8. METROPOLITAN MAQUILADORA ECONOMETRIC FORECAST ACCURACY

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Abstract

Maquiladora in-bond manufacturing activities occupy positions of collective importance within many regional economies across Mexico. To date, empirical evidence regarding the predictability of maquiladora activities in Mexico has not been attempted. To partially fill that gap in the literature, two sets of in-bond industry econometric forecasts for metropolitan economies in Northern Mexico are analyzed. Empirical results indicate that accurate forecasts of metropolitan maquiladora variables may prove elusive.

Key Words: Regional Maquiladora Forecasting

JEL Classification: M21, R15

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Introduction

International manufacturing forecasts are utilized in a variety of planning exercises that include both corporate and public sector activities. Because these forecasts involve exchange rates, global business cycles, and numerous other variables, they are generally difficult to develop (Hagdorn van der Meijden, van Nunen, and Ramondt, 1994; Birk and Bikker, 1995). Along the border between the United States and Mexico, maquiladora manufacturing plays a central role in the economic health of

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the region. The importance of the sector is widely recognized and it has been formally incorporated into econometric models and forecasts for the "borderplex" regional economy from 1999 forward (Fullerton, 2001).

Although borderplex maquiladora forecasts receive a lot of media and business group attention, they have not previously been examined for accuracy. Formal empirical testing of maquiladora forecasts can prove helpful in identifying weaknesses within the borderplex model. It can also help highlight the risks and overall reliability of these out of-sample simulation data. Accordingly, the objective of this study is to examine the historical accuracy of the structural equation maquiladora forecasts generated using the Borderplex Econometric Forecasting Model. Those forecasts are three year out-of-sample simulations published annually by the Border Region Modeling Project at the University of Texas at El Paso (UTEP) between 1999 and 2006.

Data used in the study are the taken from Borderplex Economic Outlook reports published from 1999 through 2006. Maquiladora variables included are total employment, plants in operation, total value added, and average hourly wages. The forecasts examined are for two metropolitan economies located in northern Mexico. Ciudad Juarez is the largest city in the state of Chihuahua while Chihuahua City is the state capital. Together, these metropolitan markets represent the most important concentration of in-bond manufacturing activities in Mexico (Christman, 2008).

Subsequent sections include the following. The second section provides a brief overview of prior research that has been completed on related topics. That material is followed by a description of the data and methodology utilized in the analysis. Next, forecast accuracy results are discussed. The final section summarizes the results obtained and offers suggestions for future studies.

Previous Research

International manufacturing is relatively difficult to model and simulate (Hagdorn van der Meijdan,, van Nunen, and Ramondt, 1994; Birk and Bikker, 1995). In Mexico, maquiladora manufacturing has been the focus of many empirical analyses due to its rapid growth in recent years and the impacts it has faced from de-regulation in China (Flores, 2001; Truett and Truett, 2007; Mollick and Wvalle-Vazquez, 2006). In-bond manufacturing activities are primarily located in northern areas of Mexico due to geographic proximity to the United States. The largest concentration of jobs and output is in Ciudad Juarez, with a fairly large volume of jobs and output also located in Chihuahua, City (Calderon Villarreal and Mendoza Cota, 2001).

Economic impacts of in-bond manufacturing and assembly activities are fairly widespread. This category of direct foreign investment leads to noticeably higher wages in regional labor markets (Feenstra and Hanson, 1997). Merchandise exports from northern Mexico's maquiladora sector also cause large scale cargo vehicle flows through border metropolitan areas (Fullerton and Tinajero, 2002). As noted by Hanson (2001), growth in this sector has also led to greater integration between border city pairs. From a business cycle perspective, there is positive correlation between employment in cities on the United States side of the international boundary and export production in neighboring Mexican cities. That pattern is especially prevalent for smaller cities located along the international boundary separating the two countries.

To date, studies that have conducted empirical assessments of metropolitan in-bond manufacturing predictability in Mexico have principally focused on monthly payroll fluctuations. Fairly encouraging out-of-sample simulation results have been identified for Tijuana and Chihuahua City (Coronado, Fullerton and Clark, 2004; Fullerton and Torres Ruiz, 2004). These studies document a number of correlations between maquiladora employment and real wages, United States industrial activity, and the real exchange rate value of the peso. As is the case with forecasts for other regions where demographic data are subject to large scale revisions and unemployment/underemployment rates are high, relative forecast accuracy is found to be an elusive goal for Nuevo Laredo (West, 2003; Cañas, Fullerton, and Smith, 2007).

Studies that go beyond an assessment of in-bond manufacturing employment predictability in Mexico have not previously been conducted. This effort attempts to partially fill that gap in the literature by examining the historical track records for previously published econometric forecasts of four metropolitan manufacturing data series for both Ciudad Juarez and Chihuahua City. Those four variables are annual maquiladora employment, plants in operation, hourly wages, and value-added. The forecasts are taken from reports generated between 1999 and 2006 using the UTEP Borderplex Econometric Forecasting Model (Fullerton, 2001).

Predictive accuracy is evaluated using several descriptive and statistical metrics. Random walks provide the benchmarks against which relative accuracy is measured. A random walk forecast utilizes the last available historical observation as the projected value for current and future periods (Pindyck and Rubinfeld, 1998). Several different studies have documented the relative precision of these types of simpler extrapolation procedures (Ashley, 1988; Fair and Shiller, 1990). Random walk forecasts have also been found to provide fairly good competition to structural models of regional economies that include maquiladora variables as regressors (Fullerton, 2004). To date, there have not been very many attempts to examine the historical accuracies of the out-of-sample simulations for metropolitan manufacturing variables.

Data and Methodology

Eight variables are included in the maquiladora block of the Borderplex Econometric Forecasting Model. They include total employment, plants, average hourly wages, and total value added. Table 1 lists the equation mnemonics plus descriptions for the variables for both markets. Annual frequency data are utilized. Employment is reported in thousands. Maquiladora hourly wages are reported in nominal dollars and include benefits. The wage estimates take into account the industry standard work week of 45 hours. Maquiladora value-added data are expressed in millions of nominal dollars (Fullerton and Molina, 2007). The units of measure are determined by industry reporting practices. Greater detail regarding the model structure and specification is provided below.

Table 1

Variable Acronyms and Descriptions

Series	Description	Units
CJTME	Ciudad Juarez Total Maquiladora Employment	Thousands
CJMP	Ciudad Juarez Maquiladora Plants	Number in Operation
CJAHW	Ciudad Juarez Average Hourly Wages	Nominal Dollars
CJTVA	Ciudad Juarez Total Value Added	Nominal Dollars, Millions
CCTME	Chihuahua City Total Maquiladora Employment	Thousands
CCMP	Chihuahua City Maquiladora Plants	Number in Operation
CCAHW	Chihuahua City Average Hourly Wages	Nominal Dollars
CCTVA	Chihuahua City Total Value Added	Nominal Dollars, Millions
MXPSA	Mexico Annual Average Exchange Rate	Nominal Pesos per Dollar
MXREX	Mexico Annual Average Real Exchange Rate	Real Pesos per Dollar
GDPR	United States Real Gross Domestic Product	2005 Dollars, Billions
JPGDP	United States Chained GDP Deflator	2005 = 100

General descriptive statistics for the historical values of each series are shown in Table 2. The means for all of the variables in this table are far lower than any of the 2006 figures. That is due to fairly strong rates of expansion over the course of the sample period for maquiladora activities in both cities. Most notably, more than 240 thousand employees are on the in-bond assembly payrolls in Ciudad Juarez by 2006, with more than 80 thousand on the payrolls in Chihuahua City that same year. Good variability is observed for each variable in the sample and the time span is sufficiently long enough to contain both recessionary and expansionary phases of the business cycle.

Table 2

Historical Endogenous Data Descriptive Statistics

Series	Mean	Standard Deviation	Maximum	Minimum	Number of Observations
CJTME[1]	99.14	82.07	249.38	0.76	41
CJMP[1]	172.20	100.07	308.00	5.00	41
CJAHW[2]	2.22	1.02	4.20	1.03	32
CJTVA[3]	12,382.11	15,338.05	41,610.07	3.30	29
CCTME[4]	29.32	14.30	51.17	3.70	27
CCMP[4]	55.63	21.24	84.00	17.00	27
CCAHW[4]	2.46	1.30	5.14	0.89	27
CCTVA[4]	3,337.76	3,987.66	10,447.01	0.56	27

Notes: 1. Annual frequency historical data for 1966-2006.
2. Annual frequency historical data for 1975-2006.
3. Annual frequency historical data for 1978-2006.
4. Annual frequency historical data for 1980-2006.

The predictive data being assessed are taken from Borderplex Economic Outlook reports published from 1999 through 2006. Because model coverage was geographically less extensive in the early years of the UTEP reports, there are fewer historical observations for Chihuahua City than for Ciudad Juarez. The forecast sample periods are determined by data availability and consistency. Forecast data for Ciudad Juarez range from 1999 to 2006. Forecast data for Chihuahua City range from 2000 to 2006.

To examine predictive accuracy, a set of descriptive metrics based on root mean square error (RMSE) calculations are first utilized. RMSE provides a measure of the variation of the simulated variable from its time path (Pindyck and Rubinfeld, 1998). RMSE has a disadvantage because it is unbounded from above. Given that, the Theil inequality coefficient and its three proportions are also utilized due to ease of interpretation (Stekler, 1968). Based on RMSE calculations, the Theil inequality coefficient ranges in value from zero to one. Zero indicates perfect forecast accuracy (Leuthold, 1975).

Equation (1) shows how RMSEs are calculated. In Equation (1), Y_n^s represents the out-of-sample simulation value of a variable *Y*, while Y_n^a represents its actual value. N is the number of forecast observations in the sample.

$$\text{RMSE} = \sqrt{1/N\sum_{n=1}^{N}(Y_n^s - Y_n^a)^2} \quad (1)$$

Theil inequality coefficients are also known as U-statistics. The manner in which they are defined allows them to range from zero to one. The closer the number is to zero, the better the predictive accuracy of the model, while the closer it is to one, the worse its predictive performance (Leuthold, 1975). Equation (2) presents the formula for calculating a U-statistic.

$$U = \sqrt{1/N\sum_{n=1}^{N}(Y_n^s - Y_n^a)^2} \Big/ \left(\sqrt{1/N\sum_{n=1}^{N}(Y_n^s)^2} + \sqrt{1/N\sum_{n=1}^{N}(Y_n^a)^2} \right) \quad (2)$$

Theil inequality coefficients can be decomposed into 3 separate proportions: U^M, U^S, and U^C. They, respectively, represent bias, variance, and covariance proportions. As indicated in Equation (3), the inequality coefficient proportions sum up to one.

$$U^M + U^S + U^C = 1 \quad (3)$$

The bias proportion, U^M, measures systematic error based on the difference between the average forecast values from the model and the actual values for the dependent variable. The optimal value of U^M is zero, in which case no bias present in the out-of-sample simulations for the variable of interest. Equation (4) is the formula presents the formula for the bias proportion of the U-statistic.

$$U^M = \frac{\left(\overline{Y^s} - \overline{Y^a}\right)^2}{(1/N)\sum_{n=1}^{N}(Y_n^s - Y_n^a)^2} \quad (4)$$

The variance proportion, U^S, shown in Equation (5) measures the ability of the projections to mirror the variability of the actual values. The optimal value of U^M is zero, in which case the fluctuations of the simulated values are identical to those of the actual value. The covariance proportion, U^C, shown in Equation (6), measures unsystematic forecast errors. U^C is rarely expected to be zero since out-of-sample simulations will almost never be perfect. Given that, the optimal value for U^C is one so that U^M and U^S can equal zero. Thus, the preferred values of the proportions are: $U^M = U^S = 0$ and $U^C = 1$ (Pindyck and Rubinfeld, 1998).

$$U^S = \frac{(\sigma_s - \sigma_a)^2}{(1/N)\sum_{n=1}^{N}(Y_n^s - Y_n^a)^2} \qquad (5)$$

$$U^C = \frac{2(1-\rho)\sigma_s \sigma_a}{(1/N)\sum_{n=1}^{N}(Y_n^s - Y_n^a)^2} \qquad (6)$$

Theil inequality statistics are useful, but are descriptive, only. In general, error structures associated with forecasting make statistical inference difficult, so descriptive measures tend to predominate. When degree of freedom constraints are not binding, some formal tests can be employed (Ashley, Granger, and Schmalensee, 1980; Diebold and Mariano, 1995). The error differential regression is designed to test a null hypothesis of mean square error (MSE) equality between competing sets of forecasts (Ashley, Granger, and Schmalensee, 1980).

Let the MSE of the competing forecast errors (e_1, e_2) represent, respectively, the mean square errors for the random walk benchmark (MSE(e_1)) selected for comparison against the mean square error of a specific structural maquiladora forecast equation (MSE(e_2)). The null hypothesis tested is shown in Equation (7).

$$H_0: MSE(e_1) = MSE(e_2) \qquad (7)$$

Letting

$$\Delta_t = e_{1t} - e_{2t} \text{ and } \sum{}_t = e_{1t} + e_{2t}, \qquad (8)$$

Equation (7) can be rewritten as follows,

$$MSE(e_1) - MSE(e_2) = [cov(\Delta,\textstyle\sum)] + [m(e_1)^2 - m(e_2)^2], \qquad (9)$$

where *cov* denotes sample covariance for the simulation period. If the joint null hypothesis

$$H_0: \mu(\Delta) = 0 \text{ and } cov(\Delta,\textstyle\sum) = 0 \qquad (10)$$

can be rejected in favor of the alternative hypothesis, the structural maquiladora forecast equation will be determined to be superior in terms of predictive accuracy.

The error differential regression equation used to test the null hypothesis is affected by the signs of the error means. There are two regression equations that are extracted from Equation (9) and each of those equations has two interpretations. The interpretations depend on which error mean is positive and which is negative.

The regression equation used to test the joint null hypothesis when the error means have the same sign is:

$$\Delta_t = \beta_1 + \beta_2[\textstyle\sum_t - m(\sum_t)] + u_t, \qquad (11)$$

where u_t is a randomly distributed error term. The joint null hypothesis is captured within the coefficients of β_1 and β_2. The interpretation of β_1 embodies the test for $\mu(\Delta) = 0$, while the interpretation of β_2 embodies the test for cov $(\Delta,\sum) = 0$.

When β_2 is positive, the variance of the random walk forecast errors (e_1) will always be larger than the variance of the econometric equation forecast errors (e_2), indicating structural model superiority. The signs of the error means dictate how β_1 is interpreted. Econometric forecast superiority occurs when both of the error means are positive and the joint null hypothesis is rejected. If either of the coefficients (β_1 or β_2) is significantly negative, the econometric forecast cannot be considered more accurate than its random walk benchmark. If one of the estimates is insignificantly negative and the other is positive, a one tailed t-test should be performed to test for significance. When both estimated regression parameters are positive, an F-test can be used to test if they are jointly different from zero (Ashley, Granger, and Schmalensee, 1980).

When both error means are negative, the same method is used as above however the interpretation of β_1 changes. If β_1 is found to be significantly negative, and β_2 is either insignificant or significantly positive, the structural equation forecasts are deemed to be more accurate than the corresponding random walk benchmark. Otherwise, the converse holds.

If the error means of the forecasts are of opposite signs, a different regression equation must be employed to test the null hypothesis. It is related to Equation (11).

$$\textstyle\sum_t = \beta_1 + \beta_2[\Delta_t - m(\Delta_t)] + u_t \qquad (12)$$

The interpretation of the β_2 coefficient is the same as when the error means of the forecasts are of the same sign, but the interpretation of the β_1 now depends on which of the error means is positive and which is negative.

The first of the two possibilities is that the random walk has a negative error mean while the structural maquiladora equation forecasts has a positive error mean. If β_1 is significantly negative, with β_2 being insignificant or significantly positive, the structural equation model forecast is superior. The structural model is also seen as superior when β_1 is insignificant while β_2 is significantly positive. The random walk forecasts are deemed more accurate when β1 is significantly positive, or β_2 is significantly negative.

The second possibility is when the random walk has a positive error mean while the econometric equation forecasts has a negative error mean. When this case arises, if β_1 is significantly positive or if β_2 is insignificant, the structural equation econometric forecast is superior. However, if either of the equation parameters is significantly negative, the random walk forecasts are most accurate (Kolb and Stekler, 1993). Based on the above items, readers should note that individual t-statistic and F-statistic outcomes, in and of themselves, are of less concern than in standard econometric contexts. Instead, it is the juxtaposition of these diagnostic values along with error sign mean combinations that determine whether the forecast accuracy hypotheses are accepted or rejected.

In assessing the predictive accuracy of the maquiladora sector forecasts for Ciudad Juarez and Chihuahua City, it would not be surprising to discover that the econometric model runs into difficulties. Those difficulties arise from two unavoidable circumstances associated with both of these metropolitan economies. The first is that population estimates for Ciudad Juarez and Chihuahua City are subject to substantial revision on an ongoing basis. Those revisions, whether upward or downward, are sizable enough to affect the accuracy of multi-equation regional econometric forecasts (Charney and Taylor, 1984). The second is that metropolitan economies characterized by high rates of unemployment tend to be more difficult forecast accurately (West, 2003). Labor markets in Mexico have long been characterized by high rates of under-employment, a side effect of institutional frictions and a counterpart to unemployment in more flexible labor market settings (Satchi and Temple, 2009).

Empirical Results

Table 3 lists the parameter estimation results for the structural econometric equations that make up the Ciudad Juarez and Chihuahua City maquiladora block of the Borderplex Econometric Forecasting Model. Diagnostics for the eight equations are generally good. Reflective of the partial adjustment processes that frequently characterize global manufacturing, all of the equations include one-period lagged dependent variables as regressors. All of the nominal variables in each specification are also transformed to real, inflation adjusted terms prior to estimation.

Maquiladora employment in both metropolitan economies is functionally dependent on gross dependent product (GDPR) in the United States and wages in each respective labor market. The United States is the destination market for the vast majority of all in-bond manufacturing output from Mexico (Christman, 2008; Burstein, Kurcz, and Tesar, 2008). Given that, global business cycle aggregates are not required to successfully model the demand for labor in this export sector. The signs for each of the explanatory variable regression coefficients are as hypothesized and their t-statistics satisfy the 5-percent significance criterion.

The number of maquiladora factories in operation has long been recognized as a function of real wages denominated in dollars (Calderon Villarreal and Mendoza Cota, 2001; Christman, 2008; Jordaan, 2008). That is because in-bond assembly work generally requires substantial labor inputs, causing the cost of production to be strongly influenced by currency market fluctuations and wage rate changes. Both equations for the number of plants in operation in Table 3 follow that prescription. Although the specification accounts for the vast majority of the variation in the numbers of factories in both markets, it does not successfully capture all of the systematic movements in either dependent variable. To correct for serial correlation, moving average terms are included with two-year lags in each equation.

Table 3

Ciudad Juarez and Chihuahua City Maquiladora Econometric Equations

Equation T3.1

Ciudad Juarez Total Maquiladora Employment, Ordinary Least Squares, 32 Observations

CJTME = 0.76570*CJTME[-1]+0.00948*GDPR - 380.074*CJAHW/JPGDP - 11.2336
(7.77207) (2.76806) (3.32880) (0.75381)

Sum of Squares	2454.55	Standard Error	9.3628
R Squared	0.9855	Dependent Variable Mean	125.360
Adjusted R Squared	0.9839	F-Statistic 3, 28	633.010
Durbin Watson (1)	1.3436	Durbin Watson (2)	2.1458
Durbin H Statistic	2.1870		

Equation T3.2

Ciudad Juarez Maquiladora Plants, Nonlinear Least Squares, 31 Observations

CJMP = 0.95603*CJMP[-1] - 253.994*CJAHW[-1]/JPGDP[-1] + 32.5430

(178.372) (6.10243) (11.6700)

Sum of Squares	2845.22	Standard Error	10.2613
R Squared	0.9828	Dependent Variable Mean	214.323
Adjusted R Squared	0.9809	F-Statistic 3, 27	514.576
Durbin Watson (1)	2.1272	Durbin Watson (2)	2.1299
Durbin H Statistic	-0.3582		

MA_0 = -1.05233*MA_2

(13.7970)

Equation T3.3

Ciudad Juarez Total Maquiladora Value Added, Ordinary Least Squares, 28 Observations

CJMQVA/JPGDP = 0.74831*CJMQVA[-1]/JPGDP[-1] + 0.04468*CJTME - 1.20789

(12.3258) (4.60335) (1.69428)

Sum of Squares	56.9128	Standard Error	1.5088
R Squared	0.9824	Dependent Variable Mean	16.8505
Adjusted R Squared	0.9810	F-Statistic 2, 25	699.016
Durbin Watson (1)	1.6304	Durbin Watson (2)	1.8189
Durbin H Statistic	0.7865		

Equation T3.4

Ciudad Juarez Average Hourly Wages, Ordinary Least Squares, 31 Observations

CJAHW/JPGDP = 0.55533*CJAHW[-1]/JPGDP[-1]-0.00047*MXREX+0.00005*CJMP+

(7.76782) (6.71109) (3.58145)

+ 0.06406

(6.24026)

Sum of Squares	0.0008	Standard Error	0.0055
R Squared	0.8996	Dependent Variable Mean	0.0635
Adjusted R Squared	0.8884	F 3, 27	80.6334
Durbin Watson (1)	1.3041	Durbin Watson (2)	1.3761
Durbin H Statistic	1.9437		

Eqation T5

Chihuahua City Total Maquiladora Employment, Ordinary Least Squares, 26 Observations

CCTME = 0.85584*CCTME[-1]+0.00224*GDPR - 151.462*CCAHW/JPGDP - 2.58639
(8.10624) (2.69212) (3.37994) (0.69003)

Sum of Squares	193.010	Standard Error	2.9620
R Squared	0.9584	Dependent Variable Mean	30.3013
Adjusted R Squared	0.9527	F 3, 22	168.847
Durbin Watson (1)	1.7958	Durbin Watson (2)	2.5628
Durbin H Statistic	0.4444		

Eqation T6

Chihuahua City Maquiladora Plants, Nonlinear Least Squares, 26 Observations

CCMP = 0.99902*CCMP[-1] - 73.9330*CCAHW[-1]/JPGDP[-1] + 6.99313
(24.1523) (1.77196) (4.68004)

Sum of Squares	446.726	Standard Error	4.5047
R Squared	0.9561	Dependent Variable Mean	57.1154
Adjusted R Squared	0.9501	F 3, 22	159.822
Durbin Watson (1)	2.2977	Durbin Watson (2)	1.6796
Durbin H Statistic	-0.9872		

MA_0 = -0.57771*MA_2
(3.31140)

Eqation T7

Chihuahua City Total Maquiladora Value Added, Ordinary Least Squares, 26 Observations

CCTVA/JPGDP = 0.71498*CCTVA[-1]/JPGDP[-1] + 0.06814*CCTME - 0.66564
(9.8964) (4.12280) (1.99506)

Sum of Squares	9.2668	Standard Error	0.6347
R Squared	0.9614	Dependent Variable Mean	4.2383
Adjusted R Squared	0.9581	F 2, 23	286.584
Durbin Watson (1)	1.5942	Durbin Watson (2)	1.3227
Durbin H Statistic	0.7304		

Eqation T8

Chihuahua City Average Hourly Wages, Ordinary Least Squares, 26 Observations

CCAHW/JPGDP = 0.58640*CCAHW[-1]/JPGDP[-1] - 0.00037*MXREX+
(6.44751) (3.45927)
+ 0.00034*CCMP + 0.04453
(3.47675) (3.10531)

Sum of Squares	0.0013	Standard Error	0.0078
R Squared	0.9057	Dependent Variable Mean	0.0633
Adjusted R Squared	0.8929	F 3, 22	70.4664
Durbin Watson (1)	1.5368	Durbin Watson (2)	1.9323
Durbin H Statistic	1.0969		

Notes: 1. Computed t-statistics appear in parentheses.
2. Lags appear in brackets.

Value-added is specified as a function of lagged productivity and the current level of employment in each of the respective metropolitan economies. In addition to accounting for the partial adjustment and autoregressive tendencies present in output per capita trends, this approach reduces simultaneity effects that can occasionally hamper achieving solution convergence criteria (Klein and Young, 1980). Again, the diagnostic characteristics and the simulation properties of this relatively simple specification are fairly good.

Because the parent companies for many maquiladoras are located in the United States, and the latter represents the target market for a high percentage of all in-bond factory output, the cost of doing business is monitored in dollar terms. Accordingly, hourly wages are modeled in dollars, as well. As shown in Table 3, domestic cost and pricing trends in Mexico are captured via the current period value of a real exchange rate index (Fullerton, 2001). Aggregate labor demand and overall industrial activity is approximated by the number of plants in operation in each labor market. Similar to the other equations, the estimation metrics and simulation behavior of this specification are relatively sound.

Theil inequality statistics are reported in Table 4. Each set of forecasts has Theil U-statistics that are close to zero in Table 4. For five of the eight variables modeled, the lowest inequality coefficients are calculated for the structural econometric forecasts. The best overall structural model performance is obtained for Ciudad Juarez. The random walk predictions are more competitive in the case of Chihuahua City. The scale of the in-bond manufacturing market is more limited in the state capital and the history of the industry much shorter then in its larger industrial neighbor to the north. Of most interest to international investors, model-based predictions of hourly wages are relatively accurate for both markets.

Table 4

Root Mean Square Error and Theil Inequality Statistics

Forecast	RMSE	U-statistic	U-bias	U-variance	U-covariance
Ciudad Juarez Maquiladora Employment[1]					
Structural	29.30	0.020	0.178	0.001	0.821
Random Walk	28.84	0.021	0.010	0.000	0.990
RW with Drift	57.43	0.039	0.008	0.401	0.591

Ciudad Juarez Maquiladora Plants in Operation1					
Structural	20.94	0.010	0.071	0.001	0.928
Random Walk	27.83	0.014	0.000	0.074	0.926
RW with Drift	64.98	0.033	0.038	0.501	0.461
Ciudad Juarez Maquiladora Average Hourly Wages1					
Structural	0.49	0.187	0.339	0.001	0.659
Random Walk	0.53	0.216	0.472	0.002	0.526
RW with Drift	0.77	0.336	0.019	0.498	0.483
Ciudad Juarez Maquiladora Total Value Added1					
Structural	428.31	0.007	0.040	0.386	0.574
Random Walk	609.08	0.010	0.412	0.200	0.388
RW with Drift	1260.38	0.020	0.038	0.619	0.343
Chihuahua City Maquiladora Employment2					
Structural	6.39	0.040	0.478	0.071	0.451
Random Walk	4.36	0.028	0.080	0.062	0.858
RW with Drift	13.48	0.081	0.082	0.621	0.297
Chihuahua City Maquiladora Plants in Operation2					
Structural	7.84	0.022	0.723	0.013	0.264
Random Walk	4.76	0.014	0.443	0.004	0.553
RW with Drift	8.67	0.025	0.315	0.308	0.377
Chihuahua City Maquiladora Average Hourly Wages2					
Structural	0.79	0.218	0.292	0.008	0.700
Random Walk	0.86	0.267	0.215	0.029	0.756
RW with Drift	1.74	0.485	0.098	0.534	0.368
Chihuahua City Maquiladora Total Value Added2					
Structural	146.22	0.013	0.149	0.176	0.675
Random Walk	138.27	0.013	0.056	0.212	0.732
RW with Drift	396.60	0.032	0.276	0.580	0.144

Notes: 1. Forecast data for 1999-2006, 21 total observations.
2. Forecast data for 2000-2006, 18 total observations.

In general, the covariance proportion of the U-statistic represents the largest component of the total error for all of the forecast techniques. Because it measures random error in the forecasts, it is a positive outcome for all of the approaches and indicates that bias and variance sources of error contribute relatively little to the predictive inaccuracy for these data. The exceptions to this pattern for the econometric forecasts occur for Chihuahua City employment and factories. In both cases, exhibit relatively high levels of bias are reported. For these two variables, the structural model U-statistics exceed those of the random walk benchmarks, indicating that their respective equations are candidates for possible specification improvements.

As noted above, the RMSE and Theil inequality statistics are descriptive, only. The mean square error differential regression provides an alternative other way to test which set of forecasts is superior. The exact form of the test, and its outcomes, is determined by the signs of the regression coefficients in combination with the signs of the means of the competing sets of prediction errors (Ashley, Granger, and Schmalensee, 1980). Table 5 summarizes the results of the mean square error differentiated regression tests. The regression outputs for two null hypothesis tests are reported for each variable. The first set of results compares the structural econometric forecast errors to those calculated for random walk benchmarks. The second set compares the econometric prediction errors to those for the random walk with drift forecasts.

Table 5

Mean Square Error Differential Regression Results

Variable	**Most Accurate**	**β_1 (t-statistic)**	**β_2 (t-statistic)**	**Joint F-test (significance)**
Ciudad Juarez Maquiladora Employment[1]				
CJTME	Random	-15.180	0.040	0.917
	Walk	(-6.717)	(0.958)	(0.350)
CJTME with Drift	Structural	-7.168	0.417	27.643
	Econometric	(-1.152)	(5.258)	(0.000)
Ciudad Juarez Maquiladora Plants in Operation[1]				
CJMP	Random	-5.762	0.164	16.836
	Walk	(-3.047)	(4.103)	(0.001)
CJMP with Drift	Structural	7.155	0.569	89.857
	Econometric	(1.487)	(9.479)	(0.000)
Ciudad Juarez Maquiladora Average Hourly Wages[1]				
CJAHW	Inconclusive	-0.079	-0.018	0.078
		(-1.656)	(-0.280)	(0.783)
CJAHW with Drift	Structural	0.178	0.600	9.405
	Econometric	(1.080)	(3.067)	(0.006)
Ciudad Juarez Maquiladora Total Value Added[1]				
CJTVA	Inconclusive	-305.367	0.057	0.893
		(-5.881)	(0.945)	(0.356)
CJTVA with Drift	Structural	331.193	0.617	41.402
	Econometric	(2.334)	(6.434)	(0.000)

Chihuahua City Maquiladora Employment[2]				
CCTME	Random	-3.179	-0.052	0.629
	Walk	(-5.705)	(-0.793)	(0.439)
CCTME with Drift	Structural	-0.564	0.512	68.402
	Econometric	(-0.540)	(8.271)	(0.000)
Chihuahua City Maquiladora Plants in Operation[2]				
CCMP	Random	-3.500	-0.083	1.075
	Walk	(-6.002)	(-1.037)	(0.315)
CCMP with Drift	Structural	-1.802	0.321	9.724
	Econometric	(-1.688)	(3.118)	(0.007)
Chihuahua City Maquiladora Average Hourly Wages[2]				
CCAHW	Structural	0.030	0.073	0.904
	Econometric	(0.287)	(0.951)	(0.356)
CCAHW with Drift	Structural	0.972	0.733	17.069
	Econometric	(3.112)	(4.132)	(0.001)
Chihuahua City Maquiladora Total Value Added[2]				
CCTVA	Random	-89.107	-0.002	0.002
	Walk	(-6.632)	(-0.042)	(0.967)
CCTVA with Drift	Structural	151.804	0.676	17.874
	Econometric	(2.523)	(4.228)	(0.001)

Notes: 1. Forecast data for 1999-2006, 21 total observations.
2. Forecast data for 2000-2006, 18 total observations.

The results in Table 5 lead to different conclusions than those in Table 4. There is only one variable in Table 5, Chihuahua City average hourly wage (CCAHW), for which the structural (RSEM) forecasts are judged as more accurate. In two cases, Ciudad Juarez average hourly wage (CJAHW) and Ciudad Juarez total value-added (CJTVA), the results are inconclusive. In the remaining 5 cases, the random walk projections are judged as statistically more accurate then the RSEM forecasts. Interestingly, the random-walk with drift forecasts do not perform better than any of the 8 sets of previously published econometric forecasts. For an industry that has tended to consistently grows as much as the maquiladora sector has in Northern Mexico, that outcome is surprising. Given the demographic and labor market conditions prevailing in these metropolitan economies, the relative absence of statistical evidence in favor of the structural econometric forecasts is plausible (Charney and Taylor, 1984; West, 2003).

Conclusion

For more than four decades, the maquiladora industry has played a key role in the economic growth of the border region between the United States and Mexico. In-bond manufacturing activities are particularly strong in Ciudad Juarez and Chihuahua City. Structural econometric forecasts for these two metropolitan economies are published annually by the University of Texas at El Paso. Despite the importance of maquiladora activity in the border region, formal empirical assessment of the predictive accuracy of the forecasts published for these two markets has not previously been undertaken.

This study examines the historical track record of the structural equation maquiladora forecasts generated using the UTEP Borderplex Econometric Forecasting Model. The eight variables that are included come from the Maquiladora block of equations within the model for both Ciudad Juarez and Chihuahua City. These forecasts are three year simulations that appear in the Borderplex Economic Outlook reports published from 1999 through 2006. Combined, they provide a total of 21 observations for each variable in Ciudad Juarez and a total of 18 observations for each variable in Chihuahua City. The specific data series are total maquiladora employment, operating plants, average hourly wages, and total value added.

The benchmarks employed to gauge the relative accuracy of the econometric forecasts are random walks. Two accuracy metrics employed for this study. Based on the root mean square error, the Theil inequality coefficient is easy to interpret, but is descriptive, only. The error differential regression procedure is somewhat complicated to implement, but has formal statistical tests associated with it. Results using the Theil inequality coefficients indicate overall structural model superiority. Conversely, results using the mean squared error differential regression technique point to random walk superiority. Accordingly, corporate and public sector planners should probably exercise caution when using econometric forecasts of export activities in these metropolitan economies.

Accurate maquiladora forecasts would help clarify future economic trends and developments along the United States - Mexico border. Results obtained in this study indicate that achieving that objective may be difficult. As noted above, that is a potentially inescapable fact resulting from the demographic and labor market conditions associated with this regional economy. Whether this also is true of other important maquiladora regional markets such as Tijuana or Matamoros has yet to be determined. Additional empirical analysis of those areas and other international manufacturing regions would be helpful.

References

Ashley, R. (1988),. "On the relative worth of recent macroeconomic forecasts". *International Journal of Forecasting,* 4: 363-376.

Ashley, R., Granger C.W.J., and Schmalensee R. (1980), "Advertising and aggregate consumption: an analysis of causality", *Econometrica*, 48: 1149-1168.

Berk, J.M., and Bikker, J.A. (1995), "International interdependence of business cycles in the manufacturing industry – The use of leading indicators for forecasting and analysis". *Journal of Forecasting*, 14, 1-23.

Burstein, A., Kurcz, C., and Tesar, L. (2008), "Trade, production sharing, and the international transmission of business cycles". *Journal of Monetary Economics*, 55: 775-795.

Calderon Villarreal, C., and Mendoza Cota, J.E. (2001),. "Determinantes regionales de la maquila de exportacion en la frontera norte". *Frontera Norte*, 12: 59-84.

Cañas, J., Fullerton, T.M., Jr., and Smith, W.D. (2007), "Maquiladora employment dynamics in Nuevo Laredo". *Growth and Change*, 38: 23-38.

Christman, J.H. (2008), "Maquiladora industry outlook". *Global Insight Maquiladora Industry Outlook*, 39-106.

Charney, A.H. and Taylor, C.A. (1984), "Decomposition of ex-ante state model forecasting errors". *Journal of Regional Science*, 24: 229-247.

Coronado, R., Fullerton, T.M., Clark, D.P. (2004),. "Short run maquiladora employment dynamics in Tijuana". *Annals of Regional Science*, 38: 751-763.

Diebold, F.X., and Mariano, R.S. (1995), "Comparing predictive accuracy", *Journal of Business and Economic Statistics*, 13:253-265.

Fair, R.C., and Shiller, R.J. (1990), "Comparing information in forecasts from econometric models". *American Economic Review,* 80: 375-89.

Feenstra, R.C., and Hanson, G.H. (1997), "Foreign direct investment and relative wages: Evidence from Mexico's maquiladoras". *Journal of International Economics*, 42: 371-393.

Flores, R.T. (2001), "Mexico in the context of the North American integration: major regional trends and performance of backward regions". *Journal of Latin American Studies*, 33: 377-407.

Fullerton, T.M., Jr. (2001), "Specification of a borderplex econometric forecasting model". *International Regional Science Review*, 24: 245-260.

Fullerton, T.M., Jr. (2004), "Borderplex bridge and air econometric forecast accuracy". *Journal of Transportation and Statistics,* 7: 1-15.

Fullerton, T.M., Molina, A.L., Jr. (2007), "Borderplex economic outlook: 2007-2009". *Business Report SR07-2*, El Paso, TX: University of Texas at El Paso Border Region Modeling Project.

Fullerton, T.M., and Tinajero, R. (2002), "Cross border cargo vehicle flows". *International Journal of Transport Economics,* 29: 201-213.

Fullerton, T.M., and Torres Ruiz, L.B. (2004),. "Maquiladora employment dynamics in Chihuahua City", Mexico. *Journal of Developing Areas,* 38: 1-17.

Hagdorn van der Meijdan, L., van Nunen, J., and Ramondt, A. (1994), "Forecasting – Bridging the gap between sales and forecasting". *International Journal of Production Economics*, 37: 101-114.

Hanson, G.H. (2001), "U.S. - Mexico integration and regional economies: Evidence from border city pairs". *Journal of Urban Economics*, 50: 259-287.

Jordaan, J.A. (2008), "State characteristics and locational choice of foreign direct investment: Evidence from regional FDI in Mexico, 1989-2006". *Growth and Change*, 39: 389-413.

Kelin, L.R., and Young, R.M. (1980), *An introduction to econometric forecasting and forecasting models*, Lexington, MA: D.C. Heath and Company.

Kolb, R. A., Stekler, H.O. (1993), “Are economic forecasts significantly better than naïve predictions? An appropriate test”. *International Journal of Forecasting,* 9; 117-120.

Leuthold, R. M. (1975), “On the use of Theil’s inequality coefficient”. *American Journal of Agricultural Economics*, 57; 344-346.

Mollick, A.V., and Wvalle-Vazquez, K.W. (2006), “Chinese competition and its effects on Mexican maquiladoras”. *Journal of Comparative Economics*, 34: 130-145.

Pindyck, R.S., and Rubinfeld, D.L. (1998), *Econometric Models and Economic Forecasts* (4th Edition), Boston, MA: Irwin McGraw-Hill.

Satchi, M., and Temple, J. (2009), “Labor markets and productivity in developing countries”. *Review of Economic Dynamics*, 12: 183-204.

Stekler, H.O. (1968), “Forecasting with econometric models: an evaluation”. *Econometrica,* 36: 438-463.

Truett, D.B., Truett, L.J. (2007),. “NAFTA and the maquiladoras: boon or bane?” *Contemporary Economic Policy*, 25: 374-386.

West, C.T. (2003), “Structural regional factors that determine absolute and relative accuracy of U.S. regional labor market forecasts”. *Journal of Agricultural & Applied Economics*, 35 (Supplement): 121-135.