. The values of the coefficients estimated for the variables used to construct this index “indicate the relative importance of each original variable in the new derived component.”

It should be noted on the one hand that principal components estimators are biased. So, unfortunately, are the estimators derived from other procedure designed to avoid multicollinearity problems – including for example estimators in ridge regression modeling. However, the focus of this modeling exercise is to identify the impact of NAFTA on maquiladora growth. Since the variable used to characterize NAFTA has not been converted into a principal component, the effects of estimator bias in the principal component portion of the model will have little effect on the conclusion on which this exercise concentrates. The same may be said with respect to the relation between fluctuations in US industrial production – also not captured through principal components – and maquiladora employment fluctuations.

VIII. Does NAFTA Affect Maquiladoras After All?: More Complete Results

These preceding efforts serve as preparation for the most important step of this paper, the measurement of NAFTA's effect on growth in maquiladora employment. Having applied principal components estimation to create an index variable (Wage Ratio) that is free of multicollinearity problems but captures the variation of both Mexico/Asia and Mexico/U.S. wage relationships, I used this variable in estimating equations to test for the impact of NAFTA on maquiladora employment fluctuations.

The result I present (Column IV of Table 1) is the culmination of a large number of prior estimations in which I tested for the optimal set of lags. In estimating this model I constructed alternative models that offered all possible combinations of lags from zero (that is, contemporaneous) to three lags for the principal component wage ratio variable (Wage Ratio) and for the U.S. industrial production (Industrial Production) index variable (which, again, is transformed into first differences of logarithms). By the term "all possible combinations" I include asymmetric combinations.¹⁸ I included lags up to three annual lags for U.S. industrial production and for the Mexican wage ratio principal component. In response to requests by attendees at sessions where I presented this paper, I also included lags of the NAFTA dummy variable.

The equation I present here has, among all equations that I estimated, the lowest Schwartz Criterion variable value (a model with two lags of the Mexican wage principal

¹⁸ An example of asymmetry would include a contemporaneous-only U.S. industrial production variable with three lags and only a contemporaneous principal components variable, or vice-versa. I also ran symmetrically lagged models, with contemporaneity plus three lags of the industrial production variable along (in the same equation) with the same lag structure for the principal components variable. That is, I followed the London School of Economics paradigm of running every possible combination (in this particular case up to three annual lags) of the principal components and industrial production variable. Again, note that I did not lag the NAFTA dummy variable.

component variable and with a contemporaneous U.S. industrial production variable).¹⁹ As with the preliminary models presented in Columns I through III, the model results in Column IV offer no support whatever for the arguments of San Martin (2000), Balla (1998), Carrada-Bravo(1998), the Economic Policy Institute and the United States Business and Industrial Council Educational Foundation (1997), or Perot and Choate (1993) or of Perot in his television dramatizations in opposition to NAFTA and maquiladoras (see footnote 2). The same is true in the cases of all models that I constructed but do not here report.

The Schwartz Criterion is intended to offer information about optimal lag length. The Schwartz Criterion punishes overparameterization – or overloading the model with lags of explanatory variables - more severely than other lag length criteria. The winning Schwartz Criterion model offers an interesting story overall about the dynamics of maquiladora operation and management. First, with the exception of the NAFTA dummy variable, the Schwartz winner has no coefficients with significance levels larger than .0735. That is, such coefficients as this model has are at least weakly significant, a substantially better result than the previous equations and an instructive statistical commentary on the ability of principal components to capture collective variations. More interestingly, the Schwartz winner has a first and second lag of the Mexican wage ratio principal component and a contemporaneous coefficient of U.S. industrial production.

This configuration is consistent with maquiladora decision rules that reflect markedly smaller demand-side risk than cost or supply-side risk. As for the demand side, note that the maquiladoras respond within the same year to changes in U.S. industrial

¹⁹ Note that the Schwartz Criterion is one of the most common tests for optimal lag specification. When testing alternative lag structure for a model, the one with the lowest value wins.

production. Other things equal, maquiladoras add employees in the same year in which U.S. industrial production goes up and fire them in the same year when U.S. industrial production falls.

However, the model suggests that maquiladora operators are slower to respond to shocks to relative wages (supply-price shocks) than they are to changes in U.S. industrial production (a demand shock). The lag configuration suggests that it takes time to determine whether wage shocks are long-lived or transitory.

The reason why so much time is required to decide whether wage shocks are either long-lived or transitory may be related to maquiladora owners' dollar-denominated (rather than peso-denominated) perspective on costs. When we express all wages in dollars, the largest and most sudden shocks to relative wages will involve currency devaluations. The lag structure of the Schwartz winner is consistent with maquiladora operators' waiting to see if wages will adjust to their old levels in dollars following a devaluation or if the adjustment process is a slow one. As Charts II and III show, the adjustment was very slow in the wake of Mexico's 1994 devaluation, as can also be seen after the 1982 devaluation. That is, Mexican wages not only became relatively low (compared to U.S. or Asian wages) when a devaluation occurred, but wage inflation following the devaluation did not quickly raise Mexican wages in dollar terms back to their pre-devaluation levels. Mexican wages remained relatively low.

However, from the perspective of maquiladora operators, this peso-wage stickiness in post-devaluation dollar terms may not be a certainty. First, peso-wage stickiness need not persist after every devaluation. McLeod and Welch (1991) show that

in many countries this stickiness is not typical, and that relative wages return to their old relations far more quickly in some other countries than in Mexico.

Second, the same investor pressures that trigger devaluations in Mexico can simultaneously trigger persistent exchange rate pressures elsewhere. Such devaluations could easily make owners of in-bond plants wonder whether a Mexican devaluation might set off a devaluation in other countries where they own plants, eroding the wage advantage in Mexico that the devaluation brought on. Mexico's last exchange rate crisis, in 1994-1995 sparked capital outflows elsewhere in Latin America and in the Philippines and Poland. Likewise, the Russian devaluation of the third quarter 1998 incited financial pressures in Brazil and Argentina, as well as Mexico. Russia's 1998.III crisis triggered fears about Brazil that were sufficient to cause large reserve losses (see Treuherz, 2000). In the wake of these losses, political events within Brazil incited further capital outflows until Brazil devalued the Real in January 1999. The lag structure on wage ratios is consistent with the time that firms may take in waiting to see how these exchange rate relations sort themselves out.

With respect to the NAFTA dummy variable, the conjectures of the various authors who have claimed that NAFTA drives maquiladora growth are unconfirmed, as is the case for literally every one of the scores of equations constructed in preparation for building the two models I have presented. Note that the coefficient of the NAFTA dummy variable is not significant. From the point of view of the authors mentioned, this result would offer cold comfort in and of itself. The negative sign, and the fact that every form of this model gives a negative sign to the NAFTA dummy variable coefficient, means that a coefficient value significantly different from zero would more soundly reject

those authors' claims even than significance would. It should be reiterated that this negative sign appeared in every estimation I performed, ranging from three lags of one variable and no lags of the other all the way to no lags of the one variable and three lags of the other.

IX. Instrumental Variables Approach

One last refinement that is in order for estimations of the effects of NAFTA on maquiladora growth is to account for the possible problem of simultaneity bias. This problem arises because employment and wages are jointly and simultaneously determined.

Accordingly, a final step in estimating this model was to make an instrumental variable substitution for the lagged principal components that had originally been included so as to adjust for the multicollinearity problems in the wage ratios.²⁰ A Hausmann test showed that the instrumental variables model uncorrected for heteroskedasticity was not statistically significantly different from the ordinary least squares model. That is, from a statistical point of view, there was not a need to construct an instrumental variables equation. In Column V of Table 1, I have in any case presented results for instrumental variables estimation for the simple reason that there were theoretical reasons to suspect simultaneity bias, even if statistical testing did not bear them out. As can be seen, the first lag of the instrumented principal component (wage ratio variable) is negative and significant while the second lag is negative and

²⁰ The goal in creating instruments to proxy for the original variable is to find variables that may be correlated with the right-hand-side variable subject to simultaneity bias, but not with the dependent variable. In this case, a linear combination of the contemporaneous exchange peso-dollar exchange rate together with lagged principal components were conjectured as reasonable candidates to construct an instrument for the original component. When the Sargan test of instrument validity was applied, the related

insignificant. As before, the U.S. industrial production variable is positive and significant while the NAFTA dummy variable is negative and insignificant. In any case, the results are so consistent with the ordinary least squares results presented previously that they add little to this narrative aside from offering assurances that these results are quite robust.

X. Summary and Conclusions

In response to widespread arguments in the popular press, and by business and academic writers, that Mexican maquiladoras' rapid growth since NAFTA is a result of NAFTA I have performed extensive econometric tests of the effect of NAFTA on changes in maquiladora employment. The results of these tests are resoundingly negative. NAFTA did not make maquiladoras grow faster. Such effect as NAFTA has on maquiladora growth is negative, not positive, but the effect is not significantly different from zero. Accordingly, we cannot say that NAFTA has any effect on maquiladoras at all.

Instead, the acceleration of maquiladora employment growth from the inception of NAFTA through 1999 can be explained by changes in demand factors (as expressed by changes in the U.S. industrial production index) and in supply-side/cost factors (as expressed by changes in the ratios of Mexican manufacturing wages to U.S. manufacturing wages and to manufacturing wages in four Asian countries). Growth in the U.S. industrial production index over the six years following NAFTA was roughly three times as rapid than during the six years previous. Likewise, Mexico's devaluation of 1994-1995 meant that the ratio of Mexican manufacturing wages to their counterparts

F-value was 0.3048, implying a .90243203 level of significance, clearly demonstrating that the instrumentation was valid.

in the United States, Hong Kong, Korea, Singapore and Taiwan also was during the first five years of NAFTA far below these ratios during the five years previous to NAFTA.

The basic equation presented in this paper is the culmination of many equation estimations. I have presented the first and second lag configuration equation displayed here because it had the optimal lag structure of the equations if estimated, according to the Schwartz Criterion for optimal lag length. After adjustment for degrees of freedom in the ordinary least squares version, this equation captured 67.5 percent of all variation in maquiladora employment, with 73.7 percent of variation estimated as captured before adjustments for degrees of freedom. After adjustment for degrees of freedom, the instrumental variables version captured 68.4 percent of total variation.

The approach to determining lag length turns out to have interesting implications with respect to how maquiladora-owning companies handle risk. That is, these companies relatively quickly respond to changes in demand (as expressed by changes in the U.S. industrial production index) while the response to shifts in relative wages does not occur at all during the same year as the shift in relative wages (as expressed by changes in ratios of Mexican wages to U.S. and Asian wages). Instead, these responses mainly take place one and two years after the shifts, as if maquiladora operators were waiting to see if the wage shocks were going to be permanent or if they were going to be transitory.

While there is much to suggest that NAFTA has in fact affected trade between the United States and Mexico (see Gould, 1997), the effects did not come from Mexico's maquiladora system. These effects occurred as a result of other types of U.S.-Mexico trade. Trade is a complicated process, and so are changes in trade policy.

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