

COMPETITIVENESS AND MACROECONOMIC IMPACTS OF REDUCED WAIT TIMES AT U. S. LAND FREIGHT BORDER CROSSINGS

by

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Abstract: We analyze the macroeconomic and trade impacts of reducing wait times by adding inspection staff at each of the twelve major land freight crossings of the U.S. The change in wait time stemming from staffing changes is first estimated on the basis of primary data and then translated into changes in freight costs through a logistical model. The transportation cost changes are then fed into a multi-country computable general equilibrium model. We find that adding one inspection agent at each land border crossing would, on average per crossing, generate an increase in U.S. GDP of \$250 thousand and 2.55 additional jobs.

Key Words: trade competitiveness, inspection wait times, macroeconomic impacts, freight transportation

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1. INTRODUCTION

The gains from free trade are well established. Most studies on interference with it focus on tariffs, quotas, or subsidies. However, various costs of regulation to support the orderly flow and safety of trade also interfere with achieving efficient outcomes. These include direct costs of administering and monitoring trade, as well as unintended spillover effects resulting from delays. Ideally, these transactions costs would be minimized.

Freight transportation coming into the U.S. is subject to inspections by officials of the U.S. Customs and Border Protection (CBP) agency for contraband and for national security purposes. These inspections cause delays that translate into an increased cost of doing business for shippers and their customers directly and for international trade indirectly. Although the border wait times are relatively short, the sheer volume of trade translates into potentially large impacts. Inspection delays are thus an important non-tariff barrier to trade. In this paper we analyze the macroeconomic and trade impacts of adding one CBP inspection staff member at each of the twelve major land freight crossings of the U.S.

Increased staffing by CBP will reduce the cost of transporting imports from Canada and Mexico into the U.S., and benefit the export industries of these countries, with the U.S. incurring all of the cost. However, several international trade analysts have argued that it is very important to take into account the flow of both intermediate and final goods through cross-border supply chains that link the U.S. economy to those of Canada and Mexico.¹ If a large proportion of U.S. imports are intermediate goods that are incorporated into U.S. production, reducing importing cost would lower the cost of production in U.S. industries, thereby making U.S. exports more attractive not just to Mexico and Canada but worldwide. Due to these subtle considerations and others associated with the process of international trade, it is possible that that increasing staffing at U.S. freight crossings would be a win-win outcome for all involved. To capture these effects, it is necessary to analyze the impact of change in importing cost using a model that distinguishes between flows of intermediate and final goods and incorporates a full accounting of all inputs and not just primary factors of production. We use a computable general equilibrium (CGE) model that makes these distinctions, and our results suggest that

¹ See Taylor et al. (2003) and Haralambides and Londono-Kent (2004) for assessments of supply chains linking Canada and Mexico to the U.S., respectively. OECD (2013) exhaustively reviews existing literature on cross-border supply chains.

lowering importing costs into the U.S. does in fact reduce the cost of U.S. exports and increases U.S. income and employment.

Our analysis is based on data on wait times associated with primary inspections of freight shipments collected by CBP. The change in wait time is first estimated, and then translated into changes in freight costs through a logistical model. The resulting changes in transportation costs are then fed into the Global Trade Analysis Project (GTAP) CGE multi-country model of the world economy to analyze competitiveness and macroeconomic impacts on the economies of the U.S., Canada, and Mexico. We disaggregate the inputs into GTAP for each of the twelve border crossings that we examine to further analyze the factors that most influence the outcome, including differences in wait times, effects of additional CBP staffing, effects on transportation costs, and commodity mix traversing each crossing. Figure 1 provides a schematic description of our analysis.

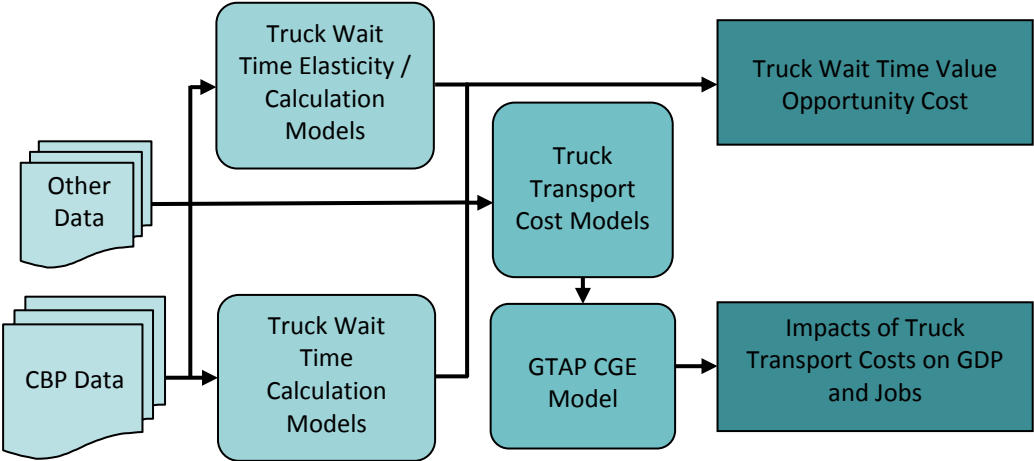


FIGURE 1 SCHEMATIC DESCRIPTION OF THE METHODOLOGY

We find that adding one CBP agent at each land border crossing would, on average per crossing, generate an increase in U.S. GDP of \$250 thousand and 2.55 additional jobs. Both Canada and Mexico would reap net macroeconomic gains as well, with those of Canada exceeding U.S. gains by several-fold. We conclude with a discussion of the policy implications of our analysis.

2. LITERATURE REVIEW

Transport time is one of the most important factors affecting trade between countries, and the longer a product travels from the country of origin to the destination country, the higher its shipping or transport cost. In addition to factors such as the quality of the logistics infrastructure, shipping time is also affected by wait times at border crossings and other checkpoints.

Hertel et al. (2001) estimate both the short- and long-run effects of the Free Trade Agreement (FTA) between Japan and Singapore on the output, consumption, investment, exports and imports, GDP and welfare of both trading partners. The authors argue that, with the decline in global manufacturing tariffs, free trade agreements began to focus on other issues, such as regulations of e-commerce, foreign investment, customs procedures, etc. The authors consider potential gains from the introduction of uniform e-commerce standards in Singapore and Japan. They study the effects of automating Japanese customs procedures to make them compatible with the computer systems used by customs in Singapore, thereby allowing faster transit times and lowering administrative costs and lag times for Japan's exports and imports. Using the dynamic GTAP model, Hertel et al. (2001) find that in the short or medium run the trade balance in both countries declines, but it improves in the long run due to increased exports. They conclude that the increase in trade volumes between the two trading partners is mainly due to customs automation. Moreover, these trade gains in Japan and Singapore positively affect their GDP and investment.

Minor et al. (2008) use a database of tariff equivalents for time in trade by product and country pairs, and a computable general equilibrium framework to simulate the reductions in trade times for four different country groups defined by level of development. They note that over the last four decades the reduction in average import taxes significantly facilitated international trade. Moreover, changes in transportation technology also contributed to the growth in trade, resulting in an average annual increase of air transport services by 10%. The authors suggest that reduced tariffs and trade times enable countries to trade a wider variety of commodities that involve low-value bulk products in contrast to advanced high value goods and food products requiring faster delivery. The study finds that "trade facilitation" is one of the important factors affecting the growth in trade across borders of developing countries. Their results also indicate that countries that reduce trade time reap significant benefits, relative to those countries that make no such improvements.

This finding is consistent with the theory of supply chain management, which suggests that the benefits from the reduction in shipping times for the fastest deliverer grow with the increase of the gap between that deliverer and the next fastest deliverer. Finally, Minor et al. (2008) find that in Sub-Saharan Africa the reduction in delivery times increases the export share of high value products.

Furthermore, a number of studies show a strong relationship between transport costs and the transit time required to ship goods from origin to destination (Djankov et al., 2010; OECD, 2003). The OECD (2003) study shows that indirect costs associated with delays in transit times have more significant impact on trade levels than the direct costs. Additionally, Djankov et al. (2010) find that a delay in trade by one day decreases trade levels by 1%. A study by Hummels and Schaur (2013) analyzes firms' choice between fast but expensive air transport, and slow but inexpensive maritime transport, a choice that depends on the value placed by consumers on the fast shipping and the price elasticity of demand. The authors find that each day of shipping is equal to an ad-valorem tariff of 0.6 to 2.3 percent, with parts and components representing the most time-sensitive trade flows, and the cost of an extra day of transport being 60% higher for importers of intermediate goods than for importers of final goods. Hummels et al. (2013) state that these results show a strong relationship between the reduction in air transport costs and fast growth in trade.

The high degree of sensitivity of intermediate goods such as parts and components to transport time suggests that border delays are particularly important in the context of cross-border supply chains, which are also often referred to as global value chains. Production of goods and services is increasingly taking place through supply chains in which different stages of production are specialized to countries that have a comparative advantage in carrying out a particular task needed to produce a good or service. Competition is thus increasingly taking place at the level of production tasks rather than sectors. The value added associated with the production of a good or service is split between the countries involved in the supply chain, and intermediate inputs in the chain can cross national borders several times in the course of production. OECD (2013) comprehensively reviews cross-border supply chains and shows that their importance in the global economy has risen dramatically in recent decades. As a result, trade in intermediate goods and services now accounts for a

majority of international trade.² The direct and indirect import content of exports has also been rising sharply since 1995 in OECD economies (OECD 2013, p.25) Given these trends, increasing the competitiveness of imports can be expected to increase the competitiveness of exports in any sector in which cross-border supply chains are significant.

Taking these supply chains into account when analyzing the economic impact of trade impediments such as tariffs, quotas, and border delays is of fundamental significance. For example, even though tariff levels are now quite low in most countries and sectors, because intermediates typically flow across several national borders in a supply chain, low tariff levels can still result in a large cumulative impact on trade cost.³ Tariff or non-tariff barriers erected to protect domestic producers could actually harm them if they are dependent on cross-border supply chains. Bringing these supply chains into trade policy analysis is still at a very early stage, and models such as GTAP do not yet explicitly incorporate all of their features. However, because GTAP does distinguish between trade in intermediate and final goods and captures the use of intermediates in the production of exports, it does capture a major portion of a cross-border supply chain.

3. IMPACT OF INCREASED STAFFING ON PRIMARY INSPECTION WAIT TIME AT COMMERCIAL VEHICLE CROSSINGS

When commercial vehicles arrive at a U.S. port of entry, CBP conducts an initial inspection, known as a primary inspection, in which required documents are checked and an initial evaluation is made of the vehicle. If a vehicle is deemed suspicious, it will be referred to secondary inspection to undergo a more intensive examination. We evaluate in this study the impacts of lowering the wait time associated with the primary inspection process for commercial vehicles. We do not evaluate the economic impacts associated with secondary inspection, which affects a minority of traffic crossing the border.

The analysis at the level of individual POEs was carried out using CBP data and operations research and economic analysis methods. Our goal is to quantify how primary wait time for commercial vehicles falls if one

² Recent evidence suggests that trade in intermediates account for 56% of goods trade and 73% of services trade (OECD 2013, p.24.)

³ This effect is amplified by the fact that tariffs are levied on the gross value of imported goods rather than on value added. See OECD (2013), particularly Box 3.1 on p. 90.

extra CBP inspection officer is added to a border crossing's staff. Quantifying how wait times change when staffing is added to or subtracted from a border crossing is challenging, because there is considerable adaptive behavior at these crossings, for both CBP officers and those traversing the border. At most crossings, traffic arrival mounts up and falls off with the rush hour cycle, and staff is added and then subtracted in reaction to the changing traffic flow. This endogenous behavioral reaction prevents the use of simple regression techniques to estimate the relationship between wait time and staffing.⁴

Rather than analyzing historical data on wait times and staffing levels, we developed a theoretical model that can be applied to any border crossing that processes vehicle traffic. This model is developed in the Appendix. We do not base our model on results from standard queuing theory, because this is only useful for queuing systems that are not "saturated," so that queues are not building up or building down in a deterministic fashion over time. However, at border crossings the dominant patterns are rush hour patterns. We have developed a model of a deterministic queuing system that is based on assuming that a stationary deterministic queue exists at the crossing that is neither rising nor falling over time. We then shock the stationary deterministic queue by adding one officer in a given hour of the crossing's operation and quantify how wait time changes using a simple algebraic approach. The approach yields a formula that contains variables for which empirical data are collected by CBP.

To carry out some validation of the theoretical model that we developed, we evaluated the results of a staffing experiment that was run at the San Ysidro port of entry on the weekend of July 21-22, 2012. Although this port processes passenger vehicles rather than commercial vehicles, the queuing systems for passenger vehicles and commercial vehicles are identical in all key respects, so we use the same theoretical model to estimate change in wait time with respect to a staffing increase for both types of crossings, so this validation is assumed to be relevant for commercial vehicle crossings as well. During the staffing experiment, CBP increased the number of open primary inspection booths by roughly 35% above the levels normally experienced on weekend hours, and wait time fell by 62%, implying an elasticity value of roughly -1.8. This experiment at San Ysidro provides some validation of our theoretical model: we used the model to predict how wait time should

⁴ Regression analysis would require identifying suitable instruments to control for simultaneity, and no instruments have yet been found.

have changed at San Ysidro if a 35 percent increase in staffing took place on the 2012 survey dates and found that the predictions were very close to how wait time actually changed.⁵

We use the theoretical deterministic queuing model to evaluate how wait time would have changed if one officer had been added to CBP staff at a particular crossing in 2012. Adding one officer to a border crossing's staff creates 8 additional hours of primary inspection capability on the days that the officer works on enforcement activities, which is 153 days in a year. For each border crossing, we identified the 8 most congested contiguous hours of each day in 2012, assumed that an additional officer would be deployed to these hours, and used the theoretical formula to determine how wait time would have changed in each hour of these 8-hour stretches. We then calculated an average change in wait time for each 8-hour stretch, and averaged across all 8-hour stretches in 2012.⁶ We also assumed that the officer would be assigned to process commercial vehicles in regular lanes rather than FAST lanes, which are dedicated to vehicles that participate in a trusted-shipper program and are subject to different conditions in primary inspection.⁷

Values for historical mean wait times at the 12 crossings evaluated in this study in 2012 are given in Table 1, as well as estimates of how these wait times would have changed if one officer had been added to the crossing's staff.

The theoretical model developed to quantify the relationship between wait time and staffing is an approximation to the true relationship. However, it is known that the approximation underestimates the degree to which wait time falls with the addition of an extra officer. This means that the impact results quantified in this study are conservative and understate the likely gains resulting from adding an extra officer.

Lower wait time reduces the monetary and non-monetary costs associated with making a cross-border trip, and the number of cross-border trips made by commercial vehicles may increase as a result. In this study, we make the assumption that the number of commercial vehicle trips across the southern and northern borders does not increase if wait time is reduced. It is not obvious how the impact of wait time on the number of commercial vehicle trips should be modeled. Shipping companies might plan a given number of trips regardless

⁵ See Roberts et al. (2013) for further discussion of this experiment and validation of model predictions.

⁶ We did not make any assumption on what 153 days of the year the extra officer would be deployed.

⁷ It would always be optimal for CBP to add an extra officer to regular lanes rather than to FAST lanes, because wait time and queue length are almost always significantly greater in the former.

of wait time, so that the primary impact of an increase or fall in wait time is to impact shipping cost. At some point, an increasing wait time level will necessarily impact the number of commercial vehicle trips, but it is not clear that current levels are so high that this will be the case. Very high levels of wait time could also have longer-run impacts on decisions about where to locate production plants and supply chain activity. Given the lack of any empirical evidence on these responses, we conservatively assume that they equal zero.

4. IMPACTS OF REDUCED WAIT TIMES ON TRUCK TRANSPORTATION COSTS

A decline in primary inspection wait time reduces the transportation cost associated with making import shipments into the U.S. by truck. This section estimates the changes in transportation costs for trucks using a logistical analysis of the border inspection process. The percent changes in freight transportation costs are then the primary input into the GTAP model to evaluate the macroeconomic impacts of changes in wait times for truck transportation.

4.1 Volumes of Truck Traffic at the Border

The number of trucks that traveled through each of the POEs during FY 2012 is given in Table 1, both in total and for only the 8 most-congested hours of each day. Table 1 also lists the total number of trucks processed per block of 8 most-congested hours (excluding those days when the truck volume is zero – perhaps because the port is not open on that particular day). The additional CBP officer is assumed to be added to the 8 most-congested hours of each day, and to work 153 days (shifts) per year. Accordingly, the number of truck that will encounter a reduced wait time at the border is the total number of trucks processed per block of 8 most-congested hours multiplied by 153 days (see last column of Table 1).

We assume that only those trucks moving through the border during the hours and days when the additional customs officer is on duty will encounter a lower wait time. While the wait time reductions induced by the additional officer's presence can extend beyond the 8 hours when the officer is actually on duty (because they help thin out the queue), we lack a basis by which to assess these 'spillover' wait time reduction effects, so we conservatively assume that they are zero.

TABLE 1. TRUCK VOLUME FOR EACH LAND PORT OF ENTRY FOR FY 2012

	Port of Entry	Crossing	No. of Trucks Processed ^a				
			Total	8 Most-Congested Hours	All Other Hours	Per Block of 8 Most-Congested Hours (average)	Per Block of 8 Most-Congested Hours x 153 Days (average)
Southern Border	Calexico	Calexico/East	320,482	211,515	108,967	680	104,040
	El Paso	Ysleta	360,470	203,124	157,346	653	99,909
		Bridge of the Americas	290,220	199,316	90,904	645	98,685
	Laredo	Columbia Solidarity	215,701	145,353	70,348	709	108,477
		World Trade Bridge	1,356,418	841,894	514,524	2,319	354,807
	Nogales	Mariposa	298,730	230,501	68,229	688	105,264
	Otay Mesa	Otay Mesa	644,925	443,118	201,807	1,221	186,813
Sub-Total (Southern POEs)			3,486,946	2,274,821	1,212,125	n.a.	1,057,995
Northern Border	Blaine	Pacific Highway	343,396	170,679	172,717	466	71,298
	Buffalo-Niagara Falls	Lewiston Bridge	309,365	82,187	227,178	225	34,425
		Peace Bridge	625,651	256,453	369,198	701	107,253
	Detroit	Windsor Tunnel	39,186	24,719	14,467	67.5	10,328
		Ambassador Bridge	1,425,757	574,819	850,938	1,571	240,363
Sub-Total (Northern POEs)			2,743,355	1,108,857	1,634,498	n.a.	463,667
Total (all POEs)			6,230,301	3,383,678	2,846,623	n.a.	1,521,662

^a Includes only those days for which data are available.

4.2 Commercial Vehicle Wait Times at the Border

Our model does not include the time spent in or waiting for a secondary inspection, nor do we include the processing time for the primary inspection itself. Accordingly, the total time needed for the border crossing is simply the wait time for the primary inspection (WT), and the change in the total border crossing time is then the change in the wait time (ΔWT). The wait times for trucks (WT) are summarized by POE in Table 2. Note that although our model uses hours as the calculational unit for time, the wait times in Table 2 are given in minutes, as their magnitudes are such that this makes for a more intuitive unit for display.

TABLE 2. WAIT TIMES FOR TRUCKS IN THE DEFAULT (STATUS QUO) CASE AND THE EXPECTED CHANGES IN WAIT TIMES FOR ADDING ONE CBP OFFICER TO EACH LAND PORT OF ENTRY

	Port of Entry	Crossing	No. Trucks Encountering Wait Time Reductions	Average Wait Time, Default Case (minutes)			Change in Wait Time During 8 Most-Congested Hours, +1 Officer Case ^{a,b}	
				Overall	8 Most-Congested Hours	All Other Hours	Percent	Minutes
Southern Border	Calexico	Calexico/East	104,040	25.3	28.8	18.7	-69.6%	-20.0
	El Paso	Ysleta	99,909	10.1	13.1	6.3	-72.9%	-9.5
		Bridge of the Americas	98,685	14.6	17.5	8.4	-58.4%	-10.2
	Laredo	Columbia Solidarity	108,477	7.4	8.6	5.0	-95.5%	-8.2
		World Trade Bridge	354,807	23.8	29.0	15.3	-69.0%	-20.0
	Nogales	Mariposa	105,264	30.4	37.5	6.1	-54.6%	-20.5
Otay Mesa	Otay Mesa	186,813	29.4	34.2	18.9	-38.1%	-13.0	
Northern Border	Blaine	Pacific Highway	71,298	11.0	16.4	5.7	-83.0%	-13.6
	Buffalo-Niagara Falls	Lewiston Bridge	34,425	2.3	8.1	0.19	-71.0%	-5.8
		Peace Bridge	107,253	5.3	11.2	1.1	-47.1%	-5.3
	Detroit	Windsor Tunnel	10,328	3.5	4.6	1.6	-100.0%	-4.6
		Ambassador Bridge	240,363	4.6	7.0	2.9	-61.2%	-4.3

^a Optimally allocated to the eight most congested hours of each day.

^b Relative to the default values.

4.3 Truck Travel Distances

Owing to a lack of other data, we use the simplifying assumption that all trucks crossing the border are registered in the country from which they are departing (Canada or Mexico). The overall freight transport distances (from origin to destination) are estimated by the proxy of the straight line distances between the population centroids of the U.S. and the country of origin of the goods (Canada or Mexico). Moreover, freight movements travel by road, and therefore likely deviate from a straight line path.⁸ Within each country, we assume that the distance traveled is proportional to the (average) trip distance for domestic shipments (not

⁸ Using data on the locations and populations of various sub-national administrative units (in the year 2000) from NASA (SEDAC, 2005) and the distance calculator from the U.S. National Hurricane Center (NHC, 2010), the total freight transport distances are determined as 674 miles for Canada-U.S. shipments, and 1,240 miles for Mexico-U.S. shipments.

imports) in that country, estimated as the ratio of domestic truck movement in ton-kilometers to domestic freight movement in tons.⁹

The ratio of the domestic distance for Mexico to that for the U.S. is $(469\text{km}/251\text{km}) = 1.87$, so we assign 87% more of the total Mexico-U.S. transport distance (1,240 miles) to Mexico. For Mexico-U.S. shipments, this results in estimated trip distances of 808 miles in Mexico and 432 miles in the U.S. Applying this procedure to Canada-U.S. shipments gives 355 miles traveled in Canada and 319 miles traveled in the U.S. Additionally for Canada, in 2009, trucks weighing 4.5 metric tons or more drove some 1,969 million vehicle-miles for “trips across Canada and United States border” (Statistics Canada, 2010). With a total of 5,020,633 truck trips into the U.S. from Canada in 2009 (BTS, 2012), and assuming that all of these trucks are Canadian-registered (see above), this equates to 392 miles traveled per trip in Canada. The average estimated trip distance in Canada is therefore 373.5 miles.

4.4 Truck Operating Costs

Unless otherwise noted, all costs are specified on a per truck and per trip basis, and are in 2011\$.¹⁰ The fuel consumed is the ratio of the distance traveled to the truck fuel efficiency (*TFE*; miles/gallon), which is a function of the (average) truck speed. Similarly, the distance traveled by the truck is the product of the truck’s speed (*S*) and the total travel time. We use an average truck speed of 40 miles/hour for the open highway (*S_h*) (ATRI, 2011), and 5 miles/hour when in the queue and during the border crossing (*S_b*). For U.S. truck fuel efficiency, we use the regression equation of Schrank et al. (2011), based on average truck speed. While not addressing 18-wheel trucks specifically, the American Transportation Statistics Database (NATSD, 2012) does include fuel efficiency data for “new light-duty trucks.” These data indicate that Canadian trucks are, on average, around 1% more fuel efficient than U.S. trucks, and that Mexican trucks are around 9% more fuel efficient than U.S. trucks, so we make the appropriate adjustments. For the cost of diesel fuel, we use

⁹ Using data obtained from the North American Transportation Statistics Database (NATSD, 2012) for 2010 (the most recent year for which data are available for all three countries), the trip distances for domestic shipments work out to 279 km for Canada, 469 km for Mexico, and 251 km for the U.S.

¹⁰ Inflation adjustments are made using the Producer Price Index (PPI—across all commodities), and conversions from Canadian to U.S. dollars using the Bank of Canada’s currency converter (Bank of Canada, 2013).

\$3.42/gallon for Mexico, \$4.03/gallon for the U.S., and \$4.94/gallon for Canada (all deflated from 2013\$ to 2011\$), as obtained from MyTravelCost.com (2013).

So that they can be readily linked to the reduced wait times at the border, in cases where truck operating cost data from the literature are specified on a per mile (rather than per hour) basis, we convert them to hourly costs using an overall average truck speed of 40 miles/hour (ATRI, 2011). The average hourly wage for “heavy and tractor-trailer truck drivers” in the U.S. is \$19.15/hour, according to the U.S. Bureau of Labor Statistics (BLS, 2012). The American Transportation Research Institute gives figures of \$18.74/hour excluding benefits, and \$24.68/hour including benefits (ATRI, 2011). Workers in Canada’s “transportation and warehousing” industry earn, on average, \$22.99/hour (Statistics Canada, 2012). Transport Canada (2005) also provides numerous truck driver wage estimates, working out to around \$23.10/hour, on average. Averaging all of these values together gives \$20.86/hour for U.S. truck drivers and \$23.05/hour for truck drivers in Canada. Driver wage data for Mexico could not be found, so this was estimated by adjusting the wage rates for the U.S. and Canada, using the relative GDPs per capita of the two countries (GDP data from World Bank, 2013), working out to \$4.48/hour (average value).

The Minnesota Department of Transportation estimates a (average) cost of \$12.80/hour for truck repairs, maintenance, tires, and depreciation (MDOT, 2003). The American Trucking Research Institute proposes \$23.95/hour (ATRI, 2011). Boyer (1997) posits \$25.28/hour for vehicle depreciation, licensing, interest, tires, and maintenance, which we have inflated to 2011 dollars. After excluding driver wages (i.e., with the average wage rate subtracted out), Schrank et al. (2011) determine a value of \$76.85/hour for vehicle depreciation, interest, insurance, general maintenance, tires, and repairs (Ellis, 2009). The average operating cost for U.S. trucks is therefore about \$34.72/hour. Data from Transport Canada (2005) indicates an average cost of about \$77.60/hour for truck repairs, cleaning, tires, depreciation, licenses, profit margin, interest, insurance, and administration. For truck operating costs in Mexico, we adapt the values for the U.S. and Canada using relative per capita GDP, yielding \$11.37/hour, on average.

Customs broker fees (per truck trip) are generally \$50-\$150 on the northern border, and \$20-\$30 on the southern border (where the process is more repetitive/organized) (Gould, 2012). We use the range midpoints, or \$25 for the southern border and \$100 for the northern border, which we assume do not depend on the wait times

encountered at the border. Based on interviews conducted with various trucking carriers, Haralambides and Londono-Kent (2004) estimate a (average) loading/unloading cost of about \$154/trip associated with the drayage operation at the U.S.-Mexico border, which we adopt.

4.5 Changes in Truck Transportation Costs

The total truck transport cost (TC) is the sum of the border-related transport costs (TC_b) and the transport costs incurred away from the border. The only component of the total truck transport cost that is affected by wait time changes is the border-related transport costs (TC_b), so the change in the total truck transportation costs is therefore:

$$\Delta TC = \Delta TC_b = (\Delta WT) \cdot \left[UC_w + UC_v + UC_f \cdot \left(\frac{S_b}{TFE_b} \right) \right] \quad (1)$$

where UC_w , UC_f , and UC_v are the unit costs of driver wages (\$/hour), fuel (\$/gallon), and all other vehicle-related operating expenses (\$/hour), respectively. Note that the customs broker and drayage fees are assumed unaffected by wait time changes, and hence why they do not appear in Equation 1. Equation 1 shows that the change in the total freight transportation costs is linear in the change in wait time.

Table 3 summarizes the truck transportation cost results for adding one customs officer to each POE during the eight most congested hours of each day. The changes in truck transport costs range (in magnitude) from a low of -0.053% (-\$0.37 M per year) for the El Paso (Ysleta) POE, to a high of -0.252% (-\$1.81 M per year) for the Blaine POE. The reduction in aggregate freight transportation costs (considering all trucks and all POEs) is \$11.67 M annually.

4.6 Sensitivity Analysis

Rather than examining the sensitivity of the results at all of the various POEs, sensitivity analysis was performed only on the Nogales (Mariposa) POE (southern border). The values of 16 model parameters were changed simultaneously by +/-25% so as to yield 'high' and 'low' truck transport cost cases, respectively. The various parameters whose values were varied are the: broker and drayage costs, unit fuel costs (3, one for each country involved), unit wage costs (3), unit truck operating costs (3), truck speeds (2, highway and queue), and

travel distances in each country (3). Note that ‘low’ and ‘high’ sensitivity cases refer to the values of the *transport costs*, and not to the values of the input parameters. This is why the higher truck speeds are used in the ‘low’ cost sensitivity case, and not in the ‘high’ cost sensitivity case.

The sensitivity analysis results indicate that the aggregate change in truck transport costs (relative to the default/status quo officer case) are -\$0.640 M and -\$1.020 M in the ‘low’ and ‘high’ transport cost cases, respectively. Relative to the change in the ‘middle’ cost case (of -\$0.832 M, as presented in Table 3), this represents changes (in magnitude) of about 23%. This indicates that the cost changes are essentially linear, as the various input parameters were all varied by 25% (in magnitude).

When the changes in total truck transport costs are viewed in percentage terms, however, the results are less straightforward. In this case, the percentage change in costs (relative to the default/status quo officer case) is actually greater (in magnitude) in the ‘low’ cost case than in the ‘middle’ cost case (-0.217% versus -0.145%, respectively), and also greater in the ‘middle’ cost case than in the ‘high’ cost case (-0.145% versus -0.096%,

TABLE 3. CHANGES IN TRUCK TRANSPORTION COSTS FOR ADDING ONE CUSTOMS OFFICER TO EACH LAND PORT OF ENTRY

	Port of Entry	Crossing	No. of Trucks Encountering Less Wait Time	Change in Truck Wait Time ^a		Changes in Total Truck Transport Costs	
				Percent	Per Truck (minutes)	Total (all trucks) (2011 US\$)	Percent
Southern Border	Calexico	Calexico/East	104,040	-69.6%	-20.0	-\$0.81 M	-0.131%
	El Paso	Ysleta	99,909	-72.9%	-9.5	-\$0.37 M	-0.053%
		Bridge of the Americas	98,685	-58.4%	-10.2	-\$0.39 M	-0.070%
	Laredo	Columbia Solidarity	108,477	-95.5%	-8.2	-\$0.34 M	-0.083%
		World Trade Bridge	354,807	-69.0%	-20.0	-\$2.74 M	-0.105%
	Nogales	Mariposa	105,264	-54.6%	-20.5	-\$0.83 M	-0.145%
	Otay Mesa	Otay Mesa	186,813	-38.1%	-13.0	-\$0.94 M	-0.076%
Sub-Total (Southern POEs)						-\$6.42 M	n.a.
Northern Border	Blaine	Pacific Highway	71,298	-83.0%	-13.6	-\$1.81 M	-0.252%
	Buffalo-Niagara Falls	Lewiston Bridge	34,425	-71.0%	-5.8	-\$0.37 M	-0.057%
		Peace Bridge	107,253	-47.1%	-5.3	-\$1.06 M	-0.081%
	Detroit	Windsor Tunnel	10,328	-100.0%	-4.6	-\$0.09 M	-0.109%
		Ambassador Bridge	240,363	-61.2%	-4.3	-\$1.92 M	-0.065%
Sub-Total (Northern POEs)						-\$5.25 M	n.a.
Total (all POEs)						-\$11.67 M	n.a.

^a Relative to the default/status quo case.

respectively). The reason for this is because the total truck transportation costs (from origin to destination, including the border crossing) change at a different rate than the border-related truck transport cost savings (induced by the reduced wait time). For example, the total transport cost in the 'middle' and 'low' cost cases differ by a factor of 1.95 (\$1,927/truck and \$989/truck, respectively), yet the change in the truck transport costs between the two cases differ only by a factor of about 1.30 (-\$2.79/truck and -\$2.14/truck, respectively). Consequently, the magnitude of the percentage change in truck transport costs is greater in the 'low' cost case than in the 'middle' case.

5. MACROECONOMIC ANALYSIS

The majority of U.S. trade with its largest trading partners, Canada and Mexico, is conducted via land transport through its northern and southern borders, respectively. In 1994, the United States, Canada, and Mexico signed the North American Free Trade Agreement (NAFTA), which eliminated various trade duties and restrictions, thereby creating the largest free trade zone in the world (the remaining restrictions were removed in 2008). According to the Office of the United States Trade Representative (2012), NAFTA has better connected 450 million people that produce goods and services worth a total of \$17 trillion. In 2009, the total value of the U.S. trade with its NAFTA partners was \$1.6 trillion, with exports and imports worth \$397 billion and \$438 billion, respectively.

Although NAFTA eliminated trade restrictions and tariffs, it only moderately improved border crossing procedures (e.g., inspections/processing). Regarding the U.S.-Canada border, Taylor et al. (2003) argue that the trade, border, and immigration policies across the U.S.-Canada border remain heavily influenced by pre-NAFTA practices. Moreover, the economies of both countries have incurred significant cost impacts due to such policies, and these cost impacts became even more significant after tightened border security following the 9/11 terrorist attacks.

We estimate the impacts of the changes in freight transportation costs on U.S. international trade with a computable general equilibrium (CGE) model. This is a multi-market model of behavioral responses of individual producers and consumers to price signals within the limits of available labor, capital, natural resources (Dixon and Rimmer, 2002). CGE is a state-of-the-art approach to economic consequence analysis. It

overcomes the major limitations of I-O because it allows for non-linearities such as input substitution, has behavioral content, provides an explicit role for prices and markets, and can distinguish between intermediate and final consumption goods (Rose, 1995).

CGE models have been widely applied to trade and transport-related issues. Sandoval et al. (2009) use a CGE model of the global economy to analyze the economic feasibility of hydrogen transportation and trade under various carbon stabilization and tax policy scenarios. Pilegaard and Fosgerau (2008) use a spatial CGE model to analyze the impact of reduced transport costs on increased employment search over longer distances. Lloyd and MacLaren (2010) suggest “semi-general equilibrium” measures, including non-tariff measures, to capture general-equilibrium effects neglected in partial-equilibrium forms of the Trade Restrictiveness Index and the Mercantilist Trade Restrictiveness Index. Finally, a recent study by Winchester et al. (2013) uses a recursive dynamic CGE model to study the impacts of a representative carbon policy on U.S. aviation operation and emissions. The topic of the CGE application in this paper is unique, as is the methodological refinement of our approach.

Changes in border wait times translate into changes in transportation costs, which, in turn, translate into changes in relative competitiveness of U.S. imports and exports. Ironically, although the costs of reductions in wait times (e.g., additional customs personnel) will be borne by the U.S., reducing the wait times for goods entering the U.S. makes them relatively cheaper, and spurs U.S. imports from its northern and southern neighbors. This has the effect of initially advantaging Canada and Mexico relatively more than the U.S. However, the vast majority of the imports are unfinished (intermediate) goods rather than finished (final, or consumer) goods. This lowers the cost of production in the U.S. and makes its exports more competitive, not only to Canada and Mexico, but to all countries. This stimulates U.S. exports worldwide, and causes increases in U.S. GDP, personal income, and employment. The extent to which the negative effect of increased import competitiveness for U.S. major trading partners is offset by the effect of increased U.S. export competitiveness requires a sophisticated economic modeling framework, such as the CGE approach.

5.1 GTAP Model

We utilize a version of the Global Trade Analysis Project (GTAP, 2012) CGE model that allows substitution among modes of transport (Avetisyan and Hertel, 2013). GTAP was developed in conjunction with

the U.S. International Trade Commission (ITC) and the World Trade Organization (WTO) and is currently the most widely used international CGE model. The model consists of 129 country economies, each of which is comprised of 57 industry commodity groupings, and incorporates the import/export trade linkages between them. In our analysis, we aggregate the model to 4 regions (United States, Canada, Mexico, and Rest of World).

Production: The production structure is an overall constant elasticity of substitution (CES) form for aggregate factors of production, though fixed coefficient relationships are used for intermediate inputs. Value added from primary factors together with intermediate inputs generates the final output in the model.

Consumption: Household consumption in the GTAP model is represented by constant-difference of elasticities (CDE) functional form, whereas the household's preferences over consumption, government spending and saving are characterized by Cobb-Douglas relationship.

Trade and Transport: International trade and transport in the Global Trade Analysis Project (GTAP) model are represented by merchandise goods and "margin" services (shipping services, or transport costs). These data are contained in a "trade matrix," which includes bilateral flows of regular commodity components, while the margins preserve the balance between global imports (CIF values) and exports (FOB values).¹¹ The difference between imports and exports of global merchandise represents global exports of transport services (transport margins).

In the GTAP model, the origins and destinations of traded goods are specified. However, this is not the case for transport services, which are grouped into a single Global Transport Services Industry, and then allocated to the various importing countries using the share of exports of traded merchandise (non-margins) for each country in the global exports of traded goods. More specifically, when the source country, r , exports a commodity to the country of destination, s , the export commodity (at FOB price) is combined with the composite international transport good (which is a mix of air, water, and other transport modes), thereby generating the CIF price of the commodity in the destination country. Figure 2 summarizes the structure of the standard GTAP model.

¹¹ Cost, insurance, freight (CIF) value includes the cost of goods, insurance, and freight up to the destination. Free on Board (FOB) value does not include the cost of shipping and insurance. The seller is required to deliver merchandise on board of a vessel specified by the buyer.

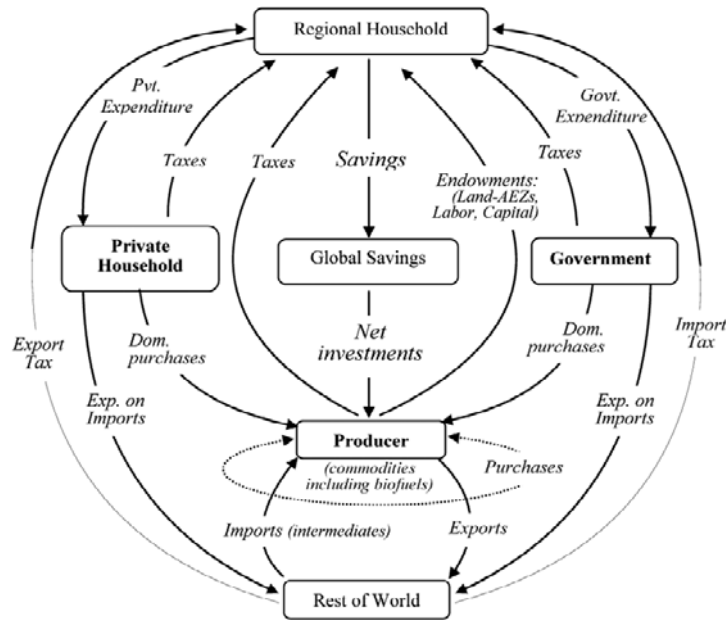


FIGURE 2 STRUCTURE OF THE GTAP MODEL (SOURCE: HERTEL ET AL., 2010)

While the transport input is a fixed composite good, our modified version of the model allows for substitution among modes within the composite transport good. The transport modal substitution is determined by a Constant Elasticity of Substitution (CES) production function. The CES elasticity of substitution, with a typical value of 0.9 to 2.8, governs modal choice changes in response to variations in the relative cost of the different transport options.

The substitution among different modes of transport is incorporated in the GTAP model by estimating the elasticities of modal substitution for land-air and water-air transport pairs (Avetisyan and Hertel, 2013). The modal substitution elasticities by commodity, source, and destination are then generated by applying the weighted transport cost shares from the GTAP data base to the estimated elasticities of substitution between land-air and water-air transport modes. The study also shows that improvement in logistics reduces the cost and amount of transportation services required to transport a given product along a particular route using a given mode.

In the GTAP model, transportation costs are endogenously determined. A transport cost reduction scenario can be modeled by exogenizing and perturbing the corresponding transportation price variables

($ptrans_{i,r,s}$ and pt_m) in the modal substitution Equation 2 from the GTAP model.¹² Specifically, $ptrans_{i,r,s}$ is the price of composite transport services in Global Transport Industry for shipping good i from source r to destination s , and pt_m is the price of global transport services by mode m . The latter is a price index for each mode that applies globally, and is not differentiated by industry, source, or destination.

$$qm_{m,i,r,s} = - am_{m,i,r,s} + qx_{i,r,s} - \sigma_{i,r,s} \cdot (pt_m - am_{m,i,r,s} - ptrans_{i,r,s}) \quad (2)$$

where:

$qm_{m,i,r,s}$ is the international usage of transport mode m to ship good i from region r to s ;

$am_{m,i,r,s}$ is the change in transportation technology of mode m to ship good i from region r to s ;

$qx_{i,r,s}$ is the export sales of commodity i from region r to s ;

$\sigma_{i,r,s}$ is the elasticity of modal substitution to ship good i from region r to s ;

pt_m is the price of composite transportation services;

$ptrans_{i,r,s}$ is the cost index for international transport shipping good i from region r to s .

If transportation costs decrease due to technological factors not included in the model, the transport cost variable $ptrans(i,r,s)$ needs to be “swapped” with another variable to maintain the equivalence of equations and variables in equilibrium models. Therefore, we use a variable representing the change in technology of shipping good i from source r to destination s . Ideally, the value of this now endogenous variable would remain zero or near zero because we do not change the transportation technology. Since the reduction of wait times at the U.S.-Canada border assumes an increase in U.S. security staff on the Canadian side, we conclude that it is best to model the corresponding reduction in transport costs as a technological change in the form of an increase in the labor input.

The other transport cost variable pt_m , representing the price index for transport commodity m in margin services usage, can become exogenous only by swapping it with the variable atm_m , representing the change in technology of transport mode m worldwide. This is the only candidate for the swap, since the transport cost variable pt_m is a source, industry, and destination generic variable.

The GTAP model has three transport industries: Other Transport, Water Transport, and Air Transport. The design of the transport cost reduction scenario becomes more complex due to a need to separate truck

¹² Note that in Equation 3 all variables represent percent changes in corresponding level variables.

transport from the Other Transport industry, which also includes rail transport, pipelines, auxiliary transport activities, and travel agencies.

The U.S. Input-Output Table, provides the use of imported truck transport services by each industry in the U.S. economy. Therefore, we use the following procedure to bridge the trucking industry of the U.S. Input-Output table and the GTAP model:

- a. Identify the total use of imported truck transport services from the U.S. Input-Output table.
- b. Use the GTAP international trade margins by commodity and source for shipments to the U.S. by Other Transport to create shares for allocating the total imports of truck transport services across industries and source countries in the GTAP model.
- c. Apply the weights/shares to the total use of imported truck transport services to estimate U.S. truck transport costs by commodity and source country.

The GTAP model has many strengths but also a few shortcomings. These include the assumption of equilibrium adjustments, perfect competition and perfect information. While the assumptions are unrealistic, their departures from reality are considered relatively minor or not likely to have a significant effect on our results.

5.2 POE Analysis

In the GTAP model the unit transportation costs ($ptrans_{i,r,s}$ -- the price of composite transport services in the Global Transport Industry differentiated by commodity, source and destination) are endogenous, so we need to make the corresponding transportation price variables exogenous to simulate the reduction in transport costs and determine the impact of these cost changes on the U.S. economy. Since the transportation cost decreases due to production inputs not factored into the model, the transport cost variable $ptrans_{i,r,s}$ must be made exogenous, which we do by swapping it with the variable representing the change in production structure (often referred to as “technology,” broadly defined) of shipping good i from source r to destination s .

An example is presented for the Blaine, Michigan, POE. In this case, we adjust the 0.25% reduction of truck transport costs to 0.18% using the share (0.7) of Truck Transport in the Other Transport Industry of the GTAP model. The results of the simulation, in terms of reduced transport costs affecting total exports, imports and GDP in each region are shown in Table 4. Overall, the results indicate that a +1 change in staffing at the Blaine POE will cause a very small positive increase in U.S. GDP of \$0.79 million in 2011 dollars.

As expected, the reduction in transport costs for shipping goods from Canada to the U.S. results in the increase of total imports to the U.S. Interestingly, the total imports to Canada from the U.S. and the Rest of the World also increase, which can be explained by Canada's increased import demand for goods from the U.S. due to the lower cost of U.S.-produced commodities, which also ripples through the global economy. Our findings demonstrate a link between reduced transport costs and growth in trade, consistent with the work of Djankov et al. (2010) and Hummels et al. (2013).

TABLE 4. CHANGES IN U. S. TRADE VOLUMES AND GDP FOR ADDING ONE CUSTOMS OFFICER TO THE BLAINE POE

Regions	Exports (percent)	Imports (percent)	Trade balance (\$US million)	GDP (\$US million)	GDP (percent)
United States	0.0011	0.0016	-4.493	0.790	0.000005
Canada	0.0026	0.0114	-10.794	3.990	0.000258
Mexico	0.0002	-0.0004	0.547	-0.030	-0.000002
Rest of World	0.0000	-0.0002	17.400	-4.741	-0.000009

In the U.S. and Canada, the change in the trade balance is negative because, in both countries, imports grow more than exports. Also, the GDP of Canada increases by \$3.99 million in 2011 dollars, or 0.00026%, due to increased exports. Note that, while the U.S. implements and pays for the changes that result in the reductions in border crossing times, it also gains from transport cost reduction policies because intermediate goods shipments (about 63 percent of total imports at this POE) reduce the cost of production in the U.S., thereby making U.S. exports more competitive world-wide. The gains, however, are not as great as those of Canada. Overall, for this POE the GDP of the U.S. and Canada increase, while the GDPs of Mexico and Rest of the World decline, because their exports to the U.S. are displaced a bit by Canadian exports. This is consistent with the results of Minor et al. (2008) that countries that reduce trade time gain significant benefits when other regions make no improvements in trade.

In terms of individual commodity trade, these results are consistent with the findings of Minor et al. (2008), as summarized in Section II. The most significant increase can be observed in the imports of Canadian paddy rice (by 0.17%), fresh fruits and vegetables (by 0.15%), mineral products (by 0.12%), processed rice (by 0.11%), coal (by 0.09%), and wood products (by 0.08%). The reduced transport costs induce the U.S. to increase its imports of relatively cheaper intermediate goods from Canada, and reduce its imports of all these

products from Mexico and Rest of World. This enables the U.S. to increase its exports of some intermediate and most final consumption products to the global economy.

The U.S. increases almost all its exports to Canada, except minerals, coal, metals, and transport equipment. Within the U.S. (that is, between U.S. states), trade declines for most U.S. industries due to the increased imports of relatively cheaper intermediate products from Canada.

Table 5 summarizes the aggregate trade results for the remaining 5 northern (U.S.–Canada Border) and 7 southern (U.S.–Mexico Border) POEs. The macroeconomic impacts for the remaining northern POEs are similar to the results of the Blaine example, but with some variation in scale. Analogously, the reduction in truck transport costs for all U.S. imports from Mexico through southern POEs increases the GDP of the U.S. and Mexico, while having a negative impact on the GDPs of Canada and the Rest of World regions. For all southern border POEs, the U.S. increases its imports of intermediate goods from Mexico and increases exports of commodities for final consumption to all world regions.

TABLE 5. CHANGES IN UNITED STATES, CANADA, AND MEXICO TRADE FOR ADDING ONE CUSTOMS OFFICER TO EACH PORT OF ENTRY

	Port of Entry	Crossing	Change in transport cost (percent)	Change in Exports (percent)			Change in Imports (percent)			Trade Balance (million 2011 US\$)		
				United States	Canada	Mexico	United States	Canada	Mexico	United States	Canada	Mexico
Southern Border	Calexico	Calexico/East	-0.13%	0.0003	0.0000	0.0000	0.0005	-0.0003	0.0045	-1.073	0.466	-2.782
	El Paso	Ysleta	-0.05%	0.0001	0.0000	0.0000	0.0002	-0.0001	0.0018	-0.433	0.189	-1.123
		Bridge of the Americas	-0.07%	0.0002	0.0000	0.0000	0.0002	-0.0002	0.0025	-0.572	0.250	-1.483
	Laredo	Columbia Solidarity	-0.08%	0.0002	0.0000	0.0000	0.0003	-0.0002	0.0029	-0.679	0.295	-1.758
		World Trade Bridge	-0.11%	0.0002	0.0000	0.0000	0.0004	-0.0002	0.0036	-0.859	0.373	-2.224
	Nogales	Mariposa	-0.15%	0.0003	0.0000	0.0000	0.0005	-0.0003	0.0051	-1.186	0.516	-3.074
	Otay Mesa	Otay Mesa	-0.08%	0.0003	0.0000	0.0000	0.0003	-0.0003	0.0025	-0.621	0.269	-1.611
Sub-Total			n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-5.424	2.356	-14.056
Northern Border	Blaine	Pacific Highway	-0.25%	0.0011	0.0026	0.0002	0.0016	0.0114	-0.0004	-4.790	-11.715	0.664
	Buffalo-Niagara Falls	Lewiston Bridge	-0.06%	0.0002	0.0006	0.0001	0.0004	0.0025	-0.0001	-1.084	-2.649	0.150
		Peace Bridge	-0.08%	0.0003	0.0009	0.0000	0.0006	0.0036	-0.0002	-1.541	-3.765	0.213
	Detroit	Windsor Tunnel	-0.11%	0.0005	0.0011	0.0001	0.0007	0.0049	-0.0002	-2.078	-5.082	0.288
		Ambassador Bridge	-0.07%	0.0003	0.0007	0.0000	0.0004	0.0029	-0.0001	-1.236	-3.021	0.170
Sub-Total			n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-10.729	-26.232	1.485
Totals			n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-16.153	-23.876	-12.571

The difference in percentage change in freight costs between Canada and Mexico is a key factor explaining the difference in GDP impacts between the two countries. The weighted average percentage decreases in costs of trucked goods delivered to the U.S. through northern POEs is about 1.3 times higher than those delivered through southern POEs (this stems to a great extent from the significant reductions in wait times at the Blaine and Windsor Tunnel crossings than at any of the southern border POEs). This helps explain why the increase in Canadian GDP is more than 1.5 times that of Mexican GDP. This correspondence between truck transport costs and GDP impacts between countries is only minimally affected by indirect and induced effects through the global economy, as well as other considerations, such as non-linearities in the model. Also, the facts that Canada's GDP is about 50 percent greater than Mexico's more than offsets Mexico's trucked imports being about 33 percent greater than trucked goods to the U.S. from Canada.

5.3 Macroeconomic Impacts

Table 6 summarizes the total GDP and employment impacts of adding one customs officer to each of the major southern and northern POE crossings. Overall, Canada is predicted to gain most from the +1 staffing change, with an increase in GDP of \$8.6 million, or more than 1.8 times that of Mexico and nearly 2.9 times that of the U.S.

TABLE 6. CHANGES IN U.S. GDP AND EMPLOYMENT FOR ADDING ONE CUSTOMS OFFICER TO EACH PORT OF ENTRY

	Port of Entry	Crossing	Change in transport cost (percent)	Change in U.S. Employment (no. jobs)	Change in U.S. GDP (million 2011 US\$)	Change in Canada GDP (million 2011 US\$)	Change in Mexico GDP (million 2011 US\$)
Southern Border	Calexico	Calexico/East	-0.13%	2.5	0.246	-0.059	0.966
	El Paso	Ysleta	-0.05%	1.0	0.104	-0.023	0.391
		Bridge of the Americas	-0.07%	1.3	0.125	-0.032	0.515
	Laredo	Columbia Solidarity	-0.08%	1.5	0.152	-0.037	0.611
		World Trade Bridge	-0.11%	1.9	0.193	-0.047	0.774
	Nogales	Mariposa	-0.15%	2.8	0.276	-0.066	1.068
Otay Mesa	Otay Mesa	-0.08%	1.5	0.152	-0.035	0.557	
Sub-Total			n.a.	12.7	1.248	-0.299	4.882
Northern Border	Blaine	Pacific Highway	-0.25%	8.1	0.790	3.990	-0.030
	Buffalo-Niagara Falls	Lewiston Bridge	-0.06%	1.9	0.182	0.902	-0.007
		Peace Bridge	-0.08%	2.6	0.248	1.283	-0.009
	Detroit	Windsor Tunnel	-0.11%	3.5	0.343	1.731	-0.013
		Ambassador Bridge	-0.07%	2.0	0.195	1.028	-0.008
Sub-Total			n.a.	17.9	1.757	8.933	-0.067
Totals			n.a.	30.6	3.005	8.634	4.815

Overall, we find that adding one CBP agent at each land border crossing, on average per crossing, would generate an increase in U.S. GDP of \$250 thousand and 2.55 additional jobs (over and above the additional border agents). Both Canada and Mexico would reap net macroeconomic gains as well, with those of Canada exceeding U.S. gains by several-fold. Note also that the implicit multiplier of 2.55 jobs generated for every new customs agent is not an ordinary economic impact multiplier calculated under normal (average) conditions, but rather one related to alleviating a bottleneck (at the margin), so is not surprisingly relatively high.

We warn against drawing inferences from our results at greater scales. Our national and international macroeconomic impact analysis of freight activity is undertaken using a non-linear model. However, we have evaluated the model using only unit changes in customs personnel staffing and can offer no explicit insights about possible non-linearities that might be associated with larger staffing changes, except referring to the law of diminishing returns.

6. CONCLUSION

We have developed macroeconomic impact estimates for adding an extra CBP officer to a particular port of entry to reduce primary inspection wait time. The paper provides some unambiguous results using primary data and a state of the art model. These results are useful to the U.S. government and other relevant stakeholders (other governments, importing firms, exporting firms and NGOs) for evaluating the optimal level of staffing of ports of entry and carrying out cost-benefit analysis related to inspections at ports of entry. They could also be used to support analysis of how port operations could be funded, for example, through budgetary appropriations or through user fees, and for designing an optimal user fee.

Our results also emphasize the importance of taking into account cross-border supply chains when conducting trade policy analysis and modeling. As tariff levels have been significantly lowered in most countries, non-tariff impediments such as inspection delays have become relatively more important as a component of trade cost. Both tariff and non-tariff barriers have cumulating impacts inside a cross-border supply chain that cause a seemingly low barrier to have a much larger impact than its level might suggest. U.S. land borders with Canada and Mexico are crossed intensively by production supply chains, and our results demonstrate that U.S. export competitiveness is significantly impacted by measures that affect importing cost

across these land borders. We thus contribute to an emerging literature that stresses the need to more fully and explicitly integrate various aspects of cross-border supply chains into trade policy analysis and modeling.

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APPENDIX A.

Simple Algebraic Approach to the Wait Time-Staffing Relationship for a Saturated Border Crossing

Although no formal results from queuing theory are available for saturated queuing systems (e.g. , rush hours), it is possible to develop a simple algebraic approach to quantifying how wait time changes if a staffed inspection booth is added to or subtracted from a saturated system. This requires that all variables be made deterministic, so that random fluctuations are stripped from the analysis. For a given hour, define the following variables as:

- V = total number of vehicles processed;
- B = average number of booths open (and each booth is staffed by one officer);
- W = average wait time in seconds spent in the queue;
- Q = average queue length expressed as number of vehicles waiting in the queue at any given time in the hour;
- $v = V/B$ = number of vehicles processed by the average booth;
- $s = 3600/v$ = seconds required to process a vehicle at an average booth;
- $n = Q/B$ = the number of time periods that are s seconds long that are required to eliminate a queue of size Q ;
- Note also that $n = W/s$.

For all land border crossings, CBP has collected data on V , B , and W , and therefore v , s , and n , since November 2009. Q is not measured by CBP. However, because $n = Q/B$ and $n = W/s$, Q can be estimated using this equation:

$$Q = \left(\frac{W}{s}\right)B \quad (\text{A.1})$$

Now consider a queue system that is in equilibrium, so that arrivals to the queue equal departures from the queue, and Q is not changing over time. Denote arrivals by A , and departures by D . If the system is in equilibrium, then every s seconds, it must be the case that arrivals equal departures. Because departures equal B , arrivals must equal B , so that the change in queue length Q is:

$$\Delta Q = (A - D) = (B - B) = 0. \quad (\text{A.2})$$

Now consider adding one extra booth at the beginning of the hour, and keeping arrivals fixed at B every s seconds. Departures every s seconds become B+1, and it must be the case that every s seconds, the change in Q is:

$$\Delta Q = (A - D) = (B - (B + 1)) = -1. \quad (\text{A.3})$$

Over the course of an entire hour, Q falls by v vehicles

$$\Delta Q = -v. \quad (\text{A.4})$$

and at the mid-point of the hour:

$$\Delta Q = -\left(\frac{v}{2}\right). \quad (\text{A.5})$$

Denote the queue length at the start of the hour as Q_0 . Then adding an extra booth leads to a new queue length at the mid-point of the hour equal to:

$$Q_M = Q_0 - \left(\frac{v}{2}\right). \quad (\text{A.6})$$

Using the equation $Q = (W/s)*B$, wait time at the mid-point of the hour is:

$$W_M = \frac{sQ_M}{(B+1)} = \frac{s(Q_0 - \frac{v}{2})}{(B+1)} \quad (\text{A.7})$$

The ratio of the new wait time to the old wait time is therefore:

$$\frac{W_M}{W} = \frac{\frac{s(Q_0 - \frac{v}{2})}{(B+1)}}{\frac{sQ_0}{B}} \quad (\text{A.8})$$

or:

$$\frac{W_M}{W} = \left(\frac{B}{B+1}\right)\left(\frac{Q_0 - \frac{v}{2}}{Q_0}\right). \quad (\text{A.9})$$

For a given hour at a given border crossing for a given lane type, actual data can be used to calculate values for n and Q_0 , and then the above equation can be used to estimate how much wait time would change if one booth was added. This is the approach taken to calculating the percentage change in wait time in an hour resulting from adding one booth. If a booth is subtracted, the equation becomes:

$$\frac{W_M}{W} = \left(\frac{B}{B-1} \right) \left(\frac{Q_0 + \frac{V}{\lambda}}{Q_0} \right). \quad (\text{A.10})$$

This approach gives a result that is an approximation, because the approach assumes that the queue is initially in equilibrium. There are two important limitations to this approach:

- *Q is not stationary.* In most hours of the day, Q is not stationary but is rising or falling;
- *Cross-hour spillover impact not captured.* When a booth is added in one hour, it reduces the queue in that hour, but it also reduces the queue length and wait time in subsequent hours. This spillover impact is not captured by the simple approach outlined here. This approach thus gives a lower bound to the impact of adding one booth for a whole day.