International Advances in Economic Research
Volume 7, 2001, pages 471-478.

Short-Run Maquiladora Employment Dynamics
JEL Category R23: Regional Labor Markets

Thomas M. Fullerton, Jr. & David A. Schauer
Department of Economics & Finance
University of Texas at El Paso
El Paso, TX 79968-0543
Telephone 915-747-7747
Facsimile 915-747-6282
Email tomf@utep.edu

Acknowledgments

Financial support for this research was provided by El Paso Electric Company, the Fulbright Council for International Exchange of Scholars, and the Public Policy Research Center at the University of Texas at El Paso. Helpful comments were provided by Jeff Brannon, Jim Peach, and seminar participants at UTEP, Universidad Autónoma de Ciudad Juárez, and New Mexico State University. Econometric research assistance was provided by Roberto Coronado and Roberto Tinajero.

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Abstract

The Ciudad Juárez maquiladora sector has grown enormously during the last three decades. In order to examine whether the trends underlying this remarkable performance are quantifiable, the short-term time series characteristics of this portion of the metropolitan economy are analyzed. Econometric methodologies employed include both univariate and transfer function ARIMA analysis augmented by causality testing for the latter. Data are drawn for the January 1981 - December 1998 sample period. Empirical results indicate that inflation adjusted wage rates, factories in operation, United States industrial performance, and the international value of the peso play important roles in determining month-to-month fluctuations in borderplex maquiladora payrolls.

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Introduction

Because fluctuation characterizes any regional economy over time, analysis of current and prospective business conditions receives much attention via academic, public policy, and corporate research efforts. Effective governmental and business policy recommendations frequently depend upon accurate understanding of regional trends in employment, income, population, housing and related variables. Fortunately, a variety of empirical modeling strategies exist that allow policy analysts to correctly identify the numerous cyclical, trend, and seasonal factors at play in regional markets.

Attempting such modeling efforts represents a complicated task for metropolitan areas that are adjacent to international boundaries. In such cases, local policy analysis must simultaneously take into account regional, national, and international business cycle effects. A well-known example of such an area is provided by the El Paso, Texas and Ciudad Juárez, Chihuahua "borderplex" economy. With approximately two million inhabitants, it represents the largest international metropolitan area along the border between Mexico and the United States.

During the past three decades, in-bond assembly manufacturing, or maquiladora, activities have emerged as one of the strongest segments of the regional border economies in northern Mexico. Economic impacts form this fast growing industry affect economic conditions on both sides of the border [Patrick, 1989; Vargas, 1995; Washington-Valdez, 2000]. In Ciudad Juárez, maquiladora plants generate approximately 57 percent of total jobs held in formal sector activities providing social security coverage. Annual fluctuations in maquiladora payrolls can be sizable and abrupt. More than ten thousand new jobs pre year were created on several occasions during the 1990s, sometimes representing double digit rates of increase [Fullerton, 2000a]. Whether such variability represents a shift in secular trends or is a consequence of shorter-term cyclical factors has important implications for future business conditions and policy design.

Given the importance of this sector to border communities, a wide variety of maquiladora industrial characteristics have been researched in recent years. Examples include employee turnover [Lucker and Alvarez, 1985; Lucker, 1987; English, Williams, and Ibarreche, 1989], international commuter flows [Cobb, Molina, and Sokulsky, 1989], cross-border jobs gains [Patrick, 1989], corporate profitability [Davila, 1990], sectoral growth determinants [George and Hoffman, 1990], global labor markets [Gruben, 1990], trade liberalization [Brannon and James, 1994], spatial employment patterns [Silvers and Pavlakovich, 1994], retail sales [Ayer and Layton, 1974], and cross-border business cycle interactions [Fullerton, 1998]. Although numerous aspects of the in-bond industries have been investigated, research efforts to date have not examined short-run employment trends of this fast growing export sector. Ciudad Juárez, Chihuahua has the greatest volume of jobs associated with maquiladora firms of any single border metropolitan area

[Christman, 1999]. It thus provides a logical starting point from which to study short-term twin plant labor market time series characteristics.

Subsequent sections of the paper are as follows. Section two provides an overview of related literature on short-term time series analysis. Section three summarizes data and methodology. Empirical results are reported in section four. Conclusions and suggestions for future research are presented in the final section.

Regional Time Series Literature

Among the several basic modeling techniques that have been adopted in the analysis of international, national, regional, and metropolitan economies, two econometric approaches stand out. The latter include large-scale systems of equations econometric models and small-scale time series statistical models. Both methodologies have been applied to the analysis of border regions between Mexico and the United States [Fullerton, 1998; 2000b; 2001]. Each technique is well-suited to the analysis of multi-faceted border markets due to their respective flexibility in handling distinct data generating processes.

Short-term time series analysis for monthly data sets frequently relies upon the broadly defined class of autoregressive moving average (ARIMA) modeling strategies [Pankratz, 1983]. Within the various categories of ARIMA methodologies, transfer function analysis allows for the incorporation of independent variables to the basic univariate equation framework that underlies much time series econometric research [Box and Jenkins, 1976]. With respect to border areas, transfer function modeling has been utilized to examine commercial electricity consumption as well as international commuter flows [Fullerton, 1998, 2000b]. It offers an attractive means for analyzing short-run employment trends in a growing industrial segment such as the maquiladora sector of Ciudad Juárez.

Data and Methodology

Metropolitan economic data in Mexico are generally published at annual and monthly frequencies. Given this fact, it is possible to apply short-term modeling techniques utilizing monthly data sets that are currently available in both hard copy and electronic formats. Maquiladora employment data for Ciudad Juárez are available from January 1981, determining the starting point for the sample period [see Instituto Nacional de Estadística, Geografía, e Informática web site]. Historically, this represents an interesting and important period for in-bond assembly activities in Mexico as it encompasses the maxi-devaluations of 1982, 1986, and 1994.

The other maquiladora data series included are the inflation adjusted wage and salaries index and the number of plants in operation in Ciudad Juárez. Maquiladora output is primarily exported to parent companies in the United States and is functionally dependent upon macroeconomic developments affecting demand for their products.

Aggregate business cycle conditions impacting in-bond assembly activities are approximated by the monthly industrial production index of the United States [Kremar, 1999]. Because the real wage index is measured in pesos, a real exchange rate index is also included in the analysis. Incorporation of the exchange rate as an independent variable is useful since it allows for heterogeneous reactions by international investment to distinct labor and currency market developments that affect dollar wage measures [Fullerton, Sawyer, and Sprinkle, 1999].

As mentioned above, transfer function analysis offers one means for examining systematic trends in a dynamic industry. Univariate ARIMA equations are first estimated for each of the variables utilized in the modeling system. The procedure entails identification, estimation, and diagnostic checking of a univariate specification for the stationary component of an individual data series (a stationary series is one whose mean and variance are both constant). Univariate ARIMA equation residuals, or unexplained movements in the dependent variable, are used to suggest input variable lag structures in multi-input transfer models. Subsequent steps involve estimation and diagnostic checking, also.

To investigate potential transfer lag structures, cross correlation functions (CCFs) are calculated between the output variable univariate residuals and the independent variable residuals [Mills, 1990]. The latter results may also be augmented by CCFs estimated for the stationary data series themselves. The transfer equation to be estimated will then involve a combination of the autoregressive and moving average parameters from the output variable univariate model plus lags of the regressor input variables. Standard diagnostic checking may require several rounds of re-estimation before a final model specification is selected. These results will indicate whether a quantifiable relationship exists between short-run maquiladora employment trends in Ciudad Juárez and real wages, factories in operation, and industrial activity in the United States.

The general functional format for modeling short-term maquiladora employment trends can be summarized as follows:

1. $$CJMQ_t = f(AR_{t-I}\ ,\ MA_{t-j}\ ,\ \underset{(-)}{\text{Real Wages}_{t-k}}\ ,\ \underset{(+)}{\text{Real Peso}_{t-m}}\ ,\ \underset{(+)}{\text{Factories}_{t-n}}\ ,\ \underset{(+)}{\text{U.S. Industrial Activity}_{t-s}})\ ,$$

where the algebraic signs under each of the independent variables indicates the nature of the hypothesized relationship between said regressor and the demand for labor. Because the real exchange rate is measured in pesos per dollar units, it is also expected to have positive coefficients associated with it. Time lags are allowed to vary for each of the explanatory variables as well as for the autoregressive and moving average parameters resulting from the univariate stage of the time series analysis.

Empirical Results

Stationary series, whose means (first moments) and variances (second moments) do not change over time, frequently have to be filtered from the raw series. For the data utilized herein, it was necessary to difference all of the series to obtain stationary working series. Table 1 summarizes the model specifications selected as part of the univariate time series modeling procedure. The sample period is from January 1981 to December 1998. Coefficient lag lengths appear in parentheses.

A total of five univariate ARIMA models are listed in Table 1, one for each of the variables utilized in the analysis. While not shown in Table 1, four of the five univariate equations contain positive and statistically significant intercepts. Because the series have been differenced prior to modeling, the positive constant terms reflect steady upward growth in each of the variables including real compensation. In addition to being statistically relevant, that characteristic of the univariate output is economically plausible for the sample period under consideration. Although the peso lost ground against the dollar during this time frame, much of that movement simply reflected large inflationary gaps between the trading partners. Consequently, the intercept for the real peso univariate equation was positive, but not significantly different from zero.

The equations for employment, compensation, the United States industrial production index, and the real exchange rate all contain first order moving average coefficients. The latter is not surprising given that all of the data were differenced prior to estimation. Three of the five series result from fairly complicated mixed data generating processes. Maquiladora factories in operation, however, is represented by a model that contains only a third degree autoregressive parameter. Similarly, the currency equation contains a sixth order autoregressive term in addition to the aforementioned moving average coefficient.

Residuals from the maquiladora aggregate employment univariate model were cross correlated against lags of the other univariate equation residuals. The CCF output suggested the initial lag structures to be built into the transfer ARIMA model for in-bond assembly payrolls in Ciudad Juárez. The final equation specification and econometric results are reported in Table 2. Regressor lag lengths appear in parentheses.

All of the regressor series are found to impact maquiladora employment within periods of twelve months or less. All of the coefficients carry the hypothesized algebraic signs shown above in Equation 1. Because the data have been differenced prior to estimation, the coefficient of determination for the dependent variable used in modeling is fairly low (R-squared = 0.263578). Adjusting the fitted data back to level form, however, allows calculating a "pseudo" coefficient of determination. This measure indicates that the model explains more than 99 percent of the variation in Ciudad Juárez maquiladora employment levels over the sample period in question.

Not surprisingly for a labor demand equation, changes in real wages were found to strongly affect jobs in this industrial sector. Four separate wage coefficients, estimated at lags 1, 2, 3, and12, appear in Table 2, twice as many as for any of the other input series. For factories in operation, one parameter is estimated at lag 11. Maquiladora payrolls react very quickly to movements in the United States industrial production index, possibly reflecting the influence of just-in-time inventory management practices and greater integration of the two national economies. Parameters associated with north-of-the border industrial activity are estimated at lags 2 and 4.

Two lags are also included for the inflation adjusted exchange rate. The reaction times with respect to changes in the real value of the peso is much longer, 11 and 12 months, respectively. The latter probably reflects the fact that flexible exchange rates tend to be relatively volatile over short-run periods. Given this, managers generally do not alter production patterns in response to short-run currency market developments. Because of the different lag structures associated with the wage and exchange rate variables, it is fairly clear that allowing for potentially heterogeneous employment responses to changes in these variables is advisable.

While all of the independent regressors have the expected algebraic signs associated with them, the intercept term and two other coefficients fail to satisfy the 5-percent significance criterion. The latter include the factories in operation series, lagged 11 months, and the 4-month lag of the working series for industrial activity in the United States. As shown by the F-statistic, the pseudo R-squared estimate, and the Q-statistic for residual white noise, the overall fit of the model is fairly good. Accordingly, the low t-statistics are likely attributable to multicollinearity resulting from the presence of twelve regressor terms and a constant. Given that the vast majority of the slope coefficients are statistically significant, this does not represent a serious flaw in the model. Because the Q-statistic is so low, it also apparent the equation specification does not overlook or fail to account for any systematic movement in the dependent variable.

Conclusion

Given its impact upon borderplex employment, income, and retail sales performance, as well as its importance as a bellwether for global manufacturing and commercial trends, numerous aspects of the maquiladora industry have been investigated in recent years. This paper employs time series econometric techniques examine short-term dynamics in monthly employment totals. Data utilized in the study are for Ciudad Juárez, Chihuahua. As Ciudad Juárez is home to the largest concentration of maquiladora jobs in all of Mexico, it makes a good starting point from which attempt such a modeling effort.

Among the various results uncovered, several stand out. The in-bond assembly industry reacts very quickly to business stimuli. None of the four input variable categories have lags associated with them that exceed twelve months. With statistically significant impacts occurring within two months or less, payroll reaction times with respect to real wages and industrial activity are especially rapid. Although exchange rate changes bear directly on dollar denominated wage equivalents, the lag structure for variations in the real currency value of the peso is distinctly different from that associated with the real wage index.

Given these initial results, additional research utilizing separate data sets and/or methodologies should be undertaken in order to confirm the relationships uncovered above. It would also be useful to attempt to extend these results to other border labor markets to provide evidence as to whether these results are unique to short-run maquiladora employment trends in Ciudad Juárez. For comparative purposes, replication of this modeling effort for interior geographic regions may also help shed light on this type of cross-border economic linkage between Mexico and the United States.

Future research should be encouraged by the fact that these initial results exhibit fairly strong econometric traits, but additional confirmation would likely prove useful. Because of numerous domestic economic policy shifts in Mexico, and ongoing commercial regulatory changes under the North American Free Trade Agreement, experimentation with both longer and shorter sample periods may help uncover potential parameter instability. Identification of such structural breakpoints should help clarify as well as quantify the empirical regularities associated with cross-border business and economic linkages between Mexico and the United States.

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TABLE 1
Univariate ARIMA Model Specifications

Variable	Description	Equation Specification	
DCJ	Ciudad Juárez Maquiladora Employment	AR(12)	MA(1, 12)
DS	Real Salary Index	AR(12)	MA(1, 4, 12)
DP	Ciudad Juárez Maquiladora Plants in Operation	AR(3)	
DI	United States Industrial Production Index	AR(1, 3)	MA(1, 3)
DX	Inflation Adjusted Exchange Rate (P/$)	AR(6)	MA(1)

Sample period: January 1981 - December 1998

TABLE 2
Transfer ARIMA Model

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	67.44990	63.69913	1.058883	0.2910
DS(-1)	-5.615133	1.113977	-5.040616	0.0000
DS(-2)	-3.642331	0.977392	-3.726580	0.0003
DS(-3)	-2.454954	0.882777	-2.780946	0.0060
DS(-12)	-4.163552	0.976175	-4.265170	0.0000
DP(-11)	39.21366	32.46117	1.208017	0.2285
DI(-2)	810.0531	231.5167	3.498897	0.0006
DI(-4)	324.7033	228.3160	1.422166	0.1566
DX(-11)	34.14305	13.60551	2.509502	0.0129
DX(-12)	32.23265	13.13452	2.454041	0.0150
AR(12)	0.515040	0.076486	6.733824	0.0000
MA(1)	-0.331375	0.056201	-5.896215	0.0000
MA(12)	-0.589285	0.056399	-10.44856	0.0000

R-squared	0.263578	**Akaike information criterion**	18.23041
Pseudo R-squared	0.997815	**Schwarz criterion**	18.44186
S.E. of regression	2133.381	**Observations**	204
Sum squared residuals	8.69E+08	**F-statistic**	5.696843
Log likelihood	-1846.502	**Probability (F-statistic)**	0.000000
Durbin-Watson statistic	2.047348	**Q(24)**	9.436600
Mean dep. variable	828.9069	**Probability (Q-statistic)**	0.997000
S.D. dependent var.	2411.425	**Iterations to convergence**	8

Sample period: January 1981 - December 1998