TRADE PATTERN ESTIMATION BETWEEN THE UNITED STATES AND MEXICO

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ABSTRACT

The North American Free Trade Agreement (NAFTA) established the largest free trade zone in the world, with a population of more than 360 million people. To evaluate potential investments in intermodal terminals near the U.S.-Mexican border—terminals that will handle the escalation in trade that is likely to result from NAFTA—transportation planners must understand current trade patterns. Unfortunately, most data required to achieve this understanding are considered confidential between the shipper and the government customs agency. However, both the governments of Mexico and the United States do release summaries of these shipment data. This paper presents a method for estimating commodity-based origin-destination matrices based on these summaries.

INTRODUCTION

The North American Free Trade Agreement is an important step in an evolutionary process that promises to integrate the economy of the United States more fully with the economies of Canada and Mexico. Currently, Canada and Mexico are the United States' first and third largest merchandise (nonservices) trading partners, representing more than $189 billion and $75.8 billion in annual merchandise trade, respectively. NAFTA established a phased elimination of tariff and most nontariff barriers to regional trade during the next 10 to 15 years and liberalized the rules governing the flow of capital investment within the three member countries. These policies will promote rational production of goods based on regional competitive advantages as individual firms struggle to become more competitive in an increasingly demanding global marketplace.

The transportation industry has a golden opportunity to facilitate this transition by making investments in infrastructure and improving operating policies designed to support these new regional trading patterns, especially between the United States and Mexico. A critical area for improvement is in the border crossings, where congestion and delays currently inhibit freight flows. Potential border crossing improvements include expansion of the physical infrastructure at existing crossings, development of entirely new crossings, improved information systems to reduce delays, and changes in regulations governing movements across the border.

SCOPE AND FOCUS OF THE PAPER

Rail, truck, and intermodal services play significant roles in moving freight across the U.S.-Mexican border. Evaluating potential investments in facilities or changes in operations at the border requires that we understand the nature of transborder freight flow patterns—by origin, destination, commodity, mode, and port of entry and exit. Furthermore, knowledge of current patterns is important in predicting possible changes in these patterns.

The U.S. and Mexican customs agencies record detailed information on each shipment that crosses the border, for import and export control and assessment of duties. However, this information is considered confidential between the shipper and the government and cannot be released publicly or used directly in public planning studies. Both customs services do release summaries of shipment data, organized so that origins and destinations cannot be directly linked and mode and port usage for any specific shipment cannot be identified.

These publicly available data are sufficient for reporting national trade statistics but are insufficient for planning studies of potential changes in border facilities and operations. The purpose of this paper is to describe a method for synthesizing estimates of origin-destination flows, by commodity class, transportation mode, and border crossing, using the data that are available. These estimated flows can then be used as the basis for a variety of planning studies.

The remainder of this paper is organized into four sections: (A) background on existing border crossings as well as the nature of the highway and rail networks with which the crossings connect; (B) description of available data on U.S.-Mexican commodity flows, which form the input to the flow synthesis process; (C) description of the process, consisting of estimating "port

FIGURE 1 Major crossings along the U.S.-Mexican border.

utilization" coefficients for various origin-destination–commodity-mode combinations and using these co-efficients within a large-scale optimization model to synthesize overall flow tables; and (D) conclusions and insights developed thus far in the continuing effort to apply this methodology to U.S-Mexican trade data.

BORDER CROSSINGS AND TRANSPORTATION INFRASTRUCTURE

There are 24 land crossings along the 2,000-mi border between the United States and Mexico. The five largest border crossings (Figure 1) account for 54 percent of the total value of imports to the United States and 83 percent of total exports to Mexico (Table 1).

In 1992 Mexican customs reported that 73 percent of the value of combined exports and imports between the United States and Mexico were transported by truck, 11 percent by rail, 10 percent by water, and 3 percent by air (1). Of the commodities moved by water, by dollar value more than 70 percent were from the oil-gas commodity groups—petroleum products moving primarily between Chiapas, Mexico, and Texas, Mississippi, and Louisiana. There is no reported category for intermodal movements in the mode-split figures reported by Mexican customs. The mode recorded for a shipment is the mode by which the shipment crosses the border; therefore, an intermodal container shipment that moves across the border by truck will be recorded as a truck movement in the data, regardless of how it reached the border.

The dominance of truck movements is related closely to the extensive *maquiladora* operations near the border. A *maquiladora* plant is a processing or manufacturing plant located in Mexico that takes imported components or materials, principally from the United States, performs further production or processing, and re-exports a majority of the result, typically back to the United States. U.S. customs duties are paid only on the value added in Mexico. In 1992 a

TABLE 1 1992 U.S. IMPORTS AND EXPORTS AT SPECIFIC BORDER CROSSINGS ($ BILLIONS)

Crossing	U.S. Imports	U.S. Exports
Laredo-Nuevo Laredo	6.5	15.4
El Paso-Juarez	6.5	6.0
San Ysidro-Tijuana	3.5	3.0
Brownsville-Matamoros	2.5	2.8
Nogales-Nogales	3.0	2.1
All others	18.6	5.9

Source: U.S. Customs Service.

TABLE 2 1992 RAILCAR VOLUMES AT SELECTED BORDER CROSSINGS (THOUSANDS)

Crossing	Rail Exports	Rail Imports
El Paso	15.6	8.6
Eagle Pass	28.3	10.2
Laredo	101.2	26.4
Brownsville	18.1	8.4

substantial fraction of the trade between the United States and Mexico was related to *maquiladora* production (41 percent of U.S. exports and 52 percent of U.S. imports).

Currently there are more than 2,000 *maquiladora* plants in Mexico, employing nearly half a million workers (2). More than half of the 100 largest companies in the United States have at least one such plant. Because of the nature of these plants, they are primarily located in the U.S.-Mexico border region. Seven cities—Juarez, Tijuana, Matamoros, Reynosa, Chihuahua, Nogales, and Mexicali—all of which are located near major border crossings, represent 60 percent of the *maquiladora* plants and employ 70 percent of the workers.

Thus many shipments between the United States and Mexico rely on only a small part of the Mexican transportation infrastructure, specifically, the highways connecting the *maquiladora* plants with the border. According to Mexican customs, more than 95 percent of transborder movements made by these plants are made by truck. By U.S. standards, the Mexican highway network is poor. In 1992 there were 28,722 mi of nontolled and 2,160 mi of tolled, paved two- and four-lane highways. The remainder of the 121,310 mi of the road system is composed of poorly paved and unpaved roads (3). Mexico is approximately one-fourth the size of the United States but has about one-twentieth of the United States' well-paved lane miles.

For movements deeper into Mexico, beyond the border *maquiladoras* region, rail plays a much larger role than trucks. The four largest rail gateways between the United States and Mexico are El Paso, Eagle Pass, Laredo, and Brownsville—all located in Texas. Table 2 presents the 1992 railcar volumes passing through these gateways, both northbound and southbound (4). The principal railroads involved at these gateways are Union Pacific, Southern Pacific, and Santa Fe. On the Mexican side of the border, connections are made with the Ferrocarriles Nacionales de Mexico.

SUMMARY OF AVAILABLE DATA

The data available for the estimation of the trade patterns between the United States and Mexico by commodity type are derived from three principle sources: the U.S. Customs Service (part of the Treasury Department), the U.S. Bureau of the Census (part of the Department of Commerce), and the Mexican Secretaria de Commercio y Fomento Industrial (Mexican customs). Almost all of the data are in the form of aggregate tables of dollar values of commodities moved.

Most commodity-specific data are reported using Standard Industrial Classification (SIC) codes, but some customs data are reported using "Schedule A" commodity groupings, which are employed for shipper's declarations. These two sets of commodity groupings frequently are inconsistent, and this represents a source of error in reporting some of the flows. For goods moving from the United States to Mexico, there are six basic sets of data:

- Value of exports to Mexico from each U.S. state by commodity class;
- Value of imports from the United States to each Mexican state by commodity class;
- Value of all goods shipped from each U.S. state through each U.S. border crossing;
- Value of goods moved through each U.S. border crossing by commodity class;
- Value of all goods shipped to each Mexican state through each Mexican border crossing; and
- Value of goods moved through each Mexican border crossing by commodity class.

Tables 3 through 8 illustrate portions of these six data sets. For imports to the United States from Mexico, the structure of the data sets is essentially identical, but the movements captured are in the northbound direction. Both U.S. customs data and census data contain information on exports and imports for each U.S. state by commodity class. However, the numbers differ between the two sources.

TABLE 3 SAMPLE OBSERVATIONS FROM THE DATA-SET REPORTING VALUE OF EXPORTS FROM SELECTED U.S. STATES BY COMMODITY CLASS ($ MILLIONS)

Exports

State	Chemicals	Electrical/ Electronics	Transportation	Total
California	266	1,388	369	6,006
Michigan	57	93	817	1,397
Texas	876	3,820	2,569	17,387

Source: U.S. Customs Service.

TABLE 4 SAMPLE OBSERVATIONS FROM THE DATA-SET REPORTING VALUE OF IMPORTS FROM SELECTED MEXICAN STATES BY COMMODITY CLASS ($ MILLIONS)

Imports

State	Chemicals	Electrical/ Electronics	Transportation	Total
Chihuahua	179	1,415	35	4,977
Sonora	57	296	26	1,508
Distrito Federal	1,044	1,350	719	12,090

Source: Mexican Customs.

TABLE 5 SAMPLE OBSERVATIONS FROM THE DATA-SET REPORTING VALUE OF ALL GOODS SHIPPED FROM SELECTED U.S. STATES THROUGH SELECTED U.S. BORDER CROSSINGS ($ MILLIONS)

State	Brownsville	El Paso	San Ysidro	Total
California	27	44	2,836	6,044
Michigan	30	8	1	1,397
Texas	1,885	5,597	7	17,387

Source: U.S. Customs Service.

TABLE 6 SAMPLE OBSERVATIONS FROM THE DATA-SET REPORTING VALUE OF GOODS BY COMMODITY CLASS EXPORTED THROUGH SELECTED U.S. BORDER CROSSINGS ($ MILLIONS)

Commodity	San Ysidro	Brownsville	El Paso	Total
Chemicals	156	490	99	2,766
Electrical/ Electronics	826	624	1,849	6,903
Transportation	162	205	176	5,440

Source: U.S. Customs Service.

TABLE 7 SAMPLE OBSERVATIONS FROM THE DATA-SET REPORTING VALUE OF ALL GOODS SHIPPED TO SELECTED MEXICAN STATES THROUGH SELECTED MEXICAN BORDER CROSSINGS ($ MILLIONS)

State	Matamoros	Juarez	Tijuana	Total
Chihuahua	8	4,634	2	4,976
Sonora	8	19	5	1,510
Distrito Federal	576	334	127	12,095

Source: Mexican Customs.

TABLE 8 SAMPLE OBSERVATIONS FROM THE DATA-SET REPORTING VALUE OF GOODS BY COMMODITY GROUP IMPORTED TO MEXICO THROUGH SELECTED MEXICAN BORDER CROSSINGS ($ MILLIONS)

Commodity	Matamoros	Juarez	Tijuana	Total
Chemical	0.46	0.18	.19	2.8
Electrical/ Electronics	1.0	1.3	1.2	7.4
Transportation	0.5	0.04	0.1	1.3

Source: Mexican Customs.

The data sets contain several problems that must be considered. First, U.S. and Mexican data are consistent. For example, the U.S. data set reports that $6.9 billion of electrical and electronic equipment is exported to Mexico, in contrast with the Mexican data set, which reports that $7.4 billion of goods within this commodity class is imported. This type of inconsistency is common throughout the data sets.

Second, each data set has a significant amount of missing information. This problem is most severe in the data sets reporting dollar value within each commodity group by U.S. port of entry and exit. Of the $40 billion in U.S. exports reported in the data set, $5.9 billion have no information regarding U.S. port of exit and/or no commodity content attached. Of the $35.2 billion in imports, $7.8 billion have no information regarding the U.S. port of entry and/or commodity content. In general, the Mexican data sets have less missing information, but the category of "nonclassifiable" is much larger. Specifically, of the $38 billion in Mexican imports and the $33.8 billion in Mexican exports, $4.9 billion and $0.5 billion, respectively, have this label.

Third, there is no commodity representation for movements with mixed loads. In general, the commodity class recorded is the one that comprises the largest part of the load.

Fourth, because many shipments switch modes and/or carriers at the border, there is a tendency to confuse these transhipping locations with the actual origin or destination of the shipment. This problem leads to incorrect recording of origins and destinations.

Finally, the data sets lack modal classification. This makes mode-specific estimation of flows based on these data virtually impossible. This problem will be alleviated somewhat through the publication of the 1994 modal split data by the Bureau of Transportation Statistics later this year. These data are derived from shipper export and entry declarations, whose reliability have been significantly enhanced through a change in regulation, instituted in May 1993, requiring all parties who file their export documentation electronically with U.S. customs to include the mode of transport and the Mexican destination state (5). Intermodal is not an option and therefore these movements will be recorded as any one of the modes used.

METHOD FOR ORIGIN-DESTINATION MATRIX GENERATION

The process for estimating an origin-destination matrix for each commodity group based on the observations in the data sets is an extension of a process developed by List and Turnquist (6), which involves inferring a set of flows that best fit the observations. The quality of the fit is measured by a weighted sum of the differences between the estimated values for the observations based on the inferred flows and the actual observations. The identification of the inferred flows that form the "best" fit is accomplished through a linear programming formulation in which each observation in the data set is expressed as a linear function of the decision variables, in this case the origin-destination flows by commodity group. The objective is to minimize the sum of the weighted difference between the estimates of the observations and the actual observations. The data sets contain three types of observations:

1. Dollar values of each commodity group at origin states and destination states;
2. Dollar values at each port within each commodity group; and
3. Dollar values by state at each port.

Dollar Value by Commodity Group at States of Origin or Destination

Originating/terminating commodity group dollar values (OT) provide estimates of the dollar value of trade within specific commodity groups originating or terminating in a particular state. For example, Table 3 reports that California exports to Mexico $265.9 million in chemicals. If the observation is at a state of origin, it represents a "row total" constraint on the origin-destination matrix of that commodity class. If the observation is at the destination state, it represents a "column total" constraint. If the observations are for originating states, they can be estimated by the decision variables as follows: observations are for terminating states, they can be estimated as follows:

$$\sum_{d} x_{odc} \quad \forall\ o, c$$

Likewise, if the observations are for terminating states, they can be estimated as follows:

$$\sum_{o} x_{odc} \quad \forall\ d, c$$

where x_{odc} = the decision variable representing the flow of commodity *c* from origin *o* to destination *d*.

Dollar Values at Each Port within Each Commodity Group

Commodity dollar values by port (CP) provide estimates of the total dollar volume, in a given commodity class, passing through a port in either the northbound or the southbound direction. For example, Table 6 reports that \$1.849 billion in electrical/electronics goods was exported through El Paso to Mexico in 1992. To express these observations in terms of the decision variables, we must estimate the proportion of the total volume passing through each port by origin-destination pair and commodity group (i.e., the proportion of a given origin-destination flow of a particular commodity group that will appear at a given port). These "port utilization" coefficients were developed using Dial's probabilistic path assignment algorithm (7). Let α_{odcp} represent the proportion of the total flow from origin o to destination d of commodity c, which will appear at port p, where

$$\sum_{p} \alpha_{odcp}=1 \quad \forall\, o,d,c\ .$$

The CP observations can be estimated by a linear combination of the decision variables and the port utilization coefficients as follows:

$$\sum_{o}\sum_{d} x_{odc}\alpha_{odcp} \qquad \forall c,p$$

Dollar Values by State at Each Port

Dollar values by port (DP) observations provide estimates of the total dollar volumes that appear at each port by state of origination or termination. For example, Table 5 reports that \$27 million in U.S. exports from California passed through the Brownsville border crossing. These observations are made either by state of export and export port or by state of import and import port. In both cases, these observations can be estimated by the decision variables and the port utilization coefficients defined previously. When the observation is by state of export and port of export the estimate is as follows:

$$\sum_{d}\sum_{c} x_{odc}\alpha_{odcp} \qquad \forall\, o,p$$

Likewise, if the observation is by state of import and port of import, the estimate is as follows:

$$\sum_{o}\sum_{c} x_{odc}\alpha_{odcp} \qquad \forall\, d,p$$

Model Description

As stated previously, the method used to infer a set of flows based on the observations is that of a large-scale linear program in which the objective is, based on the inferred flows, to minimize the weighted sum of the observations' deviations derived from the estimates, given the port utilization coefficients estimated using Dial's algorithm. The model is similar to one developed by List and Turnquist (6).

To simplify the notation used in expressing the model mathematically, we will introduce the subscript m to denote a market—a specific combination of origin, destination, and commodity—and the subscript k to denote a specific observed value of one of the three basic types described previously (i.e., OT, CP, or DP). Thus chemicals being transported from California to Chihuahua would constitute a "market" combination and be indexed by a single value of m. The observed value of chemicals originating in California and passing through the border crossing at San Ysidro would be indexed by a specific value of k.

With this change, the unknowns (decision variables) to be determined in the model can be denoted as x_m, rather than as x_{odc}, and the observed flow values from the various data sources can be denoted as b_k. The optimization model used to estimate the origin-destination flows can then be stated as follows:

Minimize

$$\sum_{k} [w_k^d(d_k^- + d_k^+) + w_k^e(e_k^- + e_k^+)]$$

Subject to

$$\sum_{m\in M_k} \alpha_{mk}x_m + e_k^- - e_k^+ + d_k^- - d_k^+ = b_k \quad \forall k$$

$$e_k^- \le E_k^- \quad \forall k$$

$$e_k^+ \le E_k^+ \quad \forall k$$

$$e_k^-, e_k^+, d_k^-, d_k^+ \ge 0 \quad \forall k$$

The notation:

α_{mk}

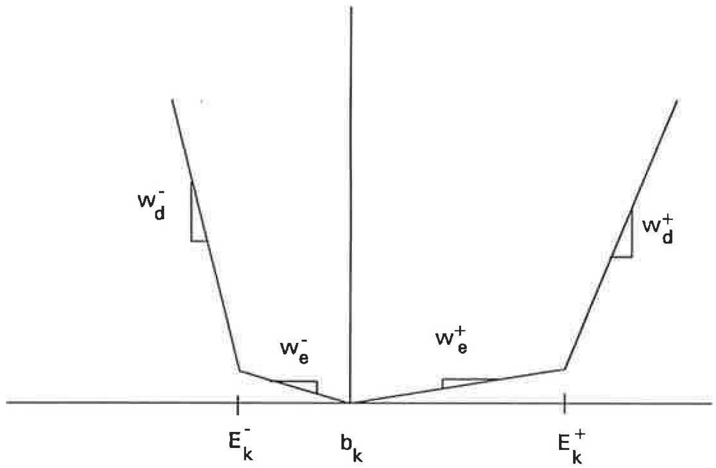

FIGURE 2 The piecewise linear penalty function.

both simplifies and generalizes the

α_{odcp}

notation used previously. The subscript m replaces the combination odc, and the subscript k allows all three types of values (OT, CP, and DP) to be written in the same way. The interpretation of

α_{mk}

is that it represents the extent to which x_m contributes to the value b_k. If observation k is an OT value, then

$$\alpha_{mk} = 1$$

for all destinations and commodities included in the observed value. We include all relevant x_m by defining M_k as the set of markets that contributes to the generation of the observation b_k. If observation k is a CP or DP value, then

$$\alpha_{mk} = \alpha_{odcp}$$

for the border crossing (p) to which observation k pertains.

The variables e_k^-, e_k^+, d_k^- and d_k^+ are model outputs and reflect the degree to which the inferred flows, x_m, differ from each of the observations, k. The values of e_k^- and e_k^+ denote "small" negative and "small" positive deviations, respectively. Similarly, d_k^- and d_k^+ denote "large" negative and "large" positive deviations. The limits placed on the magnitudes of small positive and negative deviations for each observation, k, are given by E_k^+ and E_k^-. The coefficients w_k^d and w_k^e (where $w_k^d \geq w_k^e$) are the weights attached to small and large deviations, respectively, from the observation, b_k.

The net effect of these small and large deviation variables is to create a piecewise, linear U-shaped penalty function around the observed value for each k, as shown in Figure 2. Thus the optimization model expressed in equations (6) and (7) is similar to minimizing the sum of squared errors, but has several significant advantages. First, it allows us to use commercial large-scale linear programming software to solve the problem. Second, in developing the weights for each observation, the degree of confidence in the observation can be reflected by adjusting the values of E_k^+ and E_k^-. Third, we can make the penalty function asymmetrical. For instance, if the data represent a lower bound, the weights associated with negative deviations should be larger then those associated with positive deviations. Many observations in this application were lower bounds as a result of incomplete observations.

U.S.-Mexico Trade Analysis

For estimation of trade flow patterns, two types of aggregation have been done. In both the United States and Mexico, states have been aggregated into regions. These regions, illustrated in Figures 3 and 4, form the origins and destinations for the flow patterns estimated. In addition, we have aggregated commodities into seven groups, as shown in Table 9. The six specific groups identified represent more than 60 percent of the trade between the United States and Mexico. Thus, our estimations of commodity-based origin-destination flows

FIGURE 3 U.S. regions.

involve 441 variables (nine U.S. regions, seven Mexican regions, and seven commodities) in each direction.

The data sets contained information for 30 commodity groups. From these groups, seven origin-destination matrices were estimated based on the commodity classes in Table 9. The first six commodity classes represent more than 60 percent of the trade between the United States and Mexico.

The U.S. border crossings represented in the model are Calexico-Mexicali, San Ysidro-Tijuana, Nogales-Nogales, El Paso-Juarez, Laredo-Nuevo Laredo, Hidalgo-Reynosa, and Brownsville-Matamoros. These seven ports process more than 75 percent of U.S. export trade and 70 percent of U.S. import trade. The majority of traffic not identified as being processed through these ports either has no port identified or is related to the Mexican export of energy products through the ports at del Carmen and Coatzacoalos.

Results of the Analysis

Table 10 shows the total dollar origin-destination matrix for U.S. exports (all commodities). The column titled "expected" is the result of summing the appropriate OT observations for each state included in the various U.S. regions. The row labeled "expected" is the result of parallel calculations for each Mexican region. The sum of the expected dollar values for U.S. exports by region are less than the $40.5 billion for total U.S. exports to Mexico (Table 1) because of the more than $2.9 billion in trade for which no state of origin state is recorded. The majority of the flows into Baja California are from the Pacific region, and those into Chihuahua are from Texas. The majority of these flows are manufacturing-related commodities destined for *maquiladora* plants in these regions of Mexico.

FIGURE 4 Mexican regions.

TABLE 9 AGGREGATE COMMODITY CLASSES

Commodity Class	Commodity Group
Food	Food, Livestock, Crops
Chemicals	Chemicals
Metals	Primary Metals
Machinery	Machinery
Electrical	Electrical/Electronics
Transportation	Transportation
Other	All other groups except Unknown

TABLE 10 U.S. EXPORT TRADE PATTERN ($ MILLIONS)

U.S. Regions	Baja California	Sonora	Chihuahua	Northeast	Central	District	South	*Total*	*Expected*
	Mexican Regions								
Pacific	3899	0	0	0	581	2207	0	6687	6687
Mountain	0	34	0	329	1031	680	0	2075	2075
W.N.Central	26	46	0	226	364	435	73	1170	1170
E.N.Central	12	219	0	516	239	2911	0	3897	3897
Texas	2	871	4968	3180	3218	3536	1612	17387	17387
South Central	202	9	0	1175	119	192	129	1827	1826
Mid-Atlantic	4	194	0	677	0	995	207	2078	2037
South Atlantic	121	74	0	404	174	1115	0	1889	1930
New England	4	60	6	455	96	18	0	639	639
Total	4270	1508	4974	6962	5824	12091	2021	**37650**	
Expected	4270	1508	4974	6983	6136	12091	2020	**US**	37648
								Mexico	37982

TABLE 11 U.S. EXPORTS: CHEMICALS ($ MILLIONS)

U.S. Regions	Baja California	Sonora	Chihuahua	Northeast	Central	District	South	*Total*	*Expected*
	Mexican Regions								
Pacific	226	0	0	0	0	47	0	274	270
Mountain	0	8	0	0	0	69	0	77	72
W.N.Central	0	0	0	53	0	0	0	53	48
E.N.Central	0	3	0	0	0	332	0	335	305
Texas	0	0	173	9	701	79	0	963	876
South Central	0	0	0	132	0	0	54	186	169
Mid-Atlantic	0	41	0	88	0	120	108	357	308
South Atlantic	0	0	0	0	0	396	0	396	398
New England	0	0	0	125	0	0	0	125	116
Total	226	51	173	407	701	1044	162	**2766**	
Expected	226	57	179	407	701	1044	162	**US**	2561
								Mexico	2615

TABLE 12 U.S. EXPORTS: TRANSPORTATION ($ MILLIONS)

U.S. Regions	Baja California	Sonora	Chihuahua	Northeast	Central	District	South	*Total*	*Expected*
	Mexican Regions								
Pacific	0	0	0	0	0	758	0	758	842
Mountain	0	0	0	0	92	248	0	340	378
W.N.Central	0	0	0	0	0	67	0	67	67
E.N.Central	0	0	0	0	0	1005	0	1005	1072
Texas	2	107	35	1087	109	700	273	2312	2569
South Central	202	0	0	0	0	0	0	202	206
Mid-Atlantic	4	0	0	0	0	42	0	46	52
South Atlantic	72	0	0	0	0	64	0	136	151
New England	4	0	0	0	0	18	0	22	24
Total	285	107	35	1087	200	2902	273	4888	
Expected	119	26	35	181	200	719	46	**US**	5361
								Mexico	1325

TABLE 13 U.S. IMPORT TRADE PATTERN ($ MILLIONS)

U.S. Regions	Baja California	Sonora	Chihuahua	Northeast	Central	District	South	*Total*	*Expected*
	Mexican Regions								
Pacific	3865	0	0	0	667	738	0	5270	5270
Mountain	0	2	0	421	1290	105	0	1818	1818
W.N.Central	31	0	93	57	373	0	0	555	555
E.N.Central	187	1338	968	1155	91	2669	21	6428	6428
Texas	64	0	4655	729	602	2573	4213	12836	12836
South Central	217	0	119	1553	0	31	950	2871	2871
Mid-Atlantic	73	159	97	1358	0	0	95	1782	1782
South Atlantic	57	103	100	1035	0	0	0	1294	1294
New England	7	52	79	225	0	0	36	400	400
Total	4501	1654	6111	6534	3022	6116	5315	**33254**	
Expected	4349	1654	6111	6870	3022	6219	5355	**US**	33254
								Mexico	33580

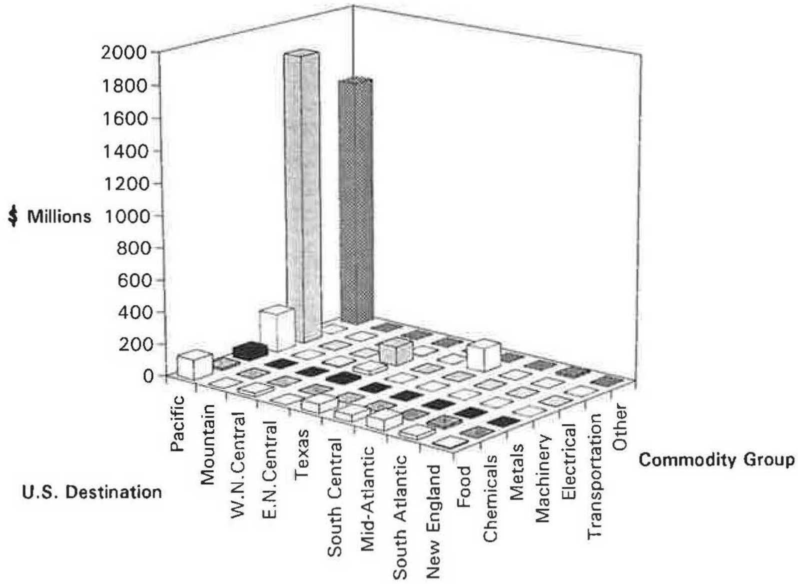

FIGURE 5 Composition of U.S. imports through San Ysidro from Baja California.

Table 11 presents a U.S. export origin-destination matrix for chemicals. The total value of this trade pattern is approximately $2.8 billion, which is closer to the OT observation from Mexican customs than to the corresponding data from U.S. customs. The model identified a pattern closer to the Mexican data because the U.S. port observations supported the Mexican observations. Table 12 shows a comparable origin-destination matrix for transportation equipment. This is an interesting case because U.S. customs records indicate that more than $5 billion in transportation equipment is exported, where as Mexican customs records indicate that only $1.3 billion is imported. The U.S. port data support the higher value, and the Mexican port data support the lower value. In the face of conflicting data, we chose to treat the Mexican observations as lower bounds. As a consequence, the model inferred a set of origin-destination flows that more closely favor U.S. customs values. Most of the additional transportation equipment flows were assigned to the destinations of Mexico City and northeast Mexico. To maintain the total dollar values imported into these regions and through the affected border crossings, the model compensated by lowering the dollar values assigned to the flows in the commodity class "other." This commodity class was roughly $5 billion larger in the Mexican data set than in the U.S. data set. The primary cause of this discrepancy was a $4.8 billion entry in the commodity group "nonclassified," most of which was cited as terminating in Mexico City and the northeast regions of Mexico.

Table 13 presents a total dollar origin-destination matrix for U.S. imports. The dollar values for total Mexican exports and for total U.S. imports are higher than the expected values due to missing states of origin and destination in both the U.S. and Mexican data sets. The large inferred flow from southern Mexico into Texas and the south central United States is mainly energy commodity movements from Chiapas to Texas and Louisiana. A substantial portion of the flows from Baja California, Chihuahua, and northeast Mexico are the return movements from *maquiladora* factories.

Figure 5 shows the composition of import flows from Baja California through the border crossing at San Ysidro. There is a predominance of electrical/electronics equipment and "other" commodities, all destined for the Pacific region. Even though this flow pattern is plausible, it is a direct outcome of the "port utilization" coefficients estimated for various origin-destination pairs and commodities. For purposes of planning major investments in terminal facilities and border crossing facilities, we need to carefully evaluate the process of estimating these utilization coefficients.

CONCLUSIONS

This paper represents a first step in the process of generating origin-destination matrices for trade between the United States and Mexico. The matrices generated resulted from a process based on synthesizing ordinary dollar-based trade data to produce dollar estimates of regional trading patterns by commodity group. With dollar-based trade observations, the process proved to be both flexible and robust in how each observation is allowed to influence the flows inferred. However, because these models were developed to facilitate the planning of improvements in the transportation systems supporting U.S.—Mexican trade, they must be extended to provide information regarding modal use. Therefore, the second step in this process will be to include the modal-based data from the Bureau of Transportation Statistics (5).

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