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# Freight Transportation Costs and the Thickening of the U. S. - Mexico Border

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A revised version of this study is forthcoming in *Applied Economics*.

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The University of Texas at El Paso  
**UTEP Border Region  
Modeling Project**

Technical Report TX14-1

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# The University of Texas at El Paso

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Technical Report TX14-1  
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# Freight Transportation Costs and the Thickening of the U.S. - Mexico Border\*

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## Abstract

Border regulatory requirements and administrative practices changed subsequent to the 11 September 2001 (9/11) terrorist attacks in the United States. This study examines the manners in which transportation cost data for merchandise imports from Mexico behaved before and after 2001. Evidence is obtained that confirms results earlier tabulated for imports from Canada. Empirical results further indicate that, beyond freight cost changes, growth in the value of imports from Mexico was disrupted by events associated with the aftermath of 9/11.

## Key Words

Border Economics; Freight Costs; International Trade

## JEL Categories

F15, Economic Integration; M21, Business Economics; R15, Regional Economics

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## Introduction

The United States, Mexico, and Canada began implementing the North American Free Trade Agreement (NAFTA) with the goal of removing barriers to trade in the region. The value of United States imports from Mexico more than tripled in real terms between 1993 and 2000 (USITC, 2012). However, with the terrorist attacks of 11 September 2001 (hereafter, 9/11), national security concerns quickly overshadowed any goals of regional economic integration between the United States and its neighbors (Andreas, 2003). In the aftermath of the attacks, increased inspection times produced unprecedented bottlenecks at ports of entry (Oppel, 2001). New regulations designed to enhance border security also had the side-effect of increasing paperwork burdens for companies engaged in cross-border trade (Brooks, 2003). One of the consequences of the 9/11 attacks was thus an intensification of efforts to control all forms of trans-boundary traffic.

The number of border crossings by private individuals likely fell off in the wake of 9/11 (Fullerton, 2007), but this should not be the case for the commercial shipment of goods from Mexico to the United States. The 9/11 disruptions have, however, had major impacts on merchandise trade. Estimates of the cost of cargo vehicle delays

at ports of entry on the southern border range from US \$5.8 billion to \$7.5 billion per year (Accenture, 2008; Del Castillo Vera, 2009). The effect of border delays on trans-boundary commercial transactions effectively amounts to increasing the distance between exporter and importer or ‘thickening’ the border (Boyer, 1997; Ackleson, 2009). It is well documented that a larger distance between countries is associated with lower trade volumes (Disdier & Head, 2008). Similarly, if stringent post-9/11 border security procedures result in a thickening of the United States-Mexico border, such measures may negatively affect the volume of bilateral trade. This analysis will employ data on cross-border transportation costs to explore whether a thickening of the border has occurred.

Material that follows reviews the literature on border barriers to international trade and the impacts of the 9/11 attacks on border security and cross-border trade. Each of the subsequent two sections consists of a data and methodology sub-section followed by a presentation of empirical results. In the first of these sections, changes in the trajectory of cross-border transportation costs are analyzed in light of the new border security measures that went into effect after the 9/11 attacks. The impacts of freight transportation costs on cross-border trade are evaluated in the subsequent section. Finally the results of the analyses are summarized in a conclusion.

## Literature Review

Several studies report fairly clear evidence that national boundaries pose substantial obstacles to trade (McCallum, 1995; Nitsch, 2000; Chen, 2004). Anderson and van Wincoop (2004) find that, for industrialized countries, border-related trade barriers are equivalent to a 44 percent ad-valorem tax on traded goods. In a multi-country analysis, Walkenhorst and Dihel (2006) report that, if border security measures raise frictional costs by one percent of the value of traded goods, the result is a 0.9 percent decrease in imports and a decline in

welfare of \$75 billion per year worldwide. While borders may represent substantial barriers to trade, Evans (2003) finds that the effect of borders on trade is not entirely the result of trade policies. About 34 percent of the border effect is traced to policy-related tariff and non-tariff barriers while 46 percent is attributed to differences between domestic and international transaction costs.

Among the factors that may inhibit trade across borders are regulatory restrictions and deficient infrastructure. Das and Pohit (2006) report that exporting a single shipment across the India-Bangladesh border takes approximately four days due partly to inadequate transportation infrastructure. Limão and Venables (2001) find that improving transportation infrastructure from median world levels to the top 25<sup>th</sup> percentile yields a 68 percent increase in trade volume. Also, some regulations on cross-border shipping may constitute policy-related barriers to trade. Haralambides and Londoño-Kent (2004), note that, partly because of limitations on the entry of Mexican trucks into the United States, shipping goods over the border may require three trucks or trailers, three or four drivers, as well as overnight cargo warehousing. The whole process may take between two and five days. Hummels (2001) calculates that the addition of one day to shipping time between two countries reduces the probability that firms will produce for export by 1.0 percent across all categories of goods and by 1.5 percent for manufactures.

Delays at ports of entry often generate secondary costs, beyond the expenses incurred by waiting in line to cross the border. As mentioned by Huang and Whalley (2008), increases in the costs of crossing borders may lead importers to reduce the frequency of shipments and, consequently, to increase inventories above optimal levels. If the goods being shipped are perishable, then excessive wait times can result in spoilage. MacPherson et al. (2006) note that an increase in border-crossing costs may also lead to inefficiency by diverting trade away from low-cost producers in

neighboring countries to higher-cost producers in home countries. Finally, if wait times are volatile, truckers may build more border-crossing time than is ultimately necessary into route planning, which inhibits taking advantage of shorter-than-expected waits (Taylor et al., 2004).

Tighter border security is a key component of the multi-pronged United States government response to the 9/11 attacks (Andreas, 2003). In a study of the United States-Canada border, Taylor et al. (2004) note that primary truck inspection times at ports of entry increased by approximately 25 percent from mid-2001 to mid-2003. The bulk of time costs derive from secondary inspections of 20 to 40 percent of trucks, which are likewise sensitive to increased security risks. Concerns about terrorism also resulted in new trade-related regulations, such as the requirement that exporters send cargo information to the Bureau of Customs and Border Protection before shipments arrive at the border (Peterson and Treat, 2008).

The increase in border security is only one of several avenues through which 9/11 may have impacted the costs of cross-border trade. Nitsch and Schumacher (2004) note that terrorist actions can affect international trade both directly, by destroying traded goods, and indirectly, by increasing the security precautions of governments, firms, and consumers. Commercial insurance premiums may have increased due to higher perceived risks of terrorist attacks, especially in developing countries with less extensive police apparatuses (DFAT, 2004). Given the importance of fuel costs for freight transportation, however, the sharp decline in oil prices in the immediate aftermath of the 9/11 attacks may have partially shielded the international freight distribution industry from the full effects of increased border security (Walkenhorst and Dihel, 2006).

Several studies examine the impacts of the 9/11

attacks on variables such as the volumes of cross-border vehicle traffic, shipping costs, and trade. The terrorist attacks are associated with declines in cross-border vehicle traffic in several areas of the United States-Mexico border (Olmedo and Soden, 2005; Fullerton, 2007). Globerman and Storer (2011) argue that increased border security after 9/11 raised the cost of shipping goods from Canada to the United States. To assess the effects of intensified border security measures on trade, Georges and Mérette (2012) calculate tariff rates that are equivalent to the non-tariff barriers erected at the northern border after 9/11. The rates range from 0.3 to 9.6 percent, depending on the sector evaluated. Elimination of post-9/11 security measures would increase Canada's trade volume by 2.8 percent according to this study. Nguyen and Wigle (2011) find that a one-percent increase in trade costs due to border wait times results in a 3.6 percent fall in Canada's international trade.

Because post-9/11 security measures imposed costs on cross-border trade, most firms involved in international trade took steps to adapt to the new rules. Vance (2008) documents that, given the new bureaucratic hurdles erected at border crossings, some exporters chose to outsource shipping and customs responsibilities to third parties with expertise in those areas. A survey of companies engaged in trade across the United States-Canada border reveals that some firms are considering switching from foreign to domestic suppliers in response to more intensive border security (MacPherson et al., 2006). Firms that practice just-in-time (JIT) inventory management are especially vulnerable to increased border wait times (Vance, 2008; Georges and Mérette, 2012). Some firms have increased inventories as a hedge against the possibility that shipments will not arrive on time due to border delays (Taylor et al., 2004). As noted above, the increased inventories are probably at sub-optimal levels that increase costs of doing business.

## Data and Methodology

Several studies note that the 9/11 attacks contributed to a thickening of international boundaries around the United States (Ackleson, 2009; Lara-Valencia, 2011). Globerman and Storer (2011) suggest using freight transportation costs to quantify impediments to cross-border commerce. One consequence of the terrorist attacks is increased transaction costs associated with international trade. Tightened security procedures at ports of entry resulted in new paperwork obligations as well as time-consuming delays that required additional expenditures on inputs like labor and fuel. Markets for freight insurance were likely affected as well. To capture these costs of cross-border transportation, the customs value of imported goods plus insurance and freight costs (the CIF value) is compared with the customs value alone (the free on board, FOB, value). The difference between these two values represents transportation costs.

The specific measure utilized in this analysis is the ratio of insurance and freight costs to the value of imports (Globerman & Storer, 2011). The manner in which it is calculated is shown in shown in Equation 1:

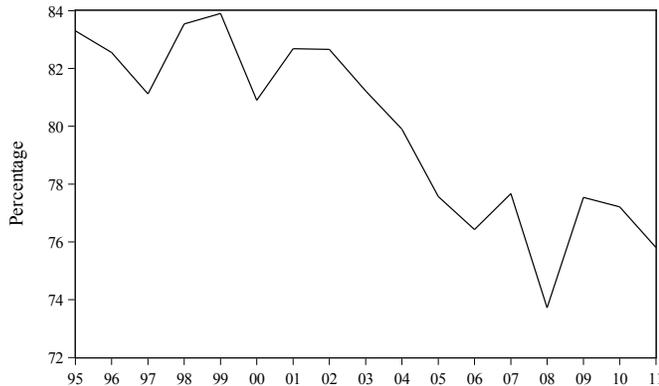
$$(1) R_{it} = ((CIF_{it} - FOB_{it}) / FOB_{it}) \times 100$$

In Equation 1,  $i$  is an index for each customs district and  $t$  is a time index. It is not necessary to deflate the transportation cost ratio,  $R$ , because both the numerator and the denominator are expressed in contemporaneous dollar values and the ratio of those measures is not a monetary unit. A number of other studies also use the CIF/FOB ratio to measure the cost of transporting goods (Frankel, 1997; Limão & Venables, 2001; Hummels, 2001; Bergstrand & Egger, 2006).

The impact of 9/11 on shipping costs has not been previously documented for the United States-Mexico border. This study focuses on United States imports from Mexico rather than exports because, at least initially, the most severe obstacles to cross-border trade have been imposed on northbound traffic. Mexico is the third largest source of imports to the United States, accounting for 12 percent of total imports in 2011 (USITC, 2012). The customs districts included in this analysis are those located along the border with Mexico, namely the districts of Laredo, El Paso, Nogales, and San Diego. During the sample period, an average of 79 percent of United States imports from Mexico entered the country through these four customs districts. CIF and FOB data are retrieved from the United States International Trade Commission (USITC, 2012) for the four border-region customs districts from 1990 to 2011.

In examining the impact of 9/11 on cross-border trade and shipping costs, information about the major modes of transportation utilized may be relevant. Unfortunately, the available data on the CIF values of imports are not disaggregated by mode of transportation. However, annual FOB values are available by mode from the Bureau of Transportation Statistics from 1995 forward (BTS, 2012). Chart 1 shows the share of total United States merchandise imports from Mexico that is transported overland across the border rather than being shipped by sea or air. While a large majority of imports cross the land border in all years, there appears to be a shift away from surface transportation after 9/11. Of imports shipped overland across the border, an average of 82 percent travelled by truck, 17 percent by rail, and the remainder by other means, including pipelines. These shares are relatively stable across all years for which data are available.

**Chart 1: Share of Overland Imports in Total Imports from Mexico**

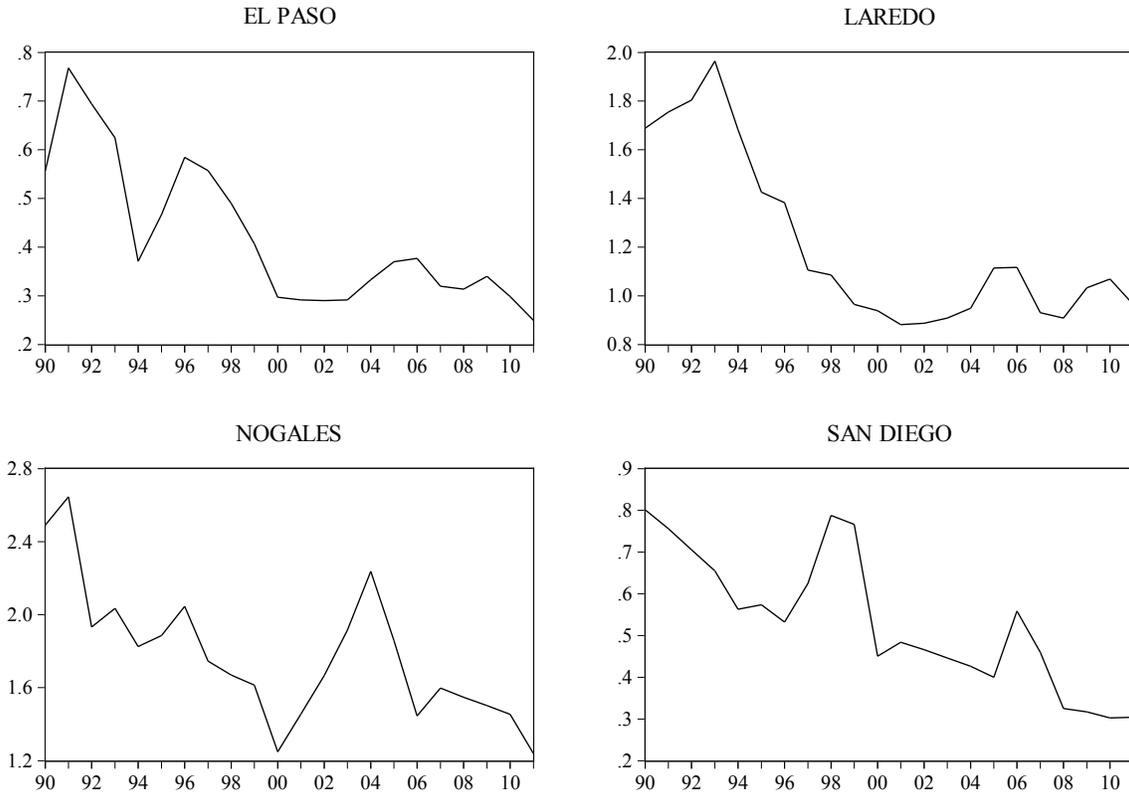


Graphs of the transportation cost ratios for each customs district are shown in Charts 2 and 3. One striking feature of all of these graphs is that cross-border transportation costs have generally tended to decline over time. This trend may be attributed to a number of factors such as declining real input prices and increasing productivity. The correlation coefficients between the aggregate transportation cost ratio for all four districts and United States industry productivity indices are -0.79 for long-distance trucking and -0.38 for line-haul railroads (BLS, 2012). Boyer (1997) documents that the cost of long haul trucking declined as a result of

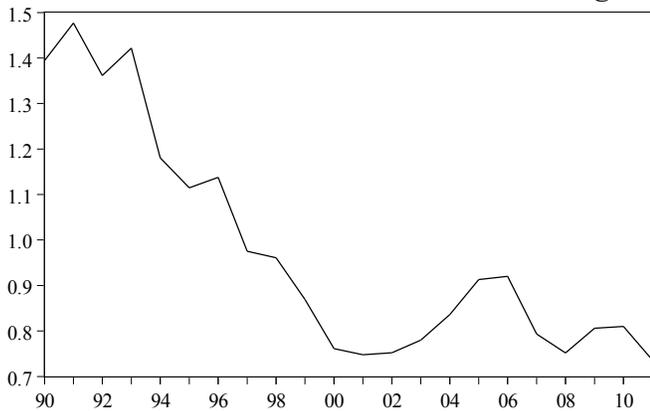
deregulation of the industry in 1980 and again in 1994, new technology and management practices that ensure trucks are fully loaded on both outbound and return trips, and declining real wages of truck drivers. Lim and Lovell (2009) report that rail transportation enjoyed productivity gains from 1996 to 2003 due largely to improvements in technology.

However, as Charts 2 and 3 illustrate, the general trend towards declining costs is arrested and, in some cases, reversed following 9/11. In order to better discern the impact of the terrorist attacks on the trajectory of cross-border transportation costs, regression exercises are conducted utilizing a dummy variable consisting of zeroes from 1990 to 2000 and ones from 2001 to 2011. This variable is included to capture structural changes in the dynamics of cross-border transportation costs occasioned by administrative responses of the United States government and other institutions to the terrorist attacks. Several other studies use dichotomous variables to capture the impacts of 9/11 (Fullerton, 2007; Gliberman and Storer, 2011; Georges and Mérette, 2012). The regression exercises are discussed in the following section.

**Chart 2: CIF/FOB Ratios for Border Customs Districts**



**Chart 3: CIF/FOB Ratio for the Border Region**



**Shipping Costs and Imports**

Table 1 summarizes the regression results for the border region as a whole and for each of the four customs districts in the region. Initial CIF/FOB ratios vary substantially from one customs district to another as indicated by the constant terms. The coefficients on the time trend variable are all

negative as expected. The 9/11 dummy variable also carries a negative coefficient for each customs district and for the border region in general. However, this does not indicate that transportation costs dropped off sharply after 9/11. Rather, those costs fell gradually during the 1990-2000 period and the vertical intercept of the regression line is substantially lower for the period from 2001 to 2011.

In a majority of cases, the terms representing changes in the transportation cost trend after 9/11 carry positive signs, implying that the reductions in shipping costs observed prior to the terrorist attacks did not continue apace in the subsequent period. In Laredo, the coefficient on the interaction term is larger in magnitude than the trend coefficient, indicating that shipping costs actually began trending upward after 9/11. The interaction coefficient is negative only in San Diego but it is not statistically distinguishable from zero. These

results are largely similar to those reported by Gliberman and Storer (2011) for the northern border of the United States.

While Table 1 shows that CIF/FOB ratios experienced pronounced changes after 9/11, it is possible that these shifts can be explained by other factors besides the barriers to cross-border commerce created in the wake of the terrorist attacks. To gauge the extent to which the dummy variable coefficients are capturing the effects of unrelated variables, it is necessary to analyze each of the determinants of the CIF/FOB ratios before and after 9/11. If systematic growth patterns in those variables are consistent with the trends observed in the transportation cost ratio, then the dummy variable coefficients may not accurately measure the impact of the terrorist attacks. Combes and Lafourcade (2005) note that transportation costs may depend on factors such as the operating costs of transportation providers, distances travelled, and the types of commodities being shipped. The following discussion considers whether such variables exerted upward pressure on shipping costs during the period from 2001 to 2011.

The operating expenses of transportation providers are affected by shifts in fuel and labor costs (Combes & Lafourcade, 2005) as well as improvements in productivity due to managerial or technological innovations (Boyer, 1997; Lim & Lovell, 2009). Real data on output per hour and unit labor costs are collected for the United States long-distance freight trucking and line-haul railroad industries (BLS, 2012). Both are found to be highly correlated with the CIF/FOB ratios. However, analysis of the trend components of these series does not reveal a post-9/11 decline in productivity or a contemporaneous increase in unit labor costs that would be expected to exert upward pressure on the transportation cost ratio. To account for the possible impact of fuel costs, real diesel prices are collected for the United States and Mexico (EIA, 2012; INEGI, 2012). Although the upward movement in United States retail diesel prices has accelerated since 2001, the pace of increase in Mexico's diesel prices decelerated slightly after 9/11. While the evidence is only suggestive, the flattening out of cross-border shipping costs does not appear to be predetermined by systematic patterns of change in the national productivity, energy cost, or labor cost variables.

**Table 1: 9/11 Impact on Shipping Costs**

	Total	El Paso	Laredo	Nogales	San Diego
Constant	1.572176 (<0.1%)	0.707460 (<0.1%)	2.040631 (<0.1%)	2.548302 (<0.1%)	0.740985 (<0.1%)
Trend	-0.070313 (<0.1%)	-0.029787 (0.1%)	-0.100754 (<0.1%)	-0.104438 (<0.1%)	-0.014176 (12.0%)
9/11	-0.762016 (<0.1%)	-0.373190 (1.6%)	-1.254588 (<0.1%)	-0.175151 (66.3%)	-0.011162 (94.6%)
9/11*Trend	0.069960 (<0.1%)	0.028705 (1.5%)	0.112062 (<0.1%)	0.060658 (5.9%)	-0.004749 (70.3%)

Significance levels for the null hypothesis that the parameter is equal to zero are in parentheses.

Another factor that might account for transportation cost trends is a change in the average distance over which goods are transported. The available data do not allow direct quantification of changes in transportation distances for goods imported to the United States. Globerman and Storer (2011) argue that a shift away from cross-border transportation and towards shipment by air or sea to points within the interior of the United States may indicate an increased average distance from origin to destination. Chart 1 shows that, after 2001, an

increasing percentage of imports from Mexico were shipped by air and sea to points beyond the border. Even if this does constitute evidence for increased average transportation distances, it does not affect the results presented in Table 1, which are based on data for the four border customs districts, only. During the entire period for which modal split data are available (1995-2011), nearly all goods entering the border customs districts from Mexico were shipped across the land border (BTS, 2012).

**Table 2: Composition of United States Imports from Mexico through the Border Region**

	Total		El Paso		Laredo		Nogales		San Diego	
	HTS	%	HTS	%	HTS	%	HTS	%	HTS	%
1990	85	33%	85	56%	85	25%	87	28%	85	37%
	87	15%	98	7%	87	22%	7	20%	84	10%
	84	9%	84	6%	84	12%	85	18%	90	6%
1995	85	31%	85	53%	87	27%	87	29%	85	39%
	87	18%	84	9%	85	21%	85	22%	84	12%
	84	11%	90	8%	84	12%	7	12%	87	7%
2000	85	30%	85	47%	87	32%	85	34%	85	40%
	87	22%	84	13%	85	20%	87	22%	84	16%
	84	13%	90	7%	84	14%	7	8%	87	6%
2005	85	29%	85	40%	87	26%	85	29%	85	44%
	87	19%	84	20%	85	20%	87	14%	84	10%
	84	15%	87	9%	84	16%	7	12%	87	7%
2010	85	27%	84	35%	87	26%	87	35%	85	49%
	87	21%	85	31%	85	20%	85	16%	90	9%
	84	18%	87	11%	84	16%	7	13%	87	8%

## HTS Codes:

85: Electrical machinery and equipment; television recorders/reproducers; sound recorders/reproducers

87: Vehicles, other than railway or tramway rolling stock, and parts and accessories thereof

84: Machinery and mechanical appliances; nuclear reactors; boilers

90: Optical, photographic, cinematographic, measuring, checking, precision, medical/surgical apparatuses

7: Edible vegetables and certain roots and tubers

98: Special classification provisions: not either specified or included

Globerman and Storer (2011) also examine whether changes in the composition of the commodities imported to the United States from Canada can account for the flattening out of the downward trend in shipping costs. Because some types of commodities are more expensive to transport

than others, shifts in commodity composition may affect overall transportation costs. A complete list of all commodities imported from Mexico through the border customs districts for all years would be unwieldy. Therefore, Table 2 only shows data for five selected years and for the top three Harmonized

Tariff Schedule (HTS) categories of imports ranked in terms of their respective shares of the total value of imports. The top three classifications together constitute the majority of imports for all districts and years shown.

For most customs districts, and for the border region in general, the composition of imports is relatively stable over time. As shown in Table 2, the top three HTS classifications are the same for all years in the Laredo and Nogales districts and the list is modified only intermittently in the El Paso and San Diego districts. In the cases of El Paso, Laredo, and San Diego, the top three HTS merchandise trade categories reflect the extensive intra-industry manufacturing trade that occurs between Mexico and the United States (Fullerton, Sawyer, & Sprinkle, 2011). In the case of Nogales, two of the top three HTS merchandise series are related to intra-industry trade (Clark, Fullerton, & Burdorf, 2001). The remaining category is related to the high volume of fresh vegetables that is exported, primarily, from the Sinaloa region of Mexico into the western United States (Jessup & Herrington, 2005).

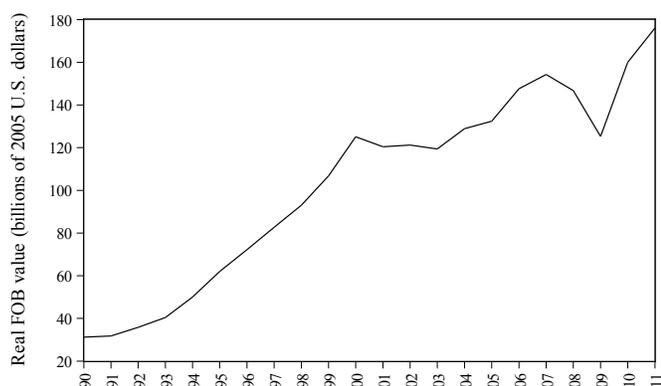
The results presented in Table 1 indicate that the rate of decrease in shipping costs for Mexican imports decelerated markedly after 9/11. It is possible that the some portion of that systematic shift in the transportation cost ratio may be unrelated to post-9/11 security measures. Nonetheless, the foregoing discussion suggests that the trend in cross-border shipping costs was probably not predetermined by changes in transportation operating costs, average distance travelled, or the composition of commodities being shipped. It is also important to remember that the 9/11 attacks may have affected

cross-border transportation costs through multiple channels. While security measures implemented by the United States government play an important role in the thickening of the border, the responses of firms and other entities may be consequential as well. For example, it is possible that increased real or perceived risks of terrorist attacks may have resulted in higher insurance premiums for carriers of international freight (DFAT, 2004). Such costs may contribute to border thickening to the extent that trade across national boundaries is disproportionately affected. The subsequent section discusses the consequences of a thickening border for the volume of United States imports from Mexico.

### **Impacts on Trade**

This section is primarily concerned with the real FOB values of imports entering the United States from Mexico through the four border region customs districts. Chart 4 shows the FOB data aggregated across the four customs districts and adjusted by the GDP deflator (BEA, 2012). While the real value of cross-border imports grew by 15.0 percent per year on average between 1990 and 2000, the rate of growth slowed to only 3.7 percent annually between 2001 and 2011. Proposed explanations for the moderation of growth in Mexico's exports to the United States include insufficient investment in manufacturing, due in part to the "China syndrome" developments of the early 2000s, within Mexico, plus adverse real peso/dollar exchange rate dynamics (Gallagher et al. 2008). The cost of cross-border freight transportation is another factor that may influence Mexico's competitiveness as an exporter, at least with regard to the United States market.

**Chart 4: Value of Goods Imported from Mexico through Border Customs Districts**



Increases in the cost of importing goods to the United States from Mexico, whether caused by heightened border security or other factors, may diminish import volumes. Limão and Venables (2001) find that doubling median world transport costs reduces the volume of international trade by 45 percent. Regression analysis is used to examine whether transportation costs impact the volume of imports crossing the border from Mexico to the United States. As in the previous section, shipping costs are measured by the CIF/FOB ratio, which encompasses costs directly related to the thickness of the border as well as other costs of moving merchandise. Though it is not possible to completely disentangle these two components using the available data, interaction terms can be included in the regression equations to examine whether the relationship between transportation costs and trade changed after 9/11 when new border security measures went into effect. Such a change could occur if the intensive screening of imports and other obstacles to trans-boundary commerce that were exacerbated after 9/11 have a different effect on trade than the standard operating costs associated with shipping goods.

As mentioned in the literature review, onerous customs procedures and uncertainty over the length of border delays often generate secondary costs in addition to direct expenditures incurred

in transporting goods. Importers may respond to delays by stockpiling goods to avoid shortages in the event that planned deliveries do not arrive on time. Indeed, inventory carrying costs may rival the direct costs of border delays (Huang and Whalley, 2008). Furthermore, uncertainty regarding the length of border delays may require freight carriers to build more time than necessary into shipping schedules, a practice that tends to reduce transportation efficiency (Taylor, et al. 2004). It is also possible that the time requirements associated with new customs paperwork obligations may be substantial enough to necessitate changes in business practices such as increased reliance on external customs brokerage firms (Vance, 2008). If heightened border security generates additional costs to importers beyond routine transportation costs, the impact on trade is likely to be amplified after 9/11.

Bilateral trade is also influenced by a number of variables besides freight transportation costs. The volume of imports is likely to be affected by income levels in the receiving country and the price of imports relative to domestic substitutes (Thursby & Thursby, 1984; Asseery & Peel, 1991). Another variable that may impact the volume of trade is the level of industrial production in the exporting country (Evans, 2003). The functional form employed to model cross-border shipments is shown in Equation 2:

$$(2) \text{RFOB} = f(\text{USGDP}, \text{MXIPI}, \text{REX}, \text{R}, \text{R} * \text{SEP11})$$

where RFOB denotes the real customs value (FOB) of imports. USGDP, United States gross domestic product, is obtained from the Bureau of Economic Analysis (BEA, 2012) and MXIPI, Mexico's industrial production index, is obtained from the International Monetary Fund (IMF, 2012). R is the CIF/FOB ratio, SEP11 is a dummy variable and REX represents a real peso/dollar exchange rate index (UTEP, 2012). The latter index is based on

a real exchange rate, which is calculated by multiplying the nominal peso/dollar exchange rate by a ratio of the price level in the United States to the price level in Mexico. As such, it serves as a measure of the relative price of exports (Fullerton & Sprinkle, 2005). All data are quarterly and extend from 1990 to 2011.

The real value of imports is expected to vary positively with the national income of the importing country and with industrial production activity of the exporter. A rise in the exchange-rate-adjusted price level in the United States relative to that in Mexico is likely to increase the volume of imports in the northern country. The real exchange rate variable is therefore predicted to move in tandem with real imports. Higher transportation costs, represented by increases in the CIF/FOB ratio, are expected to impede bilateral trade. Furthermore, the hypothesized negative impact of transportation costs on trade is predicted to increase in absolute value after 9/11 as intensified border security

generates an additional drag on trade beyond that associated with the standard costs of shipping goods.

Even after including the aforementioned determinants of cross-border shipments in the regression equations, some of the systematic variation in the dependent variables may not be fully explained by the regressors. Due to data constraints and persistence effects, it is not uncommon to observe serially correlated residuals in estimated models for border region, as well as international, transportation and economic time series (Fullerton, 2004). To account for autocorrelation, parameters are estimated using a nonlinear autoregressive moving average exogenous (ARMAX) methodology (Pagan, 1974). A big advantage of the ARMAX procedure is that it can handle multiple data generating processes. Autoregressive (AR) or moving average (MA) terms, or combinations of the two, may be added to the equations estimated using the functional form shown in Equation 2.

**Table 3: Determinants of Cross-Border Trade Volumes**

Dependent Variable: Real FOB trade volumes (in millions of 2005 dollars)						
	Total	El Paso	Laredo	Nogales	San Diego	
Constant	-46042.12 (<0.1%)	-13506.04 (0.3%)	-25191.13 (<0.1%)	-6580.209 (<0.1%)	-7084.114 (<0.1%)	
USGDP	3.144880 (<0.1%)	1.197149 (0.2%)	1.935062 (<0.1%)	0.447842 (1.8%)	0.611052 (<0.1%)	
MXIPI	385.0748 (<0.1%)	59.30575 (<0.1%)	205.0681 (<0.1%)	30.52401 (1.2%)	50.77804 (<0.1%)	
REX	42.69593 (4.4%)	7.587932 (12.7%)	5.730829 (58.2%)	5.518675 (8.7%)	2.169499 (63.7%)	
R	-996.8377 (37.6%)	-386.4732 (39.4%)	-775.5703 (22.6%)	-238.7892 (5.0%)	-292.1215 (21.3%)	
R*SEP11	-1625.396 (14.1%)	-2104.651 (1.3%)	-401.2921 (47.1%)	-218.0840 (1.8%)	-557.8309 (5.3%)	
AR(lag)*	(9) -0.54970 (<0.1%)	(1) 0.959016 (<0.1%)		(8) 0.903340 (<0.1%)	(1) 0.451046 (<0.1%)	
MA(lag)*	(1) 0.622644 (<0.1%)		(1) 0.973383 (<0.1%)	(1) 0.434758 (<0.1%)	(9) -0.85218 (<0.1%)	
MA(lag)*			(2) 0.550053 (<0.1%)			
R <sup>2</sup>	0.986090	0.984038	0.991161	0.883723	0.978612	
Log likelihood	-670.0521	-610.0699	-690.4916	-556.4145	-607.4467	
F-statistic	719.0311	821.9758	1281.577	78.17299	516.3695	
Durbin-Watson	1.333827	1.921363	1.719400	1.920433	1.762715	

Significance levels for the null hypothesis that the parameter is equal to zero are in parentheses.

\* The lag length for each AR and MA term is indicated to the left of the coefficient.

When the equations are estimated using ordinary least squares, the disturbance terms in all equations are found to be autocorrelated. Accordingly, AR and MA terms are added to account for the remaining systematic variation in the error terms. The residuals of the newly estimated equations are evaluated using chi-squared Q-statistics to determine whether serial correlation remains problematic. The parameter estimates are shown in Table 3. In three of the five equations, mixed data generating processes are encountered and require utilization of both AR and MA terms. In the equation for Laredo, inclusion of two MA terms is needed to eliminate serial correlation.

The results in Table 3 indicate that an additional billion dollars of US GDP results in more than 3.1 million dollars in additional cross-border shipments of goods from Mexico in terms of 2005 price levels. Increased industrial production in Mexico is also strongly associated with higher volumes of imports through the border region. The impacts of these variables on the real value of imports is largest in the Laredo customs district, probably because more than half of all northbound cross-border trade typically passes through that district. The real exchange rate index is positively related to import volumes as expected, indicating that real depreciations of the peso relative to the dollar increase imports from Mexico. This may occur because goods produced in Mexico become cheaper relative to substitute goods produced in the United States or because the dollar-denominated wages of workers in Mexico's export-oriented manufacturing sector decline as a result of peso depreciation, which may stimulate twin plant operations (Fullerton & Torres-Ruiz, 2004; Cañas, et al., 2007). It should be noted, however, that some of the exchange rate coefficients do not satisfy the 5-percent significance criterion.

While the first three regressors are national or international macroeconomic variables, the average values of the transportation cost ratios vary from one customs district to another. To facilitate

comparisons between districts, Table 4 reports the elasticities of cross-border imports with respect to transportation costs. In general, transportation costs have a much larger impact on trade in the Nogales customs district than in the others. This can be explained, in part, by the prominence of agricultural commodities among goods imported through this district (Jessup & Herrington, 2005). As shown in Table 2, vegetables and related farm products are among the top three categories of goods imported through the Nogales district. Transportation of such commodities may be especially time-sensitive due to the risk of spoilage (Das & Pohit, 2006), and long delays at ports of entry may result in additional freight and insurance costs. For most customs districts, the overall impact of transportation costs is relatively small, which is not unreasonable given that these are only a small fraction of total costs to consumers and producers.

For the analysis in this section, the key variable of interest is the interaction term representing changes in the impact of transportation costs on cross-border trade after 9/11. As shown in Table 4, the magnitude of the negative effect of shipping costs on trade is augmented after 9/11 for all customs districts. Though it is not possible to pinpoint the sources of change in the relationship between transportation costs and trade, tightened border security may provide at least a partial explanation. Longer and less predictable border delays, as well as increased customs paperwork, result in additional, secondary costs beyond expenditures on fuel, labor, warehousing, insurance, and similar routine shipping costs. Accordingly, the results in Tables 3 and 4 indicate that the full set of costs associated with moving freight across the international divide likely now constitute a greater barrier to United States-Mexico trade due to the post-9/11 intensification of border security.

Table 4 also summarizes regional variation in the extent to which 9/11 affected the relationship between transportation costs and trade. Although the impact of shipping costs is amplified substantially

in the El Paso and Nogales customs districts after 9/11, the change is muted in the case of Laredo. One possible explanation of the smaller coefficient for Laredo is that border congestion was already quite burdensome at the Laredo port of entry prior to 9/11 as prodigious traffic strained the limited capacity of the international bridges in that metropolitan economy (Edmonson, 2003; Brooks, 2008). Given pre-existing severe congestion, the additional costs imposed by tightened border security may have produced a smaller marginal effect on trade through this port of entry than what is observed in other regions. Another possible explanation is that long-distance freight transportation originating in the interior of Mexico dominates cross-border commerce through the Laredo district to a greater extent than in El Paso or southern California, where nearby maquiladora production accounts for larger shares of merchandise imports (Villa, 2006). If the contribution of distance to total transportation costs is larger in Laredo, then changes in the intensity of border security will potentially have relatively less pronounced impacts in that district.

## Conclusion

By raising concerns over vulnerability to terrorism, the 9/11 attacks led to escalated security efforts along United States borders and more intensive scrutiny of imports. The formation of new barriers to cross-border travel and exchange is sometimes described metaphorically as a thickening of the border. One possible consequence of border thickening in North America may be to increase the costs of carrying out international trade. The evidence presented here, like prior research conducted for the United States-Canada border, suggests that a downward trend in transportation costs was arrested and, in some cases, partially reversed after 9/11. While changes in transportation costs may result from shifts in input prices or productivity levels, these factors do not seem to consistently explain the marked flattening out of the CIF/FOB ratio in the years following the terrorist attacks. It seems likely, given the evidence, that the intensity of security at ports of entry is an important factor shaping the trajectory of cross-border transportation costs.

**Table 4: Elasticity Estimates**

	Total	El Paso	Laredo	Nogales	San Diego
R	-0.0380	-0.0305	-0.0673	-0.1803	-0.0378
R*SEP11	-0.0374	-0.0947	-0.0202	-0.1214	-0.0399

Regression analysis is conducted to determine whether changes in transportation costs affect the volume of cross-border imports from Mexico. Although some of the estimated coefficients are not significant, the signs of the transportation cost coefficients indicate that increases in those costs tend to hamper Mexico's exports to the United States. While available data do not permit isolating the impact of border security on trade, interaction between the CIF/FOB ratio and the 9/11 dummy variable indicates that the tightening of security after the terrorist attacks may have amplified the impact of transportation costs on trade. This could occur if the transportation costs related to border controls represent a greater obstacle to trade than standard shipping costs associated with labor, fuel, insurance and the like. Prior studies suggest that, in addition to contributing to routine shipping costs, border security likely generates indirect costs by increasing customs paperwork and inventory levels while reducing the efficiency of cross-border freight transportation.

Taken together, the evidence suggests that heightened border security has exerted upward pressure on transportation costs since 9/11 and thereby contributed to the slowing of growth in United States imports from Mexico. The thickening of the border therefore appears to represent a drag on trans-boundary commerce. Avenues for future research might include evaluation of the strategies of importers facing heightened security along the United States - Mexico border. For example, one report suggests that imports shipped via air, water, and rail have grown at a more rapid pace than freight transported by cargo trucks (Economist, 2012), an observation that is at least partially borne out by Chart 1. Future studies might examine whether border security measures have equivalent effects on trade conducted using different modes of transportation and whether import modal choices have been altered in response to those administrative requirements. Such efforts could enhance understanding of the interaction between border security, transportation costs, and trade documented in this analysis for the United States-Mexico border.

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