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DO MAQUILADORAS TAKE AMERICAN JOBS? SOME TENTATIVE ECONOMETRIC RESULTS

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Mexico's maquiladora industry has been subject to many controversies over the years, but one controversy has dominated. Opponents of the U.S. legal provisions that facilitate maquiladora profitability argue that the maquiladoras take jobs from U.S. workers. That is, Mexican workers compete with U.S. workers for manufacturing jobs. Advocates of the maquiladoras argue that these jobs would have gone abroad in any case, and that Mexican workers' real competition is the work forces of other Third World countries.

Even though the two sides of this controversy have argued for much more than a score of years, no one has developed a statistical testing procedure to address the dispute econometrically. The reason is that standard hypothesis-testing techniques cannot be used to treat this issue. The most obvious variables to use in testing the two competing hypotheses are so multicollinear that any conventional model using the variables always generates highly suspect results.

In this paper, I present a testing method that mitigates some of the problems of multicollinearity and allows one to examine the two competing hypotheses about maquiladoras and U.S. jobs. The test is indirect, because it measures the responses of maquiladora employment to changes in Mexican-U.S. and Mexican-Asian Third World wage differentials, and does not directly measure losses in U.S. jobs or directly resulting increases in Mexican or Asian employment. Moreover, the results of the testing procedure are highly tenuous, because very few observations with clean data are available. Accordingly, it is hard to know much about the intertemporal stability of the relationships implied by the procedures I use. Nevertheless, the results up to now are striking. They suggest that both sides of the controversy are about equally correct.

An Econometric Model of International Wage Competition in the Maquiladoras

The determinants of fluctuations in maquiladora output and employment have been the subject of a number of studies, and there is general agreement on many related issues (Navarrete Vargas and Hernãndez 1988; Amozurrutia C. 1988; Fuentes Flores 1989). There is wide agreement that changes in U.S. demand affect changes in maquiladora activity because maquiladoras chiefly serve U.S. markets. Likewise, there is little disagreement over the claim that changing disparities between wages in Mexico and those of its industrial competitors explain a substantial portion of fluctuations in maquiladora employment. When Mexican wages fall relative to wages elsewhere, maquiladora employment grows.

Despite agreement that wage differentials are important in explaining a significant portion of maquiladora employment and output fluctuations, the relative effects of Mexican wages versus U.S. wages and Mexican wages versus other Third World wages remain to be addressed econometrically. Opponents of maquiladoras contend that maquiladora investment by U.S. firms has the effect of exporting jobs from the United States. U.S. workers stay in the United States, according to this argument, while their jobs go to Mexicans. Advocates of the maquiladoras argue that Mexico is competing with the rest of the world for labor-intensive production and that U.S. jobs lost to the maquiladoras would have been lost sooner or later to other low-wage countries anyway.[1]

Hypothetically, this controversy could be indirectly addressed by using

[1] For further references to these controversies and their participants, see U.S. International Trade Commission (1986, 24) and Grunwald and Flamm (1985, 14).

measures of wage differentials in a linear regression equation that explains changes in maquiladora employment. If the maquiladora opponents' contention is correct, then Mexico-U.S. wage differentials would be significant in explaining fluctuations in maquiladora employment. As Mexican wages fell relative to U.S. wages, maquiladora employment would increase. As Mexican wages rose relative to U.S. wages, maquiladora employment would fall, other things (such as U.S. demand) equal.

If the maquiladora advocates' argument is correct, then a measure of the relation between Mexican wages and wages of other, competing low-wage countries would explain variations in maquiladora employment. As Mexican wages fell relative to those of competing low-wage countries, maquiladora employment would rise. When Mexican wages rose relative to those of competing low-wage countries, maquiladora employment would fall, other things equal.

These econometric results would be necessary to validate each side of the argument, but they would not be sufficient. For one or the other competing argument to dominate, one variable would have to be shown to have stronger statistical results than the other. If both competing arguments have merit, it is hypothetically possible to test the relative strength of each by including both wage variables in the same regression equation and then examining the values of the relevant coefficients.

Providing that both coefficient values were significantly different from zero, forming a ratio of the two would suggest something about the relative significance of each argument. That is, if the coefficient on the variable that characterized Mexico versus U.S. wage differentials were significantly larger than the coefficient on the variable that characterized Mexico versus other low-wage country wage differentials, it would suggest that the maquiladora opponents' argument was stronger, and vice versa.

In this context, however, it would be important to show by standard tests that one or both of the coefficients were significantly different from zero. If one measured coefficient were larger than the other but neither could be shown to be statistically different from zero, the results of the test would be indeterminate.

Since demand factors also clearly have important effects on fluctuations in maquiladora activity, a model that includes only wage-related arguments would suffer from misspecification.[2] Moreover, the econometric conventions of the literature on maquiladoras suggest that a measure of U.S. demand warrants inclusion in a model of fluctuations in the activity of this industrial sector.

In sum, three variables appear to be reasonable candidates to explain fluctuations in maquiladora employment. First, a measure of percentage changes in the ratio of Mexican manufacturing wages to U.S. manufacturing wages deserves inclusion.[3] As Mexican manufacturing wages fall relative to U.S. manufacturing wages, maquiladora employment is expected to increase. Second, a measure of percentage changes in the ratio of Mexican manufacturing wages to an average of manufacturing wages in Hong Kong, Korea, Singapore, and

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[2] Amozurrutia C. notes that, during the 1974-75 crisis in the maquiladora industry, the Mexican Secretary of Industry and Commerce stated that (my translation) "the degree to which the present problems in the maquila industry have been caused by the United States recession has yet to be analyzed" (1988, 249). Since then, Amozurrutia C. (1988), Navarrete Vargas and Hernández (1988), and Fuentes Flores (1989) have all provided evidence to suggest a relation between fluctuations in measures of U.S. demand and fluctuations in measures of maquiladora activity.

[3] Note that transforming the data into first differences of logarithms, as I have done in all tests presented, is essentially the same as calculating percentage changes in the data.

Taiwan is included.[4] Third, in order to capture the effect of fluctuations in U.S. demand, a measure of percentage changes in U.S. gross national product in 1982 dollars (real GNP) is included.[5]

In this model, all variables are expressed in dollars, and all data are applied in the form of first differences of logarithms. Moreover, the wage variables are lagged by one year, while the U.S. GNP variable is contemporaneous. This configuration is based on the following assumptions. First, new plants locate in Mexico in response to changes in wage differentials between that country and other nations. The location or relocation process takes time and, in this case, is conjectured to take one year. Second, existing plants respond to increases in U.S. demand by hiring more labor. They do not relocate but simply hire more workers. The limited

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[4] The source of all wage data used in this model is U.S. Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology, Supplementary Tables for "International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing," BLS Report 754 (August 1988) for 1975 and 1977-87 and BLS Report 771 (August 1989) for 1976. These data are annual and are adjusted for differences among countries in worker benefits that are not direct wage payments.

[5] In preliminary tests, levels and (separately) logarithms of levels were used in regression equations. In these tests, serial correlation proved to be significant. That is, intertemporal correlations of errors existed. Subsequently, I used first differences of logarithms. When the data were transformed in this way, serial correlations were shown not to be significant. As a result, all data used in all tests presented were transformed into first differences of logarithms.

It should be noted, however, that the Durbin-Watson statistics for some of the regression equations presented in the tables are in the indeterminate range. That is, using the Durbin-Watson test, we cannot be sure whether the serial correlation is significant, even when using first differences of logarithms. In each of these cases, and in the case of the index equation that is discussed later, ARIMA equations were constructed in order to characterize the relevant process of serial correlation. In literally every case, this procedure showed that the null hypothesis of zero intertemporal correlation of error terms could not be rejected at the 0.05 level. That is, despite the uncertain results of the Durbin-Watson tests, all these processes turn out to be white-noise processes when subject to testing by means of ARIMA equations.

number of observations available for the wage series does not permit much experimentation with alternative lag structures. Lagged wage ratios were found to offer considerably more explanatory power than contemporaneous wage ratios, however.

Table 1 presents the results of three regression equations, each of which incorporates two or more of these variables, using annual data for the period 1975-87. Regression equations that, respectively, included the Mexico-U.S. wage variable and the U.S. GNP variable and, separately, the Mexico-Pacific nation wage variable and the U.S. GNP variable provide the expected signs. Moreover, the wage variable included in each of the two-variable equations passed the usual tests used to determine whether a coefficient is significantly different from zero. The GNP variable did not pass this test, but the theoretical reasons for including a measure of demand seemed sufficiently compelling to include this variable anyway. A third equation, which contains all three variables, provides results whose signs are consistent with expectations but whose levels of significance for the wage variables are not.

Even though the coefficients of the Mexico-U.S. wage variable and the Mexico-Pacific nation wage variable took on the expected negative signs in an equation that included them and the GNP variable, neither wage coefficient was significantly different from zero. These reductions in significance (compared with the two-variable equations) suggest an econometric problem that was also encountered in a somewhat similar maquiladora-related modeling exercise by Rodolfo Navarrete Vargas and José Luis Hernández (1988).

This problem is "the existence of multicollinearity between the two variables that express relative costs."[6] That is, movements in the two wage variables are highly correlated with one another.[7] This correlation substantially reduces the ability of regression analysis to attribute variations in maquiladora employment separately to each wage variable. This problem probably explains why, despite years of controversy between pro- and anti-maquiladora groups, no published research has ever addressed this question statistically.

There exists no direct method for correcting the problems of multicollinearity in regression equations, beyond increasing the number of observations. Accordingly, the issue that I originally posed cannot be directly answered by linear regression analysis with the present data. Even though both arguments apparently are important, the arguments cannot be relatively weighted.

A procedure does exist, however, that allows for weighting these variables in a context that avoids multicollinearity. This procedure is principal components analysis.

Principal components analysis can be used to compress the variation of

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[6] Navarrete Vargas and Hernández (1988, 225), my translation. It should be noted that the Navarrete Vargas-Hernández model is quarterly and uses wage data that are not corrected for international differences in worker benefits. I used annual data because, to my knowledge, they are the only data that contain such corrections.

[7] In fact, even when the data are transformed into first differences of logarithms, the coefficient of correlation between the two wage variables is 0.985. This is substantive evidence of very serious multicollinearity. In contrast, the coefficient of correlation between the transformed version of the Mexico-Pacific nation wage ratio and the GNP variable is only 0.255, while the coefficient of correlation between the transformed version of the Mexico-U.S. wage ratio and the GNP variable is 0.311. These latter two coefficients of correlation suggest that the insignificance of the GNP variable in the equations in which it appears is not a result of multicollinearity.

several variables into one or more index variables.[8] The resulting index variable is known as a principal component. The principal component is a linear combination of some collection of variables, such as the two wage variables. A mathematical procedure is used to maximize the amount of variation, of each wage variable, that can be captured in one index. As part of this variance-maximization procedure, the effects of the two wage variables are orthogonalized,[9] so that the multicollinearity problem is much mitigated.

The result of this maximization procedure is that a coefficient is attached to each variable, which, in the present case, means each of the two wage variables. (Indeed, the index is nothing more than a variation-maximized linear combination of its component variables.) Again, in our case, those variables are the Mexico-Pacific nation wage ratio and the Mexico-U.S. wage ratio.

More importantly, the values of the coefficients estimated for the variables used to construct this index "indicate the relative importance of each original variate in the new derived component" (Morrison 1967, 225). This means that we can compare the weights of the two wage variables when they are used to create a principal component index, and we can do so with

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[8] For example, the first principal component of the complex of sample values of the responses $X_1, \ldots, X_p$ is the linear compound

$$Y_1 = a_{11}X_1 + \ldots + a_{p1}X_p,$$

whose coefficients a_{i1} are the elements of the characteristic vector associated with the greatest characteristic root l_1 of the sample covariance matrix of the data. The a_{i1} are unique up to multiplication by a scale factor. If they are scaled such that $a_1'a_1 = 1$, the characteristic root l_1 is interpretable as the sample variance of Y_1. (See Morrison 1967, 224.)

[9] That is, the principal components equation is formed so as to suppress the contaminating effects of one wage variable's correlation with the other.

confidence that the multicollinearity problems have been avoided. That is, if the weight (or coefficient) for the Mexico-U.S. wage variable were significantly larger than that of the Mexico-Pacific nation wage variable, this would suggest that the maquiladora opponents' argument had more merit than the maquiladora advocates' argument, and vice versa.

Table 2 provides the results of the principal components procedure.[10] The index-construction process has attached virtually identical weights to the two variables. These weights are expressed in the rows beneath the heading "eigenvector." The index number is then included as an independent variable, along with the same GNP variable used in previous regression equations, in a regression equation that explains variation in maquiladora employment. The diagnostic statistics of the equation (see Table 3) are largely similar to those of the three-variable equation, except that the level of significance of the wage index variable easily rejects the null hypothesis at the 0.05 level. That is, the wage index variable is highly significant whereas, when the two wage variables were included in the same equation, neither of them was significant.

It is interesting to note the ability of the alternative models to forecast maquiladora growth out of sample. If the index model forecasted less accurately than the original, multicollinear model, this would raise questions about the validity of the weighting scheme. Indeed, the purpose of constructing the forecasting equations is that they can serve as an avenue for the establishment of reliable weights. Two forecasting equations were constructed, using data for 1975-84, in order to predict maquiladora

[10] Note that this index number is an indexed version of the first principal component.

employment in 1985, 1986, and 1987. One forecasting equation incorporates the two wage variables and the U.S. real GNP variable that were discussed above. A second equation incorporates the wage index, together with U.S. real GNP.

Chart 1 depicts the out-of-sample maquiladora employment forecasts made by the index-based model and by the original three-variable model, together with actual maquiladora employment growth. This chart suggests that, despite the small number of sample observations used to construct the models, both generally manage to forecast maquiladora growth with a high degree of accuracy. More interestingly, however, Chart 1 suggests that the index-based model forecasts more accurately than the original model.

Tables 4 and 5 provide forecast results and related diagnostic statistics suggesting that the impression of relative forecast accuracy in Chart 1 is not deceiving.[11] In these results, root mean square error (RMSE) is provided as a measure of overall out-of-sample forecast accuracy. Note that the index-based model gives a lower RMSE than the original three-variable equation, suggesting the usefulness of the index equation as a forecasting instrument. That is, other things equal, an equation containing an index that weights the two wage variables about evenly is shown to be somewhat more accurate in forecasting maquiladora employment than an equation containing the original wage variables.

This result does not offer conclusive proof that the principal components-based weighting scheme provides a highly accurate picture of the

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[11] Note that, in the tables here, the forecasts are presented in the form of first differences of logarithms. The forecasts are presented in this form because that is how they were constructed, and not as the estimated values of actual maquiladora employment. This presentation facilitates the performance of diagnostic checks. Chart 1, of course, does depict the estimated values of maquiladora employment. In Chart 1, it is possible to see the difference between the employment forecasts and what actually occurred.

relative effects on maquiladora growth of fluctuations in each of the two wage variables. As yet, there are not enough observations to allow inquiry into the stability of the estimates over time.

Nevertheless, the results so far do suggest that the weighting scheme may offer more accurate forecasts than the scheme implicit in the relative values of the coefficients in the original three-variable equation. This implies that the principal components-based weighting scheme more accurately characterizes the true relative weights of the two arguments in the maquiladora controversy than do the weights in the original, multicollinear equation.

Summary and Conclusions

A statistical attempt has been made to resolve a long-standing controversy about whether maquiladoras take jobs from American workers or from workers in low-wage Pacific countries. Two conclusions can be drawn from the research presented here. One involves the easy and accurate forecastability of maquiladora employment; the other, more important conclusion involves the impact of two different classes of wage differentials on maquiladora employment.

The first conclusion is that a simple two-variable model can provide reasonably accurate forecasts of maquiladora employment growth, provided that the effects of Mexico-U.S. and Mexico-Pacific nation wage ratios are captured in one (principal component) index variable. A fairly high degree of forecast accuracy was shown, despite the use of only a small number of observations in the estimating equation. The degree of stability of the relationships captured by the forecasting equation, however, remains to be seen. The degree of stability can be observable only through additional observations.

Despite the apparent usefulness of this forecasting procedure, the most important piece of information provided by the process of model construction is that both competing arguments about maquiladoras as a sink for U.S. jobs appear to be about equally correct. That is, maquiladora growth appears about equally influenced by Mexico-U.S. wage differentials and by Mexico-Pacific nation wage differentials. Whether this result holds for future observation periods remains to be seen, but the estimation methodology presented here at least permits other researchers to make statistical amendments and reconsiderations as additional data become available. This is an improvement over what has been possible before, because the heretofore insolvable problem of multicollinearity seems to have discouraged other researchers from statistically addressing this controversy.

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Table 1

Results of Regression Equations

	Intercept	Ratio of Mexican wages to U.S. wages	U.S. GNP
Coefficient	0.079	-0.300	0.739
t statistic	2.089	-2.803	0.812
Summary statistics			
R^2	0.496		
Adjusted R^2	0.369		
Durbin-Watson	2.547		
Autocorrelation check (probability)	0.117		

	Intercept	Ratio of Mexican wages to PACNIC wages	U.S. GNP
Coefficient	0.071	-0.314	0.579
t statistic	1.776	-2.743	0.640
Summary statistics			
R^2	0.485		
Adjusted R^2	0.356		
Durbin-Watson	2.743		
Autocorrelation check (probability)	0.070		

	Intercept	Ratio of Mexican wages to PACNIC wages	Ratio of Mexican wages to U.S. wages	U.S. GNP
Coefficient	0.078	-0.034	-0.268	0.723
t statistic	1.695	-0.047	-0.390	0.705
Summary statistics				
R^2		0.496		
Adjusted R^2		0.280		
Durbin-Watson		2.572		
Autocorrelation check (probability)		0.155		

SOURCES OF PRIMARY DATA: Instituto Nacional de Estadística, Geografía e Informática.
U.S. Department of Commerce.
U.S. Department of Labor.

Table 2

Results of Principal Components Analysis

Simple statistics	Ratio of Mexican wages to PACNIC wages	Ratio of Mexican wages to U.S. wages
Mean	-0.129	-0.092
Standard deviation	0.233	0.228

Total variance = 0.1059831

	Principal component
Eigenvalue	0.104618
Eigenvector	
Mexico/PACNIC	0.714571
Mexico/U.S.	0.699563

SOURCES OF PRIMARY DATA: Instituto Nacional de Estadística, Geografía e Informática.
U.S. Department of Commerce.
U.S. Department of Labor.

Table 3

Results of Principal Components Regression

	Intercept	Principal component index	U.S. GNP
Coefficient	0.074	-0.218	0.665
t statistic	1.927	-2.792	0.735

Summary statistics	
R^2	0.494
Adjusted R^2	0.367
Durbin-Watson	2.655

SOURCES OF PRIMARY DATA: Instituto Nacional de Estadística, Geografía e Informática.
U.S. Department of Commerce.
U.S. Department of Labor.

Table 4

Forecast Results Using Original Model

	Actual values			Maquiladora employment			
	Ratio of Mexican wages to PACNIC wages	Ratio of Mexican wages to U.S. wages	U.S. GNP	Predicted	Actual	Residual	Root mean square error
1985	0.0112	0.0742	0.0656	0.1099	0.0597	-0.0502	
1986	-0.0114	-0.0209	0.0330	0.0851	0.1644	0.0792	
1987	-0.3611	-0.3493	0.0281	0.1989	0.2004	0.0014	
							0.0542

SOURCES OF PRIMARY DATA: Instituto Nacional de Estadística, Geografía e Informática.
U.S. Department of Commerce.
U.S. Department of Labor.

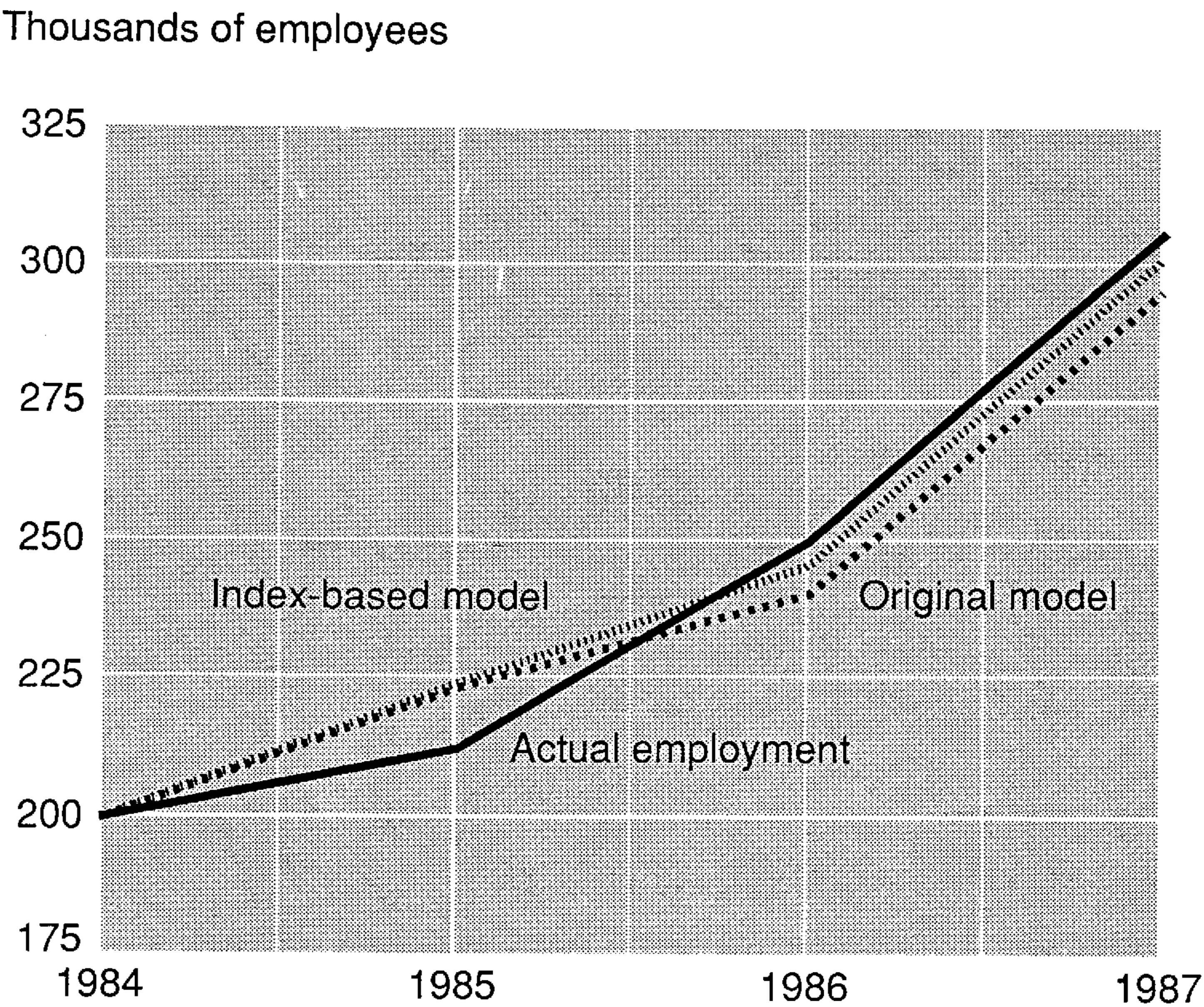
Table 5

Forecast Results Using Principal Components Model

	Actual values		Maquiladora employment			
	Principal component index	U.S. GNP	Predicted	Actual	Residual	Root mean square error
1985	0.0599	0.0656	0.1133	0.0597	-0.0536	
1986	-0.0228	0.0330	0.1011	0.1644	0.0633	
1987	-0.5024	0.0281	0.2034	0.2004	-0.0030	
						0.0479

SOURCES OF PRIMARY DATA: Instituto Nacional de Estadística, Geografía e Informática.
U.S. Department of Commerce.
U.S. Department of Labor.

Chart 1
Comparison of Actual Maquiladora Employment and the Original and Principal Components Forecasts



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