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The Economies of El Paso and Ciudad Juárez

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Abstract

Any model that seeks to explain the interaction between human populations and the environment must take into account economic activity. For a given population, the level of economic development will determine the impact of human activity on the environment. Pollution generated from mining, manufacturing, and traffic is an example of how economic development can adversely affect the environment. Moreover, the higher per capita incomes associated with economic development generates demand for imports from developing countries, thereby increasing pollution in those countries.

Economic development has positive implications for the environment as well. With higher incomes people demand greater quality of life, one aspect of which is an improved environment. Indeed, it is axiomatic among development economists that people concerned literally with providing adequate nutrition for their families will not be interested in diverting resources to protecting the environment (this result arises as a straight-forward application of Maslow's Hierarchy of Needs). Economic development creates resources that can be used to deploy mitigating technology, such as smoke stack

scrubbers and sewage treatment plants. It is no coincidence that environmental laws are stronger and more strictly enforced in developed countries than in developing countries.[1]

The complicated interaction between the environment and economic activity is evident in the Paso del Norte region. Environmental stresses originating in one region influence environmental quality in others. The consequence of rapid economic growth in Ciudad Juárez, Chih., for example, has been the deterioration of air quality in El Paso, Tex., ultimately resulting in El Paso being designated by the U.S. Environmental Protection Agency (EPA) as a nonattainment zone for three criteria pollutants (ozone, particulate matter, and carbon monoxide). That is, economic development in the relatively low-income Ciudad Juárez has resulted in unacceptably high pollution in relatively high-income El Paso.[2] Water quality in the two cities is similarly linked.

This chapter develops a model for the El Paso-Ciudad Juárez border economy as part of the larger Border Plus Twenty Years (B+20) Project. Indeed, the economy is the driver behind the evolution of the other sectors of the model. A description of the El Paso and Ciudad Juárez economies is herein provided. Overall characteristics of the border economy are discussed. Particular emphasis is placed on the connections between the local and national economies, and between the U.S. and Mexican economies. The final section addresses documentation of the Paso del Norte economic model. A simple production function is specified, the labor market is modeled, and a reduced-form equation for the production function is derived. As is shown, the dynamics of production depends on the trajectory of population and the unemployment rate. The unemployment dynamics are modeled through the introduction of the business cycle. Further refinements of the model are discussed, including the modeling of employment by industry.

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Resumen

Cualquier modelo que busca explicar la interacción entre las poblaciones humanas y el medio ambiente debe tomar en cuenta la actividad económica. Para cualquier población, el nivel de desarrollo económico determinará el impacto de la actividad humana en el medio ambiente. La contaminación generada de la minería, manufactura, y el tráfico es un ejemplo de cómo el desarrollo económico puede adversamente afectar el medio ambiente. Además, los altos ingresos per capita asociados con el desarrollo económico generan demanda por importaciones de países en desarrollo, por lo tanto incrementando la contaminación en esos países.

El desarrollo económico también tiene implicaciones positivas para el medio ambiente. Con ingresos más altos las personas demandan mejor calidad de vida, un aspecto del cual es un medio ambiente mejorado. Ciertamente, es axiomático entre economistas de desarrollo que las personas preocupadas literalmente de proporcionar alimentación adecuada a sus familias no estarán interesadas en desviar recursos para proteger el medio ambiente. El desarrollo económico crea recursos que pueden ser utilizados para desplegar tecnologías atenuantes, como plantas de tratamiento de aguas residuales. No es una coincidencia que las leyes ambientales son más fuertes y más estrictamente aplicadas en países desarrollados que en países en desarrollo.

La interacción complicada entre el medio ambiente y la actividad económica es evidente en la región del Paso del Norte. Las presiones ambientales originadas en una región influencian la calidad ambiental en otra. La consecuencia de un rápido incremento económico en Ciudad Juárez, por ejemplo, ha significado el deterioro de la calidad

del aire en El Paso resultando ultimadamente en la designación por la Agencia de Protección Ambiental de los Estados Unidos (por sus siglas en inglés EPA), como una zona de no logro para tres contaminantes (ozono, materia particulada y monóxido de carbono). Esto es, el desarrollo económico en Ciudad Juárez, como una ciudad con un ingreso relativamente bajo, ha resultado en una alta contaminación inaceptable en El Paso, ciudad con un ingreso relativamente alto. La calidad del agua en las dos ciudades está unida similarmente.

Este capítulo desarrolla un modelo para la economía fronteriza de El Paso-Ciudad Juárez como parte del amplio Proyecto Frontera Más Veinte Años (F+20). Ciertamente, la economía es el motor detrás de la evolución de los demás sectores del modelo. En este trabajo también se proporciona una descripción de las economías de El Paso y Ciudad Juárez. Se discuten las características generales de la economía fronteriza. Se da un énfasis particular a las relaciones entre las economías de México y los Estados Unidos. La sección final aborda documentación del modelo económico del Paso del Norte. Se especifica una función de producción simple, se modela la fuerza de trabajo, y se deriva una ecuación de forma reducida para la función de producción. Tal y como se demuestra, las dinámicas de la producción dependen de la trayectoria de la población y del índice de desempleo. Las dinámicas de desempleo son modelados a través de la introducción del ciclo de negocio. De igual manera se discuten mejoras posteriores al modelo, incluyendo el modelado de empleo por industria.

The Economy of Paso del Norte

The Border

The U.S.-Mexican border region faces a unique set of circumstances that arises from the juxtaposition of two economies at very different levels of development. The border is 2,000 kilometers (km) long, stretching from San Diego, Calif.-Tijuana, B.C., on the Pacific coast to the Gulf of Mexico near Brownsville, Tex.,-Matamoros, Tam. It is the longest border between a developed and developing country in the world and is also the most frequently crossed. Adjusting for purchasing power parity, per capita income in the United States is about four times that of Mexico ($36,100 vs. $9,100).[3] The difference in per capita income leads to significant differences in important quality of life dimensions, as is obvious to even the most casual observer. Crossing the border from the United States to Mexico, one leaves a relatively prosperous developed country and enters a less-developed country. Living conditions are more crowded, the infrastructure is not as well maintained, and sanitation is poorer.

The situation is further complicated by the relative positions of the border communities within their respective countries (Erickson and Eaton 2001). The northern frontier of Mexico is characterized by the low incomes typical of developing countries, yet it is the wealthiest region in Mexico. La Frontera Norte is more industrial and more urban than most other regions of Mexico. On the other hand, the U.S. borderlands are among the poorest in the United States (Peach and Williams 2000). Per capita income is less than 80% of the national average and about 60% of the national average if San Diego is excluded. Unemployment is 50% greater than the national average. The poverty rate on the border is 25% compared to 13% for the United States as a whole.

All along the border are located a series of formal ports-of-entry. These serve as conduits for both commercial and migration flows, thereby creating economic opportunities (Forster and Hamlyn 2002). Most of the population on both sides of the border resides in communities that have developed around these ports-of-entry (Peach and Williams 2000). The largest of these are the twin cities of San Diego-Tijuana; Calexico, Calif.-Mexicali, B.C. (Imperial Valley); Nogales, Ariz.-Nogales, Son. (Ambos Nogales); El Paso, Tex.-Ciudad Juárez, Chih. (Paso del Norte); Eagle Pass, Tex.-Piedras Negras, Coah.; Laredo, Tex.,-Nuevo Laredo, Tam. (Dos Laredos); McAllen, Tex.-Reynosa, Tam.; and Brownsville-Matamoros.

Maquiladora Industry

Businesses often locate along the border to take advantage of the differences between the two countries in terms of wages and working standards. This is especially true of the maquiladora (or maquila) industry, which owes its existence to the exploitation of labor cost differentials between the United States and Mexico. A maquiladora is a facility that assembles components from parts manufactured by other firms, usually performing this task under contract with the original manufacturer. Because such assembly processes are typically labor-intensive, locating maquiladoras in low labor cost countries offers the potential for substantial savings for U.S. manufacturers. This, coupled with easy access to U.S. markets, makes the location of maquiladoras in Mexico, especially along the country's northern border, an attractive alternative to the operation of assembly plants in the United States.[4] Maquilas have become the pre-eminent form of industrial production along the U.S.-Mexican border.

Mexico's maquila program was formally initiated in 1965 as a means of attracting foreign investment, increasing exports, and fostering development, particularly along the border it shares with the United States. From the start, the program was criticized for its limited contribution to Mexican economic development. Maquiladoras used relatively few domestic intermediate goods and technology transfer to the rest of the Mexican economy was limited. At the same time, maquilas put substantial pressure on the Mexican infrastructure.

Before the signing of the North America Free Trade Agreement (NAFTA), all production generated in Mexican plants had to be returned to the originating country or exported to a third country. NAFTA initiated a two-phase change in the maquila program. During the first phase, from January 1994 to December 2000, maquilas continued to benefit from a waiver on Mexican import duties on raw materials and components, but also benefited from preferential duties on products satisfying NAFTA rules of origin (Coronado de Anda and Matulewicz 2003). Starting in 1994, the restrictions on the sale of maquila production domestically in Mexico were phased out. In 1994, maquilas were allowed to sell up to 55% of the value of the previous years' imports within Mexico. Thereafter the limit was increased by 5% until 2000, at which time the maquilas' restrictions on domestic sales ended (Watkins 1994).

The maquila industry is controversial. Many labor activists criticize the maquilas for the poor working conditions and low wages. Current salaries for laborers, who are often young women from the interior of Mexico, are less than $1.50 per hour.[5] Moreover, working conditions are inferior to those typically found in the United States, and living conditions are poor. Because the industry is not subject to U.S. labor laws, long workweeks, under-age employment, and dangerous working conditions are common (Dwyer 1994). Defenders of the maquila industry, while acknowledging that wages and working conditions in Mexican factories are low by U.S. standards, argue that wages are high compared to the country's interior and even higher when compared to many developing countries. Indeed, Mexico is not considered a low-wage country by international standards. Wages in the less-developed areas of East Asia, for example, are lower than in Mexico.

A more fundamental argument against maquilas is the role they play in Mexican development. In particular, in most cases, maquilas import materials from the United States and then export their production back to the United States. Often, even managerial and technical staffs are supplied from the United States. In essence, maquilas are extensions of U.S. corporate supply chains. Thus, there is little opportunity for backward links and forward links from the maquila sector to the rest of the Mexican economy (Sklair 1989). As a consequence, technology transfer is limited and economic development is slowed. The problem is acerbated by a deliberate policy of the Mexican government to maintain low wages in the maquila industry.[6] It is difficult to conceive of a policy more successful at promoting industrialization, yet less successful in promoting overall economic development, than the Mexican maquila program.

Another concern with the maquila industry is its impact on the environment. One of the major sources of air and water pollution in the border region's twin cities is the maquila industry. Many observers have pointed to environmental regulation as an important consideration in locating on the border. They argue that pollution-intensive industries seek to escape strict U.S. enforcement of environmental laws by relocating across the border to Mexico, where, it is argued, environmental regulations are less strictly enforced. In effect, the U.S. exports pollution to Mexico through the maquila industry.

On the other hand, transnational corporations look at all costs, not just regulatory costs, in deciding where to locate production.[7] Labor, transportation, material, administrative, and regulatory costs are all important considerations. Indeed, labor costs are traditionally the primary reason for locating production in Mexico. Moreover, while it is probably true that environmental laws are less strictly enforced in Mexico than in the United States, Mexico enforces environmental laws more strictly than many other developing countries. While there is some evidence at the margin of regulatory-induced industrial migration to the border, the effect is likely small compared to other factors.

The dominance of the maquila industry along the border represents a transition period in U.S.-Mexican trade between an era of high tariffs with little trade and the current era of NAFTA. NAFTA eliminated most tariffs on North American value-added products, thereby eliminating the special status enjoyed by the maquila industry. In essence, NAFTA transformed all Mexican manufacturing into maquilas (from the prospective of tariffs). Trade between the United States and Mexico has increased dramatically. Currently Mexico is the second largest trading partner of the United States, representing 9.5% of U.S. international trade. Some 75% of Mexican trade is with the United States. The dramatic increase in trade since the passage of NAFTA has increased the exposure of Mexico to the U.S. business cycle.

El Paso

El Paso, like other cities on the border, is characterized by low incomes, at least by U.S. standards. In 2000, per capita personal income was $18,535, which was 62.9% of national per capita income. Part of the reason for low per capita income is the high unemployment rate, which was at 8.7%, compared to 6.1% for the nation as a whole in November 2002.[8] A second reason for low earnings in El Paso is low salaries. In 2000, average earnings per job were 78.8% of the national average. A third factor is a higher dependency ratio—El Paso families tend to have more dependent children living at home, for example. More fundamentally, low incomes can be explained by low education levels, poor language skills, and racism that characterizes border communities.

Table 1 compares employment in El Paso to employment nationally by industry. The first column shows the share of employment by industry in El Paso, while the second column shows the same figure for the United States. The third column shows the difference between the two columns. Employment in agriculture and agriculture-related industries is less than the national average, but not out of line with other urban areas. El Paso employment shares exceed national averages in manufacturing and retail, as well as in transportation, public utilities, and communications (TPUC). Finance, insurance, and real estate (FIRE); general services; and government are approximately the same as the national average, although government employment is greater than average while employment in FIRE and general services is less than average.

The sensitivity of the El Paso economy to national business cycles is about average. Employment in cyclically sensitive industries—mining, construction, manufacturing, and TPUC—as well as in the cyclically insensitive industries such as FIRE, general services, and government, is about at the national average. Thus, factors driving the national business cycle in the national economy will also be present in the El Paso business cycle. One mitigating factor is the relative importance of oil and natural gas in the West Texas economy. This industry tends to be counter-cyclical, a fact that tends to mitigate the business cycle in El Paso. Countering this is the relative importance of textiles, which tend to be highly cyclical compared to other industries.

Anecdotal evidence would suggest that the concentrations in TPUC and retail are generated from transborder trade. Transborder drayage operations require increased warehouse and trucking services, which increases overall TPUC employment. Mexican shoppers, attracted by the greater variety and high quality of U.S. goods, tend to patronize retail establishments near pedestrian border crossings. To further explore these issues, detailed earnings data by industry are presented in Table 2.[9] Earnings within TPUC in El Paso exceed the national average in railroad transportation and for trucking and

Table 1. Comparison of Employment by Industry

Industry	Employment Share		
	El Paso	U.S.	Difference
Farm employment	0.30%	1.90%	-1.60%
Ag. services, forestry, fishing, and other	0.60%	1.30%	-0.70%
Mining	0.20%	0.50%	-0.30%
Construction	5.80%	5.70%	0.10%
Manufacturing	12.00%	11.40%	0.60%
Transportation and public utilities	5.80%	4.90%	0.90%
Wholesale trade	4.50%	4.50%	0.00%
Retail trade	17.20%	16.30%	0.90%
Finance, insurance, and real estate	6.20%	8.10%	-1.90%
Services	26.90%	31.80%	-4.90%
Government and government enterprises	20.50%	13.60%	6.90%
Total full-time and part-time employment	100.00%	100.00%	0.00%

Source: U.S. Bureau of Economic Analysis

warehousing, consistent with the theory that transportation employment arises from activity associated with the border. (Earnings within TPUC also exceed national averages in electricity, natural gas, and sanitation, which reflects the role of west Texas as a producer of natural gas.) Retail earnings are particularly strong in automobile sales, general merchandise, and miscellaneous merchandise—all categories in which Mexican shoppers are considered important customers. The earnings data, coupled with anecdotal evidence, points to the conclusion that above-average employment in TPUC and retailing is driven by transborder trade.

Table 2. Comparison of Earnings Share by Industry

Industry	El Paso	U.S.	Difference
Transportation communications and public utilities	8.31%	6.80%	1.51%
Railroad transportation	0.72%	0.23%	0.49%
Trucking and warehousing	2.48%	1.43%	1.05%
Water transportation	0.00%	0.15%	-0.15%
Other transportation	0.00%	1.65%	-1.65%
Local and interurban passenger transit	0.23%	0.23%	0.00%
Transportation by air	0.59%	0.99%	-0.39%
Pipelines, except natural gas	0.00%	0.02%	-0.02%
Transportation services	0.46%	0.41%	0.05%
Communications	1.88%	2.13%	-0.25%
Electric, gas, and sanitary services	1.93%	1.22%	0.71%
Retail trade	10.17%	8.70%	1.46%
Building materials and garden equipment	0.37%	0.51%	-0.14%
General merchandise stores	1.30%	0.93%	0.37%
Food stores	1.28%	1.24%	0.04%
Automotive dealers and service stations	1.79%	1.45%	0.33%
Apparel and accessory stores	0.49%	0.40%	0.08%
Home furniture and furnishings stores	0.52%	0.60%	-0.08%
Eating and drinking places	2.56%	2.03%	0.54%
Miscellaneous retail	1.85%	1.53%	0.32%

Source: Bureau of Economic Analysis

Ciudad Juárez

Ciudad Juárez is wealthy compared to Mexico as a whole, primarily because of the maquila industry, which is located there because of the city's proximity to the border. About 25% of all Mexican maquila employment is located in Ciudad Juárez.[10] The Ciudad Juárez maquila industry has long been characterized by labor shortages. As a consequence, unemployment in Ciudad Juárez averages only 52% of the Mexican national average. The industry provides a large number of jobs. Maquiladoras in Ciudad Juárez employed 289,000 people in 2001, of which 265,000 were hourly employees *(obreros)* and 24,000 were salaried employees *(empleados).* The median wage paid is $7,800 per year for hourly employees and $30,000 per year for salaried employees.

The maquila industry has recently fallen on hard times. Employment peaked in October 2000 and had declined by 25% by September 2002. The cause of the decline is controversial—different authorities point to different causes. One reason given is the slowing in the U.S. economy. However, the sharp decline in maquila production seems excessive given the relatively mild decline in the U.S. economy. Many observers believe that a major cause of the employment decline in Ciudad Juárez has been the loss of maquiladoras to China as a result of its entry into the World Trade Organization (WTO). The significance of this is difficult to assess. It is true that employment declines occurred during previous recessions, between 1983 and 1984 (6%) and 1990 and 1991 (9%), although those declines were for a shorter duration and were smaller in magnitude.

The Model

Basic Structure of the Model

The comprehensive approach envisioned by the Border Plus Twenty Years (B+20) Project requires compromises in the development of any one sector of the model for the overall model to be operational. Because the emphasis is on the interactions among the sectors, internal details of a given sector model are downplayed. These sorts of compromises are evident in the economy sector model described here. The model consists of a simplified production function coupled with a labor market and highly stylized business cycle. On the other hand, the model recognizes transborder interaction between national and local economies and through the inclusion of four sub-sectors—the United States and Mexico at the national level, and El Paso and Ciudad Juárez at the local level. This allows for a more detailed modeling of transborder economic interactions than is typical of most modeling efforts.

Economists have developed a number of models for evaluating an aggregate economy. Selecting a model to use in a given setting depends on the goal. In the context of the B+20 project, which seeks to evaluate the effects of various policies over a 20-year period, a relatively simple model that still captures the essence of long-run economic dynamics is needed. A model that achieves these goals is Solow's neoclassical growth model (see, for example, Jones 2002). The Solow growth model assumes that the economy uses two inputs—capital and labor—to produce a single product.[11]

The production function, which specifies the relationship between capital and labor inputs and production, is given by Equation 1:

$$Y_{it} = F(E_{it}, K_{it}, A_{it})$$

where,
Y_{it} = production per period
E_{it} = number of workers employed in production
K_{it} = the capital stock
A_{it} = a parameter-capturing technology[12]

Here, as well as in the rest of the chapter, the subscript $i \in \{US, Mex, EP, CJ\}$ indicates the sub-sector in which production takes place, and the subscript t = (1,2,3,...T)indicates the time period. Equation 1 says that production depends on employment, capital stock, and technology.

Operationalizing the model requires that a functional form for the production function be specified. Here, in Equation 2, it is assumed that production function in Equation 1 is Cob-Douglas:

$$Y_{it} = A_{it}\, K_{it}^{\beta}\, E_{it}$$

where,
Y_{it} = a parameter indicating the effect of capital deepening on labor productivity

The next step in operationalizing the model is to specify the accumulation rules for the stock variables of the model—A_{it}, K_{it} and E_{it}. Ideally, accumulation rules would be specified for each of the three stock variables. Unfortunately, reliable data for the capital stock are not available at the local level for El Paso and Ciudad Juárez, nor are they available at the national level for Mexico. Moreover, even for the United States, for which better data are available, disentangling the effects of capital deepening and technological progress on labor productivity is notoriously difficult. Therefore, a strategy of modeling labor productivity directly is adopted in Equation 3:

$$\alpha_{it} = A_{it}\, K_{it}^{\beta}$$

where,
α_{it} = labor productivity

Equation 3 says that labor productivity depends on two factors: technological progress, which is captured by A_{it}, and capital deepening, which is captured by K_{it}. α_{it} is assumed to increase at an exogenously determined rate, g_i. That is, $\alpha_{it} = (1+g_i)^t\, \alpha_{i0}$. The initial level of productivity, α_{i0}, is set to be consistent with the initial calibration of the model, i.e., $\alpha_{i0} = Y_{i0}/E_{i0}$.

Turning to the labor market, the following identity describes the relationship between the labor force, employment, and unemployment:

$$L_{it} \equiv E_{it} + U_{it}$$

where,
L_{it} = labor force
U_{it} = number of unemployed workers

Equation 4 says that, by definition, a labor force participant is either employed or not employed but seeking work. Those in the second category are considered unemployed. A person who is neither employed nor seeking work is not a labor force participant. The labor force is assumed to depend on population:

$$L_{it} \equiv \lambda_i P_{it}$$

where,
P_{it} = population
λ_i = the crude labor force participation rate

Substituting Equation 5 into Equation 4 and rearranging yields Equation 6:

$$E_{it} = (1-u_{it})\lambda_i P_{it}$$

where,
$u_{it} = U_{it} / L_{it}$= unemployment rate

Equation 6 indicates that the number of employed workers depends on population, the crude labor participation rate, and the rate of unemployment. Substitution of Equation 6 into Equation 2 results in the following, Equation 7:

$$Y_{it} = (1+g_{it})^t \alpha_{0t}(1-u_{it})\lambda_i P_{it}$$

This shows that the dynamics of production are driven by the population trajectory and the rate of unemployment. The population trajectory is taken from the demographic sector of the B+20 model. The rate of unemployment is determined by the business cycle, which is discussed in detail in the next section. Equation 7 also shows that to calibrate the model requires determining the value of g_i, α_{0i}, and λ_i. The values for these variables are given in Table 3.

Table 3. Initial Values Used to Calibrate the Simulation Model

Symbol	Variable	Value
g_i	Annual Productivity Growth	
	El Paso	2%
	Ciudad Juárez	2%
	United States	2%
	Mexico	2%
α_{Oi}	Initial Productivity	
	El Paso	50.00
	Ciudad Juárez	20.00
	United States	73.30
	Mexico	17.66
λ_i	Labor Force Participation Rate	
	El Paso	41%
	Ciudad Juárez	48%
	United States	51%
	Mexico	56%
U_{Nation}	Full Employment/Unemployment	
	United States	5%
	Mexico	5%
$\varphi_{i,i}$	Unemployment Sensitivity to an Employment Shock	
	United States/United States	1
	Mexico/Mexico	1
	Mexico/United States	1
$\Psi_{Local,National}$	Local Unemployment Sensitivity to National Unemployment	
	El Paso/United States	0.75
	Ciudad Juárez/Mexico	0.50
θ_{ij}	Industry Share	
	El Paso manufacturing	12.0%
	El Paso trade	24.7%
	El Paso other	66.3%
	Ciudad Juárez maquial	64.6%
	Ciudad Juárez trade	30.4%
	Ciudad Juárez other	15.0%

Source: Author

Business Cycles

The trajectory of the unemployment rate is determined by the business cycle. The business cycle, in turn, is modeled by assuming that recessions arrive at random intervals. This strategy was chosen for three reasons. First, there are theoretical reasons to believe that business cycle peaks and troughs are random events (Hall 1978). Second, several empirical studies have found that modeling the behavior of business cycles as random events is not inconsistent with the actual experience of the U.S. economy (e.g., Neftci 1984). Third and most important, developing a more complete business cycle model would be difficult and arduous yet would not enhance the usefulness of the economy sector to the B+20 Project.

A separate business cycle is developed for each of the sub-sectors. For the United States, the unemployment rate is given by Equation 8:

$$u_{USt} = u_{US} + \varphi_{US} D_{USt}$$

where,
u_{USt} = U.S. unemployment rate in period t
u_{US} = U.S. full employment rate of unemployment
φ_{US} = a coefficient indicating the magnitude of the business cycle
D_{USt} = a dummy variable indicating an employment shock in the form of a U.S. recession[13]

Equation 8 says that U.S. unemployment will be u_{US} percent, except during recessions, when it is $u_{US} + \varphi_{US}$ percent. Consistent with historical experience, the probability of a recession is set at 20% per year and the duration of recessions when they occur is set to one year.

The business cycle for the Mexican national sub-sector is assumed to consist in part on an internal component and in part on the status of the U.S. business cycle:

$$u_{Mext} = u_{Mex} + \varphi_{Mex} D_{Mext} + \varphi_{Mex,US} D_{USt}$$

where,
$u_{Mex,t}$ = Mexican unemployment rate in period t
u_{Mex} = Mexican full employment rate of unemployment
$D_{Mex,t}$ = a dummy variable indicating an employment shock originating domestically in Mexico[14]
φ_{Mex} = a coefficient indicating the sensitivity of the Mexican unemployment rate to Mexican employment shocks
$\varphi_{Mex,US}$ = a coefficient indicating the sensitivity of the Mexican unemployment rate to U.S. employment shocks

Equation 9 indicates that the Mexican unemployment rate depends on the status of the Mexican and U.S. business cycle. If neither economy suffers an employment shock, Mexican unemployment is at its full employment value, u_{Mex}. An employment shock to the Mexican economy increases Mexican unemployment by φ_{Mex} percent. An employment shock in the U.S. economy increases Mexican unemployment by $\varphi_{Mex,US}$ percent. The effects of U.S. and Mexican employment shocks are cumulative. The probability of a domestic employment shock in Mexico is set at 10% and it is assumed to be one year in duration.

Unemployment at the local level is assumed to depend on the unemployment in the respective national economy. Let $u_{EP,t}$ be unemployment in El Paso, and let $u_{CJ,t}$ be unemployment in Ciudad Juárez. Then Equations 10 and 11 are:

$$u_{EPt} = \psi_{EP,US} u_{USt}$$

$$u_{CJt} = \psi_{CJ,Mex} u_{Mext}$$

where,
$\psi_{EP,US}$ = sensitivity of El Paso unemployment rate to changes in U.S. unemployment rate
$\psi_{CJ,Mex}$ = defined similarly

Examination of Equations 8 through 11 shows that calibration of the model requires values for u_{US}, u_{Mex}, φ_{US}, φ_{Mex}, $\gamma_{Mex,US}$, $\psi_{EP,US}$, and $\psi_{CJ,Mex}$. These values are given in Table 3.

Further Refinements

Because employment in different industries may have different effects on the environment, especially on air quality, the model of employment is further refined to include employment by major industry. To accomplish this, employment in each industry is assumed to be a fraction of total employment:

$$E_{ijt} = \theta_{ijt}E_{it} = \theta_{ijt}(1-u_{it})\lambda_i P_{it}$$

where,
E_{ijt} = employment in region i by industry j in time period t
θ_{ijt} = share of total employment of the industry

The second equality in Equation 12 makes use of Equation 5. The industries modeled for Ciudad Juárez include maquila, retail and wholesale trade, and other; for El Paso the industries modeled include manufacturing, retail and wholesale trade, and other.

The trajectory of θ_{ijt} varies by industry. For each industry, θ_{ijt} consists of two components: a fixed share based on the long-term share of employment of that industry (denoted by $\bar{\theta}_{ijt}$), and an adjustment factor for the sensitivity of the industry to the business cycle (denoted by η_{ijt}). Thus, the trajectory of θ_{ijt} is given by Equation 13:

$$\theta_{ijt} = \bar{\theta}_{ijt}\eta_{ijt}$$

Table 4 gives the formula for the adjustment factor for each of the six industries included in the model. For the maquila industry, the adjustment factor is assumed to depend on employment growth in the U.S. and Mexican national economies. Given the export orientation of the maquila industry, the effect of the growth in the United States is given a greater weight than Mexican growth. The Ciudad Juárez trade sector adjustment is assumed to depend on growth of Mexican employment and on growth of maquila employment. Both the adjustment factor for El Paso manufacturing employment and El Paso trade employment are assumed to depend on growth employment in the Ciudad Juárez maquila industry.

Finally, other employment in both Ciudad Juárez and El Paso are assumed to track the general business cycle. That is, the adjustment factor for other employment in both cities is unity.

Table 4. Industry Cyclical Adjustment Factor

El Paso manufacturing	= 1 + % Δ Maquila Employment
El Paso trade	= 1 + % Δ Maquila Employment
El Paso other	1
Ciudad Juárez maquila	= 5 x % Δ U.S. GDP + % Δ Mex GDP
Ciudad Juárez trade	= % Δ Maquila Employment + % Δ Mex GDP
Ciudad Juárez other	1

Source: Author

Summing employment by industry determines adjusted total employment in Equation 14:

$$E'_{it} = \sum_i E_{ijt} = \sum_j \bar{\theta}_{ij}\eta_{ijt}(1 - u_{it})\lambda_t P_{it}$$

where,
E'_{it} = adjusted employment

Given that each η_{ijt} is a function of national employment, which in turn each depend on the national unemployment rates, it follows from Equation 14 that E'_{it} is a nonlinear function of the national unemployment rates. Using Equations 6 and 12 through 14 allows recovery of the El Paso and Ciudad Juárez unemployment rates in Equation 15:

$$u'_{it} \equiv \frac{U'_{it}}{L_{it}} = \frac{L_{it} - E'_{it}}{L_{it}} = \frac{\lambda P_{it} - \sum_j \bar{\theta}_{it}\eta_{ijt}(1 - u_{it})\lambda_t P_{it}}{\lambda_t P_{it}} = 1 - \sum_j \bar{\theta}_{it}\eta_{ijt}(1 - u_{it})$$

where,
u_{it} = adjusted unemployment rate

U'_{it} = adjusted unemployment

Substituting Equations 11 through 13 into Equation 3 yields Equation 16:

$$Y_{it}' = (1 + g_i)^t \alpha_{0t} \sum_j \bar{\theta}_{ij} \eta_{ijt} (1 - u_{it}) \lambda_t P_{it}$$

where,
Y'_{it} = adjusted production

Equation 16 says that production in El Paso and Ciudad Juárez is a nonlinear function involving population, the status of the adjustment factor for each of the six industries, and the status of the Mexican and U.S economies. Evaluation of Equation 16 reveals that in addition to the values previously specified, calibration of the model requires values for $\bar{\theta}_{ij}$, which are given in Table 2.

Endnotes

[1] The complicated interaction between economic development and the environment is summarized in the relationship referred to as the Environmental Kuznets Curve (EKC), which supposes an inverted-U relationship between development and pollution. The EKC assumes three stages of development. In the initial stage of development, increased economic activity results in increased pollution as production is shifted from relatively benign traditional agriculture toward industrial production. In the later stage, pollution drops as stricter enforcement of environmental standards take effect. At the middle stage of development, a balance is struck between increasing industrialization and increasing environmental enforcement so that pollution levels peak. There are two versions of EKC. The first version, for which there is strong evidence, measures pollution per unit of gross domestic product (GDP). The second version, for which there is weak or contradictory evidence, measures pollution in absolute terms. The failure of EKC in absolute terms means that economic

development, as measured by GDP, will generally result in environmental degradation. For further discussion of EKC, see Wheeler 2001.

[2] It might be argued that nonattainment status is determined by the U.S. Environmental Protection Agency (EPA) in accordance with federal law, therefore, it does not necessarily reflect local tastes for environmental quality. Rather, nonattainment status is based on national standards. Nevertheless, the basic argument still holds: Low environmental standards in the low-income community results in the compromise of standards in the high-income community.

[3] These are estimates for 2000, according to the CIA World 2002 Fact Book available at http://www.cia.gov/cia/publications/factbook/index.html.

[4] An important additional incentive for locating maquilas in Mexico is the favorable duty treatment that North American content enjoys under NAFTA.

[5] This number is derived from data provided by INEGI (www.inegi.gob.mx) in 2003 and is based on the author's calculations. The figure assumes an exchange rate of 10 pesos to the dollar and includes the value of fringe benefits.

[6] Generally speaking, wages in Mexico are not determined in the market. Instead, wages are set by negotiation between semi-official labor unions and the federal government. Thus, the central government has considerable influence over wages.

[7] If this was not true then all maquilas would relocate from Mexico to, say, Indonesia, where wages are far lower.

[8] The source of this section is the U.S. Bureau of economic activity.

[9] The detail presented in Table 2 is not available for employment at the SMA level.

[10] All data reported in this section are taken from www.inegi.gob.mx.

[11] The single output can be thought of as consisting of units of gross domestic product at the national level or as units of personal income at the regional level.

[12] A clarification concerning stocks verses flows is appropriate at this point. The STELLA® modeling software treats Y_{it}, A_{it}, K_{it} and E_{it} as stock variables. From an economic point of view, however, Y_{it} is a flow variable (e.g., income per year). Care needs to be taken to avoid confusion.

[13] That is, $D_{it} = \begin{cases} 1 & \text{if recession in economy.} \\ 0 & \text{otherwise.} \end{cases}$

[14] See footnote 12.

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