Borderplex Economic Growth: Chicken, Egg, or Scrambled?

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ABSTRACT

Regional economic growth patterns exhibit a wide variety of patterns throughout the world. While some areas may have clearly dominant growth poles, others may not. Debates over what area is the primary engine of growth for a particular region can be intense. Such discourse is often voiced with respect to expansion in the El Paso – Ciudad Juarez borderplex regional economy. To date, there have been no empirical studies conducted that attempt to answer this intriguing question. By applying statistical analyses to employment and population growth rates, the current study examines the nature of economic growth within these sister cities. Does Ciudad Juarez employment growth cause El Paso employment growth? Has population driven employment in these areas, or has employment caused population to expand? Is there clear evidence in favor of economic dominance in either city?

INTRODUCTION

In recent years, economic expansion among cities located along the United States - Mexico border has become increasingly reliant on international factors. Such is the case in the El Paso - Ciudad Juarez Borderplex economy. Favorable economic conditions north of the border have helped enhance labor market conditions in Ciudad Juarez (Fullerton & Tinajero, 2005). Growth in Ciudad Juarez has also buttressed economic performance in El Paso (Cañas, 2002). Furthermore, international trade agreements such as the North American Free Trade Agreement (NAFTA) have also led to increased economic interplay between these two cities (Hanson, 2001).

Despite extensive investigation into their economic linkages, inquiry into the cause-effect relationships of these border markets is surprisingly absent. This study analyzes growth patterns for the El Paso - Ciudad Juarez borderplex in an attempt to identify if one city is the primary source of expansion for the region as a whole. Similar questions have been examined in previous research, most colorfully by Thurman & Fisher (1988). That effort presents relatively conclusive unidirectional evidence that the egg, indeed, came before the chicken. A similar argument rages on the border regarding which sister city is the hub and which is the peripheral wheel rim.

Earlier studies confirm a symbiotic economic relationship between the borderplex markets. Structural econometric evidence reported in Fullerton (2001) indicates that growth in both economies is interdependent on business conditions in the other. The maquiladora sector of Ciudad Juarez employs more than 200,000 workers, the highest of all Mexican cities. That translates into increased employment in several key El Paso sub-sectors (Cañas, 2002).

Furthermore, the maquiladora industry is dependant upon several segments of the El Paso economy. To date, it has not been determined whether cross-border growth patterns between these cities are sequential or simultaneous.

In a recent study of eleven Virginia metropolitan statistical areas (MSA), Shuai (2005) examines the causal links between sub-urban and urban economies. That effort employs statistical tools to help clarify the nature of regional development in that state. This paper carries out a similar effort for the El Paso-Ciudad Juarez borderplex. By applying statistical analyses to employment and population growth rates, the current study examines the nature of economic growth within these sister cities. Does Ciudad Juarez employment growth cause El Paso employment growth? Has population driven employment in these areas, or has employment caused population to expand?

Subsequent segments of the study are arranged as follows. The second section contains a literature review of related studies. That section is followed by a description of the methodology used for testing the causal relationships between employment and population growth rates. Next, a brief summary of the available data for the El Paso-Ciudad Juarez borderplex utilized in this exercise is presented. Empirical results are then summarized. Finally, implications for regional economic development and suggestions for future research are provided in the conclusion.

LITERATURE REVIEW

Shuai (2005) examines the causal links between urban and suburban economic growth among eleven Virginia metropolitan statistical areas (MSA). Total employment is used as a broad measure of economic activity and economic growth is approximated by the employment growth rate. Variables in this study include employment and population growth rates for both urban and suburban economies. Although ten of the eleven metropolitan statistical areas (MSAs) within this study exhibit positive correlations between urban and sub-urban employment growth, a Granger causality F-test is used to determine the temporal order between the two (Granger, 1969). Using pooled data over a fifteen year period, the results indicate that suburban economic growth is not caused by city employment expansion. Tests on population growth suggest that both suburban and urban employment growth are caused by demographic expansion.

Carlino & Mills (1987) provide a highly integrated approach to understanding employment and population fluctuations throughout various regions. The approach utilizes a wide range of variables for approximately 3,000 counties in the United States. Dependent variables in this study include population, total employment, and manufacturing employment. A key sector for many counties within the sample is manufacturing. Accordingly, the effects of the independent variables on manufacturing employment are analyzed separately. Results support the traditional view that suburbanization stems from factors such as increased crime rates and higher taxes. A negative relationship is also uncovered between manufacturing sector employment and population. The elasticities calculated indicate that income positively affects regional employment and population patterns.

Sole-Olle & Viladecans-Marsal (2004) evaluate economic growth trends within 28 Spanish metropolitan areas over a 35-year period. Linkages between urban and suburban growth are examined in order to determine whether or not urban growth generates significant returns to metropolitan growth. It is noted that rising incomes and changing economic structure have fueled an increase in urban sprawl. Long-run equilibrium relationships between urban and suburban

growth are estimated using a vector error correction model. Results suggest that central city growth leads to long run suburban expansion in Spain.

Vias (1999) studies employment and population trends within the Rocky Mountain region of the United States. This region has exhibited cycles of economic growth and decline that coincide with rural area trends. Employment in this region is found to be driven by population. This trend has resulted from an increase in the demand for environmental amenities, as well as from an increase in the ability of firms to relocate into non-metro areas. Increased demand for environmental amenities within the Rocky Mountain West has also lessened the volatility typically associated with resource based regional economies.

Voith (1992) analyzes whether suburban and urban growth rates substitute or complement each other. Suburban growth may be viewed as a substitute for urban growth when there is a negative correlation between the two. A negative correlation would also imply that suburbs may still grow during periods of urban decline. Numerous factors such as changes in public policy have led to an increase in suburban appeal in recent decades. Suburban and urban economies may be subject to similar external forces, so correlation between growth in these areas should be interpreted cautiously. Positive correlations between suburban and urban growth rates within the sample indicate that they are complementary in nature.

Voith (1998) also examines the relationships between city and suburban growth rates. Relatively limited attention has been given to city and suburban economic linkages despite rapid suburban and metropolitan expansion. Sample correlations suggest that suburban and urban economies move in the same direction. This study ties city income growth to suburb income, employment, and population growth to test whether or not urban growth causes suburban growth. Simultaneity, along with exposure to similar external influences, pose obstacles to evaluating causal linkages. The model developed addresses these issues by incorporating three separate indicators of suburban expansion. Results indicate that urban income growth leads to significant growth in suburban areas, especially in those areas with large metropolitan cities.

Hanson (2001) observes economic activity within ten major border city pairs over a 10-year period. The objective is to assess whether or not further United States - Mexico integration has lead to economic growth along the border. One outcome of greater integration has been an increase in manufactured goods trade. Border cities provide good settings for examining trade policies. Labor demand across several U.S. border city industries is estimated as a function of export manufacturing in Mexican border cities. Ordinary least squares (OLS) regression results indicate that increased export manufacturing in Mexico border cities leads to greater demand for goods and services produced north of the border. The results further suggest that there is no statistically significant relationship between Mexican export manufacturing and United States interior city employment.

Other studies also provide evidence regarding the demand-side approach to economic growth, or the "people follow jobs" hypothesis as it commonly known. Freeman (2001) notes that outcomes supporting either the demand-side or supply-side approach are possible due to empirical difficulties in distinguishing causality. Results often vary depending on the empirical approach utilized, and the time period in question. For the border region, an elasticity of employment with respect to population of 2.22 is calculated. This figure suggests that the effect of population on employment is greatest in states located along the border. The latter is attributed to the significant impact of immigration shocks on border employment growth, a trend that differs substantially from other regions of the United States. Overall, the findings of this study support the demand-side approach to economic growth.

Mendoza-Cota (2006) studies the role of increases in border commerce and foreign direct investment on economic growth along the United States - Mexico border. Fluctuations in foreign direct investment significantly impact employment dynamics within the maquiladora industry, with this industry fueling economic activity within the border region. OLS regressions are used to estimate the effects of several explanatory variables on real per capita incomes in seven major border cities. Results obtained therein confirm that increases in foreign direct investment positively affect income performance. Overall, this study suggests that increased economic integration has fueled metropolitan economic growth along the border.

South-of-the-border growth engine proponents abound, also. Cañas (2002) contends that recent El Paso expansion should be attributed to proximity to Ciudad Juarez. Location quotient analysis of several basic industries is used to study business development in El Paso. Industry concentration shifted toward service oriented forms of employment during the 1990s. Transportation industry concentration is found to be much higher than what it is in other major urban economies. Results indicate that the regional economy is heavily influenced by business conditions on both sides of the international border.

In a subsequent study of border region economies, Cañas, Pallares, & Ruiz (2005) study key sectors among the four major Texas-Mexico city pairs. Because 32 percent of in-bond industry employment is located next to Texas, growth in Mexico's border cities is argued as having been driven by the maquiladora industry. Growth in the in-bond assembly sector also drives the demand for goods and services produced on both sides of the border. Location quotients suggest that the four city pairs exhibit complementary growth patterns as consequences of cross border economic linkages. Simultaneity, rather growth primacy, would seem to be likely on the basis of those observations. Formal testing can potentially help unravel the evidence.

DATA AND METHODOLOGY

Several studies have attempted to quantify cross-border economic ties between El Paso and Ciudad Juarez (Fullerton, 1998; 2001). Those efforts, have not, however, attempted to establish causality directions in the borderplex regional economy. This section summarizes the data and econometric approach used in this analysis.

Data sets for international border cities are limited in nature and scope (Fullerton, 2003). However, annual time series data for population and employment exist for the El Paso-Ciudad Juarez borderplex. For El Paso, total employment and population data for the period of 1975-2004 are utilized. Maquiladora employment and total population data for Ciudad Juarez are used for the same period. Ciudad Juarez total formal sector employment data are also used, but they only date back to 1990. Formal sector jobs are those covered by the Mexican social security system. All of these data are available on the University of Texas at El Paso Border Region Modeling Project website (www.academics.utep.edu/border).

Granger causality F-tests are applied to growth rates for each of the variables included (Pindyck & Rubinfield, 1998). Similar to other recent studies (Shuai, 2005; Sollie-Olle & Viladecans-Marsal, 2004), total employment growth is used as the primary indicator for economic activity. Variable definitions appear in Table 1.

Figure 1 depicts the various causality scenarios that may be uncovered by an empirical analysis of the data series listed in Table 1. The estimates in Tables 2 and 3 exhibit positive correlations between El Paso and Ciudad Juarez employment growth. That relationship also strengthened during the second half of the sample period when trade barriers between the two

countries began to be reduced. These correlations indicate that cross border economic growth is complementary (Voith, 1992). Simple correlation coefficients, of course, do not reveal causality. A positive correlation can result from numerous factors (Shuai, 2005). Importantly, causal linkages between growth in both areas may be bi-directional. F-tests tests can help clarify whether expansion on one side of the border precedes growth on the other side.

Table 1
Mnemonics and Definitions

Variable	*Definition*
G_t^{EP}	El Paso total employment growth rate
POP_t^{EP}	El Paso population growth rate
G_t^{CJ}	Ciudad Juarez total employment growth rate
G_t^{CJM}	Ciudad Juarez maquiladora employment growth rate
POP_t^{CJ}	Ciudad Juarez population growth rate

Figure 1
Potential Causal Linkages among Variables

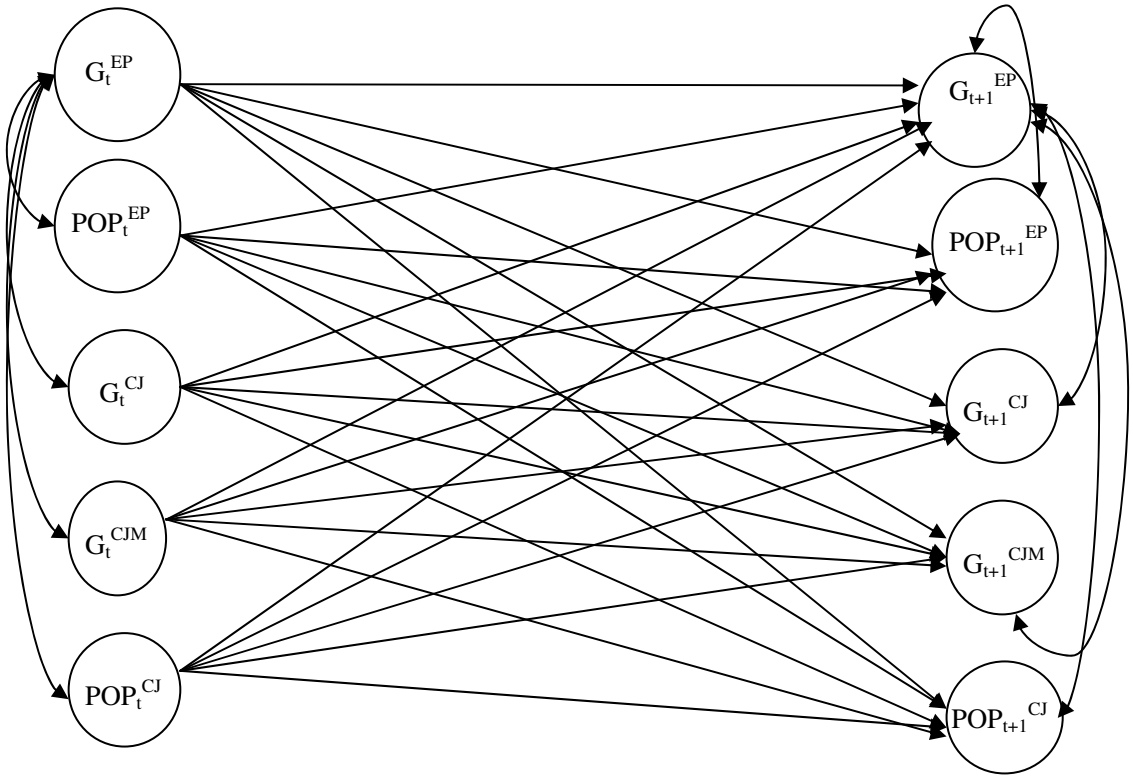

Table 2
El Paso Total Jobs & Cd. Juarez In-Bond Jobs Growth Correlation1975-2004

Variable	G_t^{EP}	G_t^{CJM}
G_t^{EP}	1	0.33
G_t^{CJM}	0.33	1

Table 3
El Paso Total Jobs & Cd. Juarez In-Bond Jobs Growth Correlation, 1990-2004

Variable	G_t^{EP}	G_t^{CJ}
G_t^{EP}	1	0.42
G_t^{CJ}	0.42	1

To test whether total employment growth in El Paso precedes maquiladora employment growth in Ciudad Juarez in a statistically reliable manner, two sets of symmetric regression equations are estimated. Evaluation of the results is carried out using an F-test for each pair of OLS regressions. Given the small number of sample observations, one-year lags are utilized in the equation specifications. Rejection of the null hypothesis for Equations (1) and (2), $\beta_1 = 0$, suggests that total employment growth in El Paso precedes Ciudad Juarez maquiladora employment growth, but does not guarantee causality.

Unrestricted regression $$G_t^{CJM} = c_1 + \alpha_1 G_{t-1}^{CJM} + \beta_1 G_{t-1}^{EP} + e_t \quad (1)$$
Restricted regression $$G_t^{CJM} = c_2 + \alpha_2 G_{t-1}^{CJM} + u_t \,, \quad (2)$$

where c_1 and c_2 represent constant terms while e_t and u_t are random error terms.

Hypothesis 1: Total employment growth in El Paso precedes maquiladora employment growth in Ciudad Juarez.

A symmetric equation is also estimated to test whether or not maquiladora employment growth in Ciudad Juarez precedes total employment growth in El Paso. In order to conclude that total employment growth in El Paso causes employment growth in the Ciudad Juarez maquiladora sector, the null hypothesis for Equations (3) and (4), $\beta_1 = 0$, must be accepted.

Unrestricted regression $$G_t^{EP} = c_1 + \alpha_1 G_{t-1}^{EP} + \beta_1 G_{t-1}^{CJM} + e_t \quad (3)$$
Restricted regression $$G_t^{EP} = c_2 + \alpha_2 G_{t-1}^{EP} + u_t \,. \quad (4)$$

Hypothesis 2: Maquiladora employment growth in Ciudad Juarez precedes total employment growth in El Paso.

The formula to compute the F-statistics is shown in the Equation (5):

$$F_{q,\,n-k} = \frac{(ESS_R - ESS_{UR})/q}{(ESS_R)/(n-k)}\ , \qquad (5)$$

where:
q = number of coefficient restrictions,
n = number of observations,
k = number of estimate parameters in the unrestricted equation,

$ESS_{UR} = \sum_{t=1}^{T} e_t^{\,2}$, and

$ESS_R = \sum_{t=1}^{T} u_t^{\,2}$.

Similar equations are also estimated to examine the relationship between population and employment growth in the borderplex. The following equations are used to examine the causal linkages between El Paso population growth and total employment growth. Rejection of the null hypothesis embodied in Equations (6) and (7), $\beta_1 = 0$, implies that population growth precedes employment growth in El Paso.

Unrestricted regression $G_t^{EP} = c_1 + \alpha_1 G_{t-1}^{EP} + \beta_1 POP_{t-1}^{EP} + e_t$ (6)
Restricted regression $G_t^{EP} = c_2 + \alpha_2 G_{t-1}^{EP} + u_t$. (7)

Hypothesis 3: Population growth in El Paso does not lead employment growth in El Paso.

To complete the causality test, the possibility that El Paso total employment growth occurs prior to El Paso population growth is examined. Failure to reject the null hypothesis associated with Equations (8) and (9) must occur in order to conclude that total employment growth is Granger caused by population growth.

Unrestricted regression $POP_t^{EP} = c_1 + \alpha_1 POP_{t-1}^{EP} + \beta_1 G_{t-1}^{EP} + e_t$ (8)
Restricted regression $POP_t^{EP} = c_2 + \alpha_2 POP_{t-1}^{EP} + u_t$. (9)

Hypothesis 4: Employment growth in El Paso does not lead population growth in El Paso.

The relationship between Ciudad Juarez population and maquiladora employment is tested next. Rejection of the null hypothesis for Equations (10) and (11), $\beta_1 = 0$, would indicate that maquiladora employment growth precedes population growth within Ciudad Juarez.

Unrestricted regression $POP_t^{CJ} = c_1 + \alpha_1 POP_{t-1}^{CJ} + \beta_1 G_{t-1}^{CJM} + e_t$ (10)
Restricted regression $POP_t^{CJ} = c_2 + \alpha_2 POP_{t-1}^{CJ} + u_t$. (11)

Hypothesis 5: In-bond assembly employment growth in Ciudad Juarez does not lead population growth in Ciudad Juarez.

Next, the reverse relationship is tested. Accordingly, the null hypothesis for Equations (12) and (13), $\beta_1 = 0$, must be accepted in order to conclude that maquiladora employment leads Ciudad Juarez population growth in a unidirectional manner. Given the labor shortages that have been frequently observed in this metropolitan economy, this is a reasonable hypothesis.

Unrestricted regression $G_t^{CJM} = c_1 + \alpha_1 G_{t-1}^{CJM} + \beta_1 POP_{t-1}^{CJ} + e_t$ (12)
Restricted regression $G_t^{CJM} = c_2 + \alpha_2 G_{t-1}^{CJM} + u_t$. (13)

Hypothesis 6: Population growth in Ciudad Juarez does not precede in-bond manufacturing growth in Ciudad Juarez.

To determine whether El Paso population growth precedes in-bond manufacturing employment growth in Ciudad Juarez requires the following tests. If Ciudad Juarez maquiladora employment follows population growth in El Paso, then the null hypothesis for Equations (14) and (2), $\beta_1 = 0$, will be rejected.

Unrestricted regression $G_t^{CJM} = c_1 + \alpha_1 G_{t-1}^{CJM} + \beta_1 POP_{t-1}^{EP} + e_t$ (14)
Restricted regression $G_t^{CJM} = c_2 + \alpha_2 G_{t-1}^{CJM} + u_t$. (2)

Hypothesis 7: Maquiladora employment growth in Ciudad Juarez follows El Paso population growth.

A symmetric set of equations is next estimated to allow for the possibility that Ciudad Juarez maquiladora employment growth leads El Paso population growth. In this case, the null hypothesis for Equations (15) and (9), $\beta_1 = 0$, must be accepted in order to conclude that El Paso population growth occurs prior to Ciudad Juarez maquiladora employment growth.

Unrestricted regression $POP_t^{EP} = c_1 + \alpha_1 POP_{t-1}^{EP} + \beta_1 G_{t-1}^{CJM} + e_t$ (15)
Restricted regression $POP_t^{EP} = c_2 + \alpha_2 POP_{t-1}^{EP} + u_t$. (9)

Hypothesis 8: Maquiladora employment growth in Ciudad Juarez does not occur prior to El Paso population growth.

Equations are then estimated in order to test whether Ciudad Juarez population growth leads to total employment growth in El Paso. Rejection of the null hypothesis, $\beta_1 = 0$, for Equations (16) and (7) would indicate that El Paso employment growth is preceded by population growth in Ciudad Juarez.

Unrestricted regression $G_t^{EP} = c_1 + \alpha_1 G_{t-1}^{EP} + \beta_1 POP_{t-1}^{CJ} + e_t$ (16)
Restricted regression $G_t^{EP} = c_2 + \alpha_2 G_{t-1}^{EP} + u_t$. (7)

Hypothesis 9: In-bond assembly employment growth in Ciudad Juarez does not lead to total employment growth in El Paso.

Next, a test is conducted to determine if El Paso total employment growth occurs prior to population increase in Ciudad Juarez. If Ciudad Juarez population growth precedes El Paso employment growth in a statistically significant manner, the null hypothesis, $\beta_1 = 0$, for Equations (17) and (11) will fail to be rejected.

Unrestricted regression $POP_t^{CJ} = c_1 + \alpha_1 POP_{t-1}^{CJ} + \beta_1 G_{t-1}^{EP} + e_t$ (17)
Restricted regression $POP_t^{CJ} = c_2 + \alpha_2 POP_{t-1}^{CJ} + u_t$. (11)

Hypothesis 10: Employment growth in El Paso does not lead population growth in Ciudad Juarez.

A sequence of equations is also estimated using Ciudad Juarez total employment. Those data are available from 1990 forward. The following equations are estimated to determine whether or not El Paso total employment growth leads total employment growth in Ciudad Juarez. Rejecting the null hypothesis, $\beta_1 = 0$, for Equations (18) and (19) would suggest that total employment growth in Ciudad Juarez is statistically linked to El Paso total employment growth.

Unrestricted regression $G_t^{CJ} = c_1 + \alpha_1 G_{t-1}^{CJ} + \beta_1 G_{t-1}^{EP} + e_t$ (18)
Restricted regression $G_t^{CJ} = c_2 + \alpha_2 G_{t-1}^{CJ} + u_t$. (19)

Hypothesis 11: Total employment growth in El Paso does not precede total employment growth in Ciudad Juarez.

Symmetric equations are then estimated to test if El Paso total employment growth is functionally dependent on total employment growth in Ciudad Juarez. If El Paso total employment growth precedes Ciudad Juarez total employment growth in a unidirectional manner, the null hypothesis, $\beta_1 = 0$, for Equations (20) and (7) will be accepted.

Unrestricted regression $G_t^{EP} = c_1 + \alpha_1 G_{t-1}^{EP} + \beta_1 G_{t-1}^{CJ} + e_t$ (20)
Restricted regression $G_t^{EP} = c_2 + \alpha_2 G_{t-1}^{EP} + u_t$. (7)

Hypothesis 12: Total employment growth in Ciudad Juarez does not occur prior to total employment growth in El Paso.

Causality F-tests are then conducted to determine whether population growth leads total employment growth in Ciudad Juarez. Rejection of the null hypothesis, $\beta_1 = 0$, for Equations (21) and (19) indicates that population growth occurs in advance of total employment growth in Ciudad Juarez.

Unrestricted regression $G_t^{CJ} = c_1 + \alpha_1 G_{t-1}^{CJ} + \beta_1 POP_{t-1}^{CJ} + e_t$ (21)
Restricted regression $G_t^{CJ} = c_2 + \alpha_2 G_{t-1}^{CJ} + u_t$. (19)

Hypothesis 13: Population growth in Ciudad Juarez does not precede total employment growth in Ciudad Juarez.

Determining whether population growth Granger causes total employment growth in Ciudad Juarez also requires the following test. If total population growth Granger causes total employment growth in Ciudad Juarez, failure to reject the null hypothesis, $\beta_1 = 0$, for Equations (22) and (11) will be observed.

Unrestricted regression $POP_t^{CJ} = c_1 + \alpha_1 POP_{t-1}^{CJ} + \beta_1 G_{t-1}^{CJ} + e_t$ (22)
Restricted regression $POP_t^{CJ} = c_2 + \alpha_2 POP_{t-1}^{CJ} + u_t$. (11)

Hypothesis 14: Total employment growth in Ciudad Juarez does not occur in advance of population growth in Ciudad Juarez.

The final causality test examines the relationship between total employment growth in Ciudad Juarez and El Paso population growth. Equations are first estimated to determine if El Paso population growth changes in advance of Ciudad Juarez total employment growth. The null hypothesis, $\beta_1 = 0$, for Equations (23) and (19) will be rejected if El Paso population growth leads Ciudad Juarez total employment growth.

Unrestricted regression $G_t^{CJ} = c_1 + \alpha_1 G_{t-1}^{CJ} + \beta_1 POP_{t-1}^{EP} + e_t$ (23)
Restricted regression $G_t^{CJ} = c_2 + \alpha_2 G_{t-1}^{CJ} + u_t$. (19)

Hypothesis 15: Total population growth in El Paso does not precede total employment growth in Ciudad Juarez.

Equations are also estimated to test whether total employment growth in Ciudad Juarez precedes population growth in El Paso. In order to conclude that El Paso population growth leads to Ciudad Juarez total employment growth in a unidirectional manner, the null hypothesis, $\beta_1 = 0$, for Equations (24) and (9) must be accepted.

Unrestricted regression $POP_t^{EP} = c_1 + \alpha_1 POP_{t-1}^{EP} + \beta_1 G_{t-1}^{CJ} + e_t$ (24)
Restricted regression $POP_t^{EP} = c_2 + \alpha_2 POP_{t-1}^{EP} + u_t$. (9)

Hypothesis 16: Total employment growth in Ciudad Juarez does not change prior to population in El Paso.

Empirical results are summarized in the next section. The material discusses the outcomes for each pair of the causality F-tests specified above. The discussion also considers factors that may influence the estimation outcomes obtained.

Empirical Results

Recent regional economic studies involving Granger causality tests evaluate computed F-statistics at the 5-percent significance level (Freeman, 2001; Shuai, 2005). This study utilizes the same critical value benchmark. Table 4 summarizes the results of the causality test on growth between El Paso total employment and Ciudad Juarez maquiladora payroll employment. The F-statistic for the hypothesis that total employment growth in El Paso does not lead Ciudad Juarez maquiladora employment growth is 3.49 with a p-value of 0.07. Given that, the null hypothesis

cannot be rejected at the 95- percent confidence interval. However, the test results also indicate that the null hypothesis stating that maquiladora employment growth in Ciudad Juarez does not precede total employment growth in El Paso must be accepted at the same level of significance. The F-test score for that hypothesis is 2.48 with a p-value of 0.13. Each of the four equations used in this test exhibit relatively low coefficients of determination. This may reflect the general difficulty associated with modeling metropolitan growth rates and the fact that rates of change are generally harder to model than data in levels (Shuai, 2005). Autocorrelation does not appear to be present. Overall, the results in Table 4 indicate that El Paso total employment growth and Ciudad Juarez maquiladora employment growth are either contemporaneous as modeled in Fullerton (2001) or unrelated to each other.

Table 4
El Paso Employment Growth & Cd. Juarez Maquiladora Jobs F-Test Results

Hypothesis	**F-Test Score**	**P-Value**
H_0: $\beta_1 = 0$ => G^{EP} does not cause G^{CJM}	3.49	0.07
H_0: $\beta_1 = 0$ => G^{CJM} does not cause G^{EP}	2.48	0.13
	R^2	**Durbin-Watson**
Equation (1)	0.26	1.72
Equation (2)	0.14	1.86
Equation (3)	0.12	1.90
Equation (4)	0.02	1.95

The computed F-statistic for the hypothesis that El Paso population growth does not change in advance of El Paso total employment growth is 0.22 with a p-value of 0.64, indicating that the null hypothesis fails to be rejected (Table 5). The null hypothesis that total employment growth does not lead to population growth in El Paso exhibits an F-test score of 3.13 with a p-value of 0.09. At a 95- percent confidence interval, failure to reject the null hypothesis is observed in this case as well. Two of the four equations have low coefficients of determination. Serial correlation does not appear to be present in the residuals. Since failure to reject either hypothesis is observed, a statistically significant causal tie between prior period population and total employment growth rates in El Paso cannot be distinguished. The results in Table 5 suggest that current –year El Paso population and total employment growth may be mutually inter-dependant (Freeman, 2001).

Table 5
El Paso Total Employment Growth and El Paso Population Growth F-Test Results

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => POP^{EP} does not cause G^{EP}	0.22	0.64
H_o: $\beta_1 = 0$ => G^{EP} does not cause POP^{EP}	3.13	0.09
	R^2	**Durbin-Watson**
Equation (6)	0.03	1.98
Equation (7)	0.02	1.95
Equation (8)	0.68	2.12
Equation (9)	0.63	1.90

Table 6 reports the results of the Granger causality test on growth rates for Ciudad Juarez population and maquiladora employment. The first hypothesis tests whether population growth is not preceded by in-bond manufacturng employment growth in Ciudad Juarez. Surprisingly, with an F-test score of 0.03 and a p-value of 0.86, that null hypothesis fails to be rejected. Next, the reverse hypothesis is examined. The test of whether maquiladora employment follows population growth in Ciudad Juarez also produces a computed F-statistic of 0.03 with a p-value of 0.86. Once again, the null hypothesis cannot be rejected. Table 6 also exhibits low coefficients of determination for all four equations, while the Durbin-Watson statistics indicate minimal first-order autocorrelation. Because failure to reject both null hypotheses occurs, a clear case for causality cannot be made. Instead, the absence of a causal leader suggests that population and maquiladora employment growth rates move independently of each other in Ciudad Juarez or may occur simultaneously.

Table 6
Ciudad Juarez Population Growth & Maquiladora Jobs Growth F-Test Results

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => G^{CJM} does not cause POP^{CJ}	0.03	0.86
H_o: $\beta_1 = 0$ => POP^{CJ} does not cause G^{CJM}	0.03	0.86
	R^2	**Durbin-Watson**
Equation (10)	0.002	2.02
Equation (11)	0.001	2.03
Equation (12)	0.14	1.85
Equation (13)	0.14	1.86

Table 7 examines the relationship between population growth in El Paso and employment growth in the Ciudad Juarez maquiladora sector. The test of whether Ciudad Juarez maquiladora growth is not preceded by population growth in El Paso produces an F-statistic of 2.44 with a p-value of 0.13. Accordingly, the null hypothesis must be accepted. When the reverse hypothesis is tested, an F-statistic of 0.41 with a p-value of 0.53 is observed. Consequently, the null hypothesis that growth in the Ciudad Juarez maquiladora sector does not cause El Paso population growth cannot be rejected. The Durbin-Watson statistics for each equation are favorable, while the coefficients of determination are once again relatively low. Failure to reject both null hypotheses prevents a temporal order from being distinguished for these two variables. The results in Table 7 potentially indicate that El Paso population growth and employment growth in the Ciudad Juarez maquiladora sector occur simultaneously. The presence of the border may also cause the relationship between these series to be too weak to detect.

Table 7
El Paso Population and Ciudad Juarez Maquiladora Employment F-Test Results

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => POP^{EP} does not cause G^{CJM}	2.44	0.13
H_o: $\beta_1 = 0$ => G^{CJM} does not cause POP^{EP}	0.41	0.53
	R^2	**Durbin-Watson**
Equation (14)	0.22	2.03
Equation (2)	0.14	1.86
Equation (15)	0.64	1.88
Equation (9)	0.63	1.90

Table 8 presents the results of the Granger causality test on population growth in Ciudad Juarez and total employment growth in El Paso. A test of the first null hypothesis generates an F-statistic of 0.01 with a p-value of 0.90. This indicates that the hypothesis that Ciudad Juarez population growth does not lead to employment growth in El Paso cannot be rejected at a 95-percent confidence level. A test is then conducted to test whether El Paso total employment growth precedes Ciudad Juarez population growth in statistically significant manner. It results in an F-test score of 0.04 with a p-value 0f 0.85, suggesting that this null hypothesis must also be accepted. The Durbin-Watson statistics for each equation uncover little autocorrelation, while distinctly low coefficients of determination are exhibited. Based on the failure to reject the null hypotheses in both cases, a unidirectional causality link from population growth rates in Ciudad Juarez and El Paso total employment growth rates is not detected.

Table 8
Cd. Juarez Population Growth & El Paso Employment Growth F-Test Results

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => POP^{CJ} does not cause G^{EP}	0.01	0.90
H_o: $\beta_1 = 0$ => G^{EP} does not cause POP^{CJ}	0.04	0.85
	R^2	**Durbin-Watson**
Equation (16)	0.03	1.93
Equation (7)	0.02	1.95
Equation (17)	0.002	2.02
Equation (11)	0.001	2.03

Table 9 summarizes the results of the Granger causality test between total employment growth rates in Ciudad Juarez and El Paso. A test of the hypothesis that Ciudad Juarez total employment is preceded by El Paso total employment generates an F-test score of 0.04 with a p-value of 0.85. At a 5-percent significance level, the null hypothesis that total employment growth in El Paso does not move in advance of total employment growth in Ciudad Juarez cannot be rejected. The converse test is then conducted to see whether El Paso total employment growth follows Ciudad Juarez total employment growth. An F-statistic of 0.31 with a p-value of 0.58 results, suggesting that, once again, the null hypothesis must be accepted. The Durbin-Watson statistics in Table 9 are inconclusive at the 5-percent significance level. The growth rate equations also have noticeably low coefficients of determination. Because both null hypotheses are accepted, a clear case for total employment growth in El Paso occurring prior to employment expansion in Ciudad Juarez cannot be made.

Table 9
El Paso Total Employment Growth & Total Employment Growth in Cd. Juarez

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => G^{EP} does not cause G^{CJ}	0.04	0.85
H_o: $\beta_1 = 0$ => G^{CJ} does not cause G^{EP}	0.31	0.58
	R^2	**Durbin-Watson**
Equation (18)	0.48	1.35
Equation (19)	0.48	1.31
Equation (20)	0.02	1.51
Equation (7)	0.007	1.49

Table 10 summarizes the causality F-test results used to determine whether population growth precedes total employment growth in Ciudad Juarez. The test of the hypothesis that total employment growth is led by population growth yields a computed F-statistic of 3.07 with a p-value 0.09. That suggests that the first null hypothesis must be rejected. Next, the reverse relationship is tested. As shown in Table 10, a computed F-statistic of 2.94 with a p-value of approximately 0.10 is obtained. Consequently, the null hypothesis that Ciudad Juarez total employment growth does not occur prior to Ciudad Juarez total population growth is also rejected. Together, the results of this Granger causality test indicate that population and total employment growth in Ciudad Juarez are either independent of each other or may occur contemporaneously.

Table 10
Ciudad Juarez Population Growth & Total Employment Growth

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => POP^{CJ} does not cause G^{CJ}	3.07	0.09
H_o: $\beta_1 = 0$ => G^{CJ} does not cause POP^{CJ}	2.94	0.10
	R^2	**Durbin-Watson**
Equation (21)	0.54	1.33
Equation (19)	0.48	1.31
Equation (22)	0.15	1.97
Equation (11)	0.04	1.87

The final causality test examines the relationship between employment growth rates in Ciudad Juarez and population growth rates in El Paso. Equations are first estimated to determine if Ciudad Juarez employment growth follows El Paso population growth. With a computed F-test score of 2.25 and a p-value of 0.15, this first null hypothesis fails to be accepted at the 5-percent significance level (Table 11). A symmetric test is then conducted to determine whether total employment growth in Ciudad Juarez contributes to El Paso population growth. The second null hypothesis is rejected at the 5-percent significance level. That result implies that Ciudad Juarez total employment growth in one year precedes El Paso demographic expansion the following year in a statistically reliable manner.

Table 11
Ciudad Juarez Total Employment & El Paso Population Growth

Hypothesis	**F-Test Score**	**P-Value**
H_o: $\beta_1 = 0$ => POP^{EP} does not cause G^{CJ}	2.25	0.15
H_o: $\beta_1 = 0$ => G^{CJ} does not cause POP^{EP}	5.66	0.02
	R^2	**Durbin-Watson**
Equation (23)	0.52	1.60
Equation (19)	0.48	1.31
Equation (24)	0.49	2.35
Equation (9)	0.35	2.07

Tables 4 through 8 report the results of unidirectional causality tests on growth within the El Paso-Ciudad Juarez borderplex between 1975 and 2004. Variables included in the sample are El Paso total employment, El Paso population, Ciudad Juarez population, Ciudad Juarez

maquiladora employment, and Ciudad Juarez total employment. Although the debate has engulfed border economic discussions for many years, the test statistics reported herein are largely inconclusive with regard to which side of the borderplex is most economically catalytic.

Economic relationships between El Paso and Ciudad Juarez may be influenced not only by regional factors, but also by a multitude of economic factors within their respective countries. Institutional aspects of the international border that separates these urban economies undoubtedly weaken the economic linkages that geographic proximity and a sometimes waterless river channel would otherwise encourage. Potentially, these results also indicate that economic expansion within these two border cities occurred contemporaneously during the sample period in question. Variable regulatory and administrative practices may cause growth rate patterns to be so temporary in nature that they do not persist long enough for statistically verifiable patterns to be documented.

Tables 9 through 11 summarize the results of Granger causality tests on growth within the borderplex for the 1990-2004 sample period. For those tests, the length of the sample period is dictated by the availability of total formal sector employment data for Ciudad Juarez. Results reported in Tables 9 and 10 do not support Granger causality in either direction. The information in Table 11, however, indicates that growth in Ciudad Juarez total employment precedes demographic expansion on the El Paso side of the international boundary. Such an outcome may occur because economic expansion in Ciudad Juarez creates business opportunities in El Paso and reduces pressures to migrate from a labor market characterized by relatively high joblessness (Fullerton, Kelley, & Molina, 2007). Net migration into El Paso may also accelerate due to improved business conditions. The evidence in Table 11 is partially in line with time series evidence obtained using monthly frequency data for a different sample period (Mollick, Cortez-Rayas, & Olivas-Moncisvais, 2006).

The statistical results shown above indicate that neither economy serves as a catalyst for expansion on the opposite side of the Rio Grande. As noted earlier, the fact that these two markets are separated by an international boundary poses an obstacle that likely impedes the development of the types of causal linkages that might otherwise exist between these two economies (Fullerton, 1998). Under that circumstance, El Paso's economy will be influenced primarily by business conditions north of the border, while economic conditions in Ciudad Juarez will be dictated by business cycle developments outside of El Paso. Essentially, the fact that these geographically adjacent markets reside in separate countries may weaken the ties between them so much that statistically verifiable linkages are simply too elusive to uncover.

The unidirectional causality tests utilized in this exercise attempt to uncover statistically significant temporal patterns among population and employment growth rates. The fact that seven out of eight tests fail to distinguish causality may provide a key insight to the manner in which economic growth is transmitted within this region. Overall, these results potentially indicate that growth within these two markets occurs simultaneously. Since the results reported in Tables 4 through 10 do not support any specific causality paths, this may suggest that growth in the El Paso-Ciudad Juarez borderplex is contemporaneous in nature. Structural econometric evidence of such a relationship has been reported previously (Fullerton, 2001).

Finally, it should be noted that regional data quality may obscure the true nature of the cross-border economic relationships between these sister cities. On the north side of the river, numerous factors may contribute to erroneous population estimates due to migrant undercounts (Hill & Wong, 2005). On the south side of the river, rapid population inflows from other regions in Mexico have made it difficult to obtain accurate census counts in recent years. Similarly,

large numbers of workers work in the informal sector of the labor market and are not counted in the official employment statistics for Ciudad Juarez (Martin, 2000). Data for Ciudad Juarez are often subject to large revisions as well. Together, these problems make available statistical information for the borderplex imperfect at best and may contribute to the absence of causality patterns detailed above.

CONCLUSION

The relatively strong economic expansion recently observed within the borderplex is expected to continue well into the future. For the El Paso metropolitan economy, total employment and population are forecast to expand steadily during the next two decades. Similar trends are projected in Ciudad Juarez for total employment, population, and maquiladora sector employment (Fullerton, Kelley, & Molina, 2007). At present, it is not clear how cross-border growth patterns are transmitted between these two border economies. This research endeavor attempts to partially fill that gap.

To achieve that objective, Granger causality tests are applied to population and employment growth rates within the El Paso-Ciudad Juarez borderplex in order to determine whether economic expansion on one side of the border precedes growth on the other. Two distinct sample periods are utilized. In most cases, the results are inconclusive, indicating that growth in this regional economy is either contemporaneous or occurs independently of what happens on the opposite side of the border. One set of F-test results indicate that Ciudad Juarez total employment growth in one year is associated with stronger El Paso population growth during the following year.

The results reported for seven of the eight causality tests fail to distinguish any statistical precedence of one side of the border relative to the other. Collectively, these results suggest that growth within the El Paso-Ciudad Juarez region is potentially bi-directional and contemporaneous. As noted earlier, these results may also be affected by institutional factors associated with the border and issues regarding data quality. Also, while maquiladora sector employment figures are available from 1975, total employment data for Ciudad Juarez are available only as far back as 1990. Consequently, as more data become available, it will be important to confirm these initial results. Future efforts could also potentially incorporate data for other major border pairs located along the international boundary with Mexico in order to examine growth patterns in other border economies. For the time being, it appears that neither side of the border is catalytically more important than the other in an economic sense.

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Data Appendix
Population and Employment data for El Paso, TX and Ciudad Juarez, Chihuahua, Mexico

	Ciudad Juarez Population	Ciudad Juarez Maquiladora Employment	Ciudad Juarez Total Employment	El Paso Population	El Paso Total Employment
1975	486.934	19.775		427.292	181.964
1976	500.568	23.580		440.333	188.72
1977	514.584	26.792		450.007	192.976
1978	528.992	30.374		460.611	199.704
1979	543.804	36.206		472.343	207.56
1980	567.365	39.402		483.711	214.113
1981	587.790	43.994		497.523	222.769
1982	608.951	42.695		511.892	222.224
1983	630.873	54.073		521.038	219.06
1984	653.584	72.495		529.668	227.589
1985	677.113	77.592		538.809	232.684
1986	701.489	86.526		549.592	235.286
1987	726.743	97.805		559.479	245.712
1988	752.906	110.999		568.804	254.861
1989	780.010	124.386		580.982	264.76
1990	798.499	122.231	215.364	595.35	269.744
1991	832.834	123.971	213.482	608.206	271.741
1992	868.646	129.146	216.935	619.138	282.199
1993	905.998	132.046	225.545	634.044	289.462
1994	958.278	140.045	248.279	646.181	296.042
1995	1011.786	153.322	272.863	654.25	300.045
1996	1057.316	172.926	286.510	656.482	299.47
1997	1104.896	190.506	319.855	665.066	307.951
1998	1154.616	206.623	355.763	671.25	314.796
1999	1206.574	218.456	390.622	675.397	319.893
2000	1218.817	249.380	411.485	681.508	326.272
2001	1297.379	228.445	375.988	687.635	325.114
2002	1338.624	200.891	340.966	693.682	331.676
2003	1379.589	194.642	325.212	702.507	335.469
2004	1420.262	204.542	331.521	712.617	340.167

Notes:

1. Employment and population data for El Paso, TX are reported in thousands.
2. Employment and population data for Ciudad Juarez, Chihuahua, Mexico are reported in thousands.
3. These data are subject to annual revisions that periodically extend back several years.