# Indirect Transportation Cost in the border crossing process: The United States-Mexico trade

# Costos Indirectos de Transporte en el proceso de cruce fronterizo: El comercio entre Estados Unidos y México

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Abstract
Using a Social Accounting Matrix as database, a Computable General Equilibrium model is implemented in order to estimate the Indirect Transportations Costs (ITC) present in the border crossing for the U.S.-Mexico bilateral trade. Here, an "iceberg-type" transportation function is assumed to determine the amount of loss that must be faced as a result of border crossing process through the ports of entry existing between the two countries. The study period covers annual data from 1995 to 2009 allowing the analysis of the trend of these costs considering the trade liberalisation that is experienced. Results show that the ITC have experienced a decrease of 12% during the period.
*Keywords*: Indirect Transportation Cost, CGE model, U.S.-Mexico bilateral trade, economic integration, border crossing process.

Resumen
Utilizando una Matriz de Contabilidad Social como base de datos, se implementa un Modelo de Equilibrio General Computable buscando estimar los Costos Indirectos de Transporte (CIT) presentes en el cruce de la frontera para el comercio bilateral entre Estados Unidos y México. Se utiliza una función de transporte de tipo "*iceberg*" para determinar la cantidad de pérdida que debe ser enfrentada como resultado de proceso de cruce fronterizo a través de los puertos de entrada existentes entre los dos países. El periodo de estudio abarca datos anuales desde 1995 hasta 2009 que permiten el análisis de la tendencia de estos costos, considerando la liberalización del comercio que se experimenta. Los resultados muestran que los CIT han experimentado una disminución de 12% durante el periodo.
*Palabras clave*: Costos Indirectos de Transporte, Modelo de Equilibrio General Computable, comercio bilateral México-E.U., integración económica, proceso de cruce fronterizo.

Received: November 7, 2014.
Approved: July 30, 2015.

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## Introduction

Extensive literature highlights the important role that trade openness can have in promoting economic performance and growth rates (Edwards, 1993; Dornbusch, 1992; Frankel and Romer, 1999; Krueger, 1998). Thus, trade facilitation policy can improve the economic flows through borders. Transportation cost is also an important aspect of trade flow.

Economic costs and benefits of trade facilitation have been studied extensively by intergovernmental organizations. In particular, the Organization for Economic Co-operation and Development (OECD) has provided an important insight through its research on the welfare gains of multilateral reduction of tariffs (OECD, 2003), by assessing the economic impact of the facilitation (OECD, 2009).

The present paper focuses on the Indirect Transportation Costs (ITC) that are present in trade between the United States and Mexico. Since the creation of the North American Free Trade Agreement (NAFTA), an important aspect has been the way in which this treaty can facilitate the flow of goods and services. The trilateral trade among NAFTA partners has more than tripled since the agreement took effect, reaching the US$ 1 trillion threshold for 2011 (Villarreal and Ferguson, 2014). Trade between the United States and Mexico contributed for 49% of the increase in intra-NAFTA trade. Between 1993 and 2012, total U.S. trade with Mexico increased by 506%. In comparison, U.S. trade with Canada increased by 192%.

The assessment of the ITC is an economically relevant issue given the fact that 80% of this U.S.-Mexico trade is done via ground transportation, which implies friction in itself, mainly due to the bureaucracy at the border which delays freight movement and to the physical constraints of the ports of entry.

The ITC is defined as the average extra cost spent throughout the export process when trading goods and services. This cost can come from loss resulting from the physical conditions of the transport modes, the distance between the point where production is realised and the market where it will be consumed, the failures on the loading/unloading of production, delays due to bureaucratic requirements in the border crossing process. These indirect costs impact the economy in different ways, for example by changing the real cost of moving goods within modes of transport. Thus, this impact may be change the mode of transport among the producers. Finally, the overall effect of the ITC may be quantified in the ratio of goods exported to Gross Domestic Product (GDP).

With this in mind, the following issues will be considered. First, the average extra cost spent in the export process, in addition to the transportation cost registered by the economic agents. Second, these amounts will be put into a Social Accounting Matrix (SAM) framework that will present a Computable General Equilibrium (CGE) model, as this issue will increase the size of the resulting matrix providing more information about the sectoral impacts.

The iceberg transportation function is a form to model the ITC that has been considered in international trade and is assumed to be a standard issue in the New Economic Geography literature. Samuelson (1954) proposed the basic idea that trade implies transaction costs and that these can be considered of as a fraction of the traded goods, which means that the iceberg melts on the way and only a fraction of the exported goods reach its destination.

The aim of the paper is to introduce indirect transportation costs under the iceberg-form proposed by Samuelson within the framework of SAM and to calibrate a CGE model, using the available data that estimates the behaviour of bilateral trade under certain parameters.

The rest of this paper is organized as follows: at first, discusses the characteristics of the SAM; immediately, presents the treatment that has been given to the transportations costs in the framework of CGE models; next section shows the situation of trade between the U.S. and Mexico in the last twenty years; then provides a description of the iceberg transportation function and explains the model; later describes the data used to calibrate the model and discusses the estimation and results; finally, the last section concludes the paper.

## The Social Accounting Matrix

A Social Accounting Matrix (SAM) is an analytical framework that provides a conceptual basis to analyse economic activities, which are the transactions involving goods and factors, and the concurrent flows of funds between agents in an economy. A SAM presents in a matrix form the interactions between production, consumption, income and capital.

As database, a SAM includes both socio and economic data, providing a broader detail than an Input-Output (I-O) table about of the economic interrelationships within an economy by including data sources as the National Accounts System and household income and expenditures statistics, for example, a SAM displays the distribution of the income of the factors of production for different sectors, or shows the expenditures on consumption, investment and savings made by the economics agents. Thus, a SAM records all the economic activities and flows of funds among agents in a base year, and it is used as a database for estimation of coefficients and exogenous variables of CGE models.

Since the SAM is written in a matrix-form table, the agents specified above are used as both row labels and column labels. The entries in a SAM indicate flows of goods and services from the agents listed in the rows to the counterpart agents listed in the columns. The corresponding payments are made in the opposite direction. Concerning the composition of a SAM, the order of row and column entries can be freely arranged, and row/column entries can be added depending on the purpose of analysis and data availability.

With the objective of constructing the matrix is necessary to gather data from different sources. Almost all the data included in the SAM are provided in the I-O tables. When is not possible to get the data from the I-O table, the selection of data should be made in consideration of the reliability of the data sources. Table 1 depicts a basic SAM with dimension 3 by 3 sectors for the Mexican Social Accounting Matrix for 1995, values are in US$ millions. In the case of the current account balance a minus sign is a surplus.

Now, it is possible to define which sector is labour-intensive or capital-intensive. Also, it is possible to know how is distributed the final demand among the economic agents. Thereby, by analysing the data contained in the above figure we can formulate policy recommendation, for example regards employment, taxes and imports tariffs among others.

A crucial point in the Input-Output analysis is the availability of the I-O tables. To this end, the World Input Output Database (Timmer, 2012) containing observations for the period from 1995 to 2009 is used to make a full analysis of the evolution of intersectorial relationships in the economy.

## Table 1. Mexican Social Accounting Matrix for 1995

| | | *Activities* | | | *Factors* | | *Taxes less subsidies on products* | *International Transport Margins* | *Final Demand* | | | *Exports* | *Total output* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Primary* | *Secondary* | *Terciary* | *Capital* | *Labour* | | | *Households* | *Government* | *Investment* | | |
| Activities | Primary | 3 350 | 28 841 | 463 | | | | | 8 056 | 0 | 5 518 | 9 276 | 55 504 |
| | Secundary | 4 400 | 51 972 | 15 849 | | | | | 56 460 | 51 | 60 081 | 54 878 | 243 690 |
| | Terciary | 5 077 | 37 263 | 43 222 | | | | | 124 804 | 31 116 | 4 333 | 16 604 | 262 421 |
| Factors | Capital | 31 480 | 49 534 | 120 323 | | | | | | | | | 201 337 |
| | Labour | 8 389 | 30 215 | 69 663 | | | | | | | | | 108 267 |
| Taxes less subsidies on products | | 365 | 3 387 | 1 955 | | | | | | | | | 5 707 |
| International Transport Margins | | 129 | 2 649 | 581 | | | | | | | | | 3 359 |
| Final Demand | Households | | | | 201 337 | 108 267 | 5 707 | 3 359 | 12 936 | | | | 309 604 |
| | Government | | | | | | | | 107 348 | - 9 166 | | - 28 251 | 22 002 |
| | Investment | | | | | | | | | | | | 69 931 |
| Imports | | 2 313 | 39 828 | 10 366 | | | | | | | | | 52 507 |
| Total output | | 55 504 | 243 690 | 262 421 | 201 337 | 108 267 | 5 707 | 3 359 | 309 604 | 22 002 | 69 932 | 52 507 | |

Source: Author's calculation.

## Transportation inside the cge model

Transportation is implicit inside the Input-Output model, and is made explicit when identified as a branch in the economy. Leontief (1936) recognised transportation (steam rail road) as an industry and determined how much is purchased by other industries in order to produce. However, the available data does not allow one to calculate the share of the final price that can be attributable to the transportation cost. Hence, the empirical solution proposed by Leontief is to distribute the transportation costs in an equal ratio for all the products of a branch. This is done under the assumption that transportation costs are a fixed proportion of the final price paid by the consumer.

The external sector is "adjusted" using the same technique. In the case of imports and exports, the value of these is added to a proportional amount to the domestic transportation costs. This addition is different to the transportation costs that the industries paid directly to the transportation services needed for production. In the I-O table for 1939, approximately one sixth of the total transportation costs remain unaccounted for.

The above lines are the first attempt to include the issue of transportation costs within the I-O analysis. However this explanation is not entirely satisfactory since the requirements of transport vary according to the location of the production and target markets. Additionally, there exists lost information about transportation costs since these are accounted for as part of the traded goods.

Isard (1951) established a link between the I-O model and the spatial economy by including the transport cost as a relevant element in making decisions about the location of industries. In order to analyse these relationships in a more efficient way, Isard extended the I-O model toward a less aggregated level by developing interregional I-O tables. Isard and Peck (1954) introduced the distance and the transportations into an I-O table that records the international and interregional trade flows.

The best I-O table is one that best describes and records the economic transactions at the industry level. However, now the problem is that as it grows, the level of description of the tables also increases its size. Thus, a specific I-O table and SAM can be modelled according to the objectives and needs of the study: of course this implies a massive amount of information and resources. From then the CGE models the tendency was to build regional databases that however barely take in account the transportation cost.

A SAM is designed to display a detailed matrix of internal transactions. This includes an external sector that contains information about the uses of the exported goods. Despite the massive amount of information that is contained into the SAM, all CGE models face a common issue regarding the base data. These models use I-O tables that may well represent a transportation sector. However, in practice the model relies on national accounts that do not include the additional costs of goods.

With the developments of CGE models based on Scarf's algorithm (1967) and its posterior standard implementation by Shoven and Whalley (1984), the spatial models tend to take into account the transportation cost between regions but not within region. These works relied mainly on the cost-benefit analysis to measure the impact of new infrastructure or economic reforms on consumers and producers.

In this regard, the recent developments in economic geography have incorporated the issues related to transport costs by using Krugman's (1980) adaptation of Samuelson's iceberg form (1954), this allows for the modelling of the spatial allocation without need to model transportation related issues. In these kinds of models (Krugman, 1990; 1991a; 1991b) the distance is not displayed separately. Thus, transportation costs and all such costs are introduced via the iceberg model in a simple way: greater distances imply a larger value that melts away. The basic assumption of the function implies assuming that the technology to produce the goods is the same used for the transportation of them. This formulation allows for the representing of transportation costs without the need for expressing them in an explicit way through a transport sector.

The economic relevance of the space is important given the cost implied to deal with the transactions around the whole economy; however, multi-region CGE models rarely make the modelling for a geographical space explicit. Since the establishment of the free trade agreements giving rise to commercial regions with different characteristics, some studies are responsible for analysing the differences between international transport margins, both between the regions as well as within regions.

Following this line of analysis, several studies have been conducted to assess the benefits from trade facilitation either on a regional or worldwide level. Hummels (1999) provides insight about the time delays on international trade by estimating the economic cost of using the maritime shipping instead air cargo. This work uses a multi-sector model of trade that allows isolating channels through which trade barriers affect trade volumes. Laskhmanan, Subramanian, Anderson y Leautier (2001), describe the relevance of transportation in the trade facilitation process. They point out the use of non-tariff barriers as regulation on truck loads as a main constraint for the intra-NAFTA trade. They also highlight the role of the border as a barrier, since border crossing may be subject to long delays.

Hummels (2001) emphasises the importance of time as a trade barrier by estimating the time costs. The results show that each additional day spent in transport reduces the probability that the U.S. will source from that country by 1-1.5%. By contrast, each day saved in shipping time is equivalent to a 0.8% ad-valorem tariff for manufactured goods. The literature survey on trade facilitation provided by the OECD (2002) shows that trade costs may vary by a wide range. According to the survey, the estimation for the trade costs is between 2 to 15% of the goods value. This variation is attributed to efficiency issues on the logistics, the size and type of the business, kind of goods and the year of the study.

Fox, Francois and Londoño-Kent (2003), describe the situation of the U.S.-Mexican border by using the results from Hummels (2001) and the database obtained by Haralambides and Londoño-Kent (2002) to estimate the border crossing costs. They used the Global Trade Analysis Project (GTAP) developed by Hertel (1997) to estimate the iceberg trade costs. This model is a global CGE model the database of which describes bilateral trade patterns, production, consumption and intermediate use of commodities and services. Walkenhorst and Yasui (2003) performed research into the cost of border barriers. They divide the trade transaction costs into two categories: direct and indirect. The first are those derived from the logistics required to move goods across the border, like the efficiency of the administrative process of customs services. The second, indirect costs, relates to the border waiting times and delays in freight movement.

Löfgren and Robinson (2002) introduced an explicit formulation of the spatial variable into a SAM-based model. The aim of this exercise was to determine the impact of changes in world prices and transportations costs. They proposed the use of a restructured SAM to include the space into the model; this is done looking to preserve the multiregional values. However, the SAM aggregates the payments to the transport sector and assumes that these pays are distributed according to shares in traded values. The transportation costs are treated as endogenous.

Therefore, given the lack of literature on this regard, there is further research necessary to provide a different approach by using a SAM-based CGE model. Thereby, in this manner achieve results through the estimation of different scenarios taking advantage of the data availability to perform such analysis.

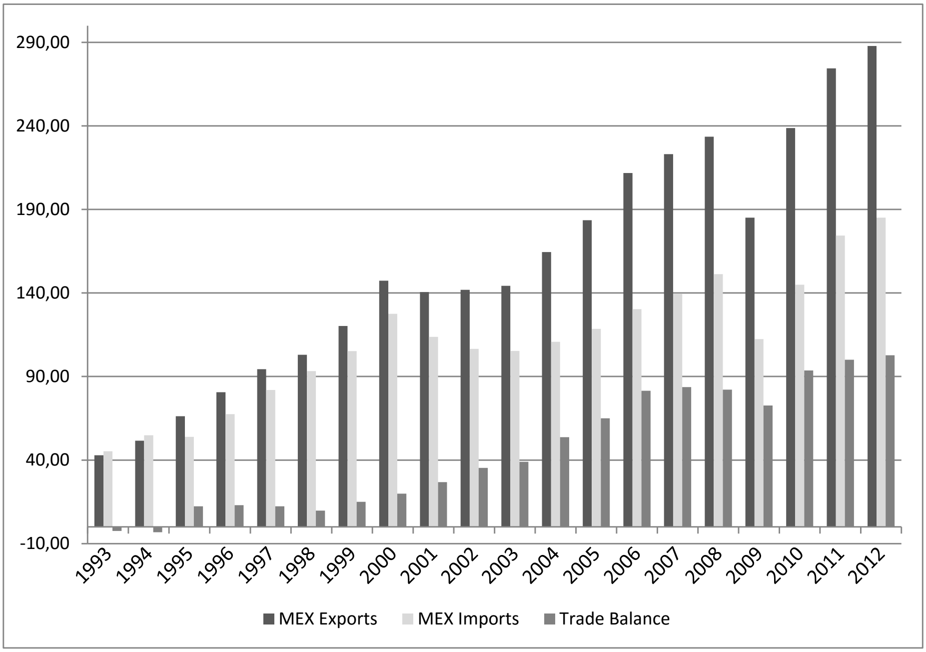
## United States-Mexico economic relation

The bilateral economic relationship between Mexico and the United States is of key interest for both countries because the strong ties between them that not only results from the economic aspects, also because the wide border shared (1954 miles in length) that implies strong cultural and demographic links.

Mexican trade with the U.S. has increased quickly since NAFTA came into effect in January 1994. In the first year of the treaty, trade increased by 20% in both directions. As of 2012 Mexico increased exports from US$51.6 billion in 1994 to US$287.4 billion in 2012, an increase of 457%. Imports from the U.S. increased from US$54.8 billion in 1994 to US$185.1 billion in 2012, an increase of 238%. The trade balance with the U.S. went from a deficit of US$3.2 billion in 1994 to a surplus of US$102.7 billion in 2012 (Figure 1).

The overall effect of NAFTA on the U.S. economy has been relatively small, due to the fact that the two-way trade with Mexico amounts to less than 3% of the U.S. GDP. However, in the case of the Mexican economy, the amount traded represents 40% of the GDP in 2012. Along the United States-Mexico border, according to the International Boundary and Water Commission, there are found 54 crossings and international bridges (of which, 26 ports of entry allow trucks and 8 are rail crossings) where the trade between the two countries takes place. Thus, to transport this large amount of goods from Mexico to the U.S. about 70% of the value of trade is carried via road transport, 8.4% via rail, 16.4% via ship and

**Figure 1. Mexico's trade with the United States (U.S. dollars in billions)**




Source: Author's calculations.

the remaining by other means of transport. Therefore, the road transport plays a main role for the bilateral trade.

The massive amount of merchandise that crosses the border every day in both directions entails waiting times for inspection and processing all the necessary paperwork. Delays at this time are common due to an insufficient number of checkpoints relative to the growing number of border crossings made due to the increase in bilateral trade over the last two decades. Thus, a bottleneck is formed when the economy gains speed and demand grows but the customs service cannot keep up with the flow.

Given this close business relationship, in recent years the capacity of the ports of entry have been studied in order to identify possible bottlenecks that may cause borders delays and thus assess the economic impact of such time-outs. This cost-benefit analysis focuses its attention on the delays experienced by commercial vehicles, passenger vehicles and pedestrians, and by calculating the economic costs of such long waiting times at the border, to measure its impact on the Economy.

The greatest difficulty in carrying out such studies lies in the fact that they are based with data obtained from surveys conducted in border ports of entry. This is because, although the U.S. Customs and Border Protection (CBP) provides data on waiting times, it only shows the estimated wait times for reaching the primary inspection booth, the first point of contact with the CBP when crossing the U.S.-Mexico border. Therefore, official data does not take into account the waiting time due to paperwork and inspections that are performed after that point. However, these studies are focus on a specific border crossing or in the best of the cases, in a group of them that concentrate most of the trade flow. Despite this, these works provide a perspective of how to measure the indirect transportations cost associated to freight movement.

Since the signing of the NAFTA, several studies have been conducted in order to track the behaviour of border crossings between the U.S. and Mexico, the San Diego/Tijuana Metropolitan Area being the most studied border region, having a combined population around 5 million in 2010. These works put emphasis on border queuing times and their impact on the economy (San Diego Dialogue, 1994; SANDAG, 2000; 2003; 2006; 2010). In this line of research the work by El Colegio de la Frontera Norte (El Colef) (2007) stands out as one of the most comprehensive analyses on this topic by including a compilation of waiting times in the 4 major ports of entry in terms of trade flows, since they represent nearly a half of the two-way trade. Based on the realisation of a broad survey, this document provides information on border crossing average wait times and attempts to estimate their economic impacts.

"U.S.-Mexico ports of entry: a capacity analysis and recommendations for increased efficiency" (El Colef, 2007) provides a comprehensive look at the nature and characteristics of land ports of entry in order to develop action plans to facilitate border crossing. The study undertook a comprehensive and significant sample of about 17 000 people crossing the border in both ways. Data from this survey are compared with respect to data provided by the U.S.CBP. Thus, are estimated the economic impact associated with the movement of people and goods and finally calculated the annual loss in terms of production, jobs and salaries due the bottlenecks. The relevance of El Colef study for this paper is that provides an estimate of the total cost per truck for each hour spent waiting to pass through to the U.S. border which together with the total number of trucks crossing, could give us an idea about the indirect transportation costs that are originated due to border delays.

## The model

Once the SAM is ready to be used as a database for the CGE as described in the previous section, the following stage is to perform a numerical specification of the model. In this stage is necessary to specify the functional forms and parameters. Since the SAM described previously depicts the economy as a whole, is possible to decompose the information contained in the matrix into a system of equations.

Since the model is a static SAM-based model, is necessary to introduce the assumptions about fixed coefficients and cost prices that are inherent to the Input-Output model. Thus, this model does not intent to capture policy effects that work through price incentives.

A Computable General Equilibrium (CGE) model is a system of mathematical equations that describes an economy as a whole, and the interactions among its parts. A CGE model is a general equilibrium model that calculates the effect of changes in a particular exogenous variable when it is introduced to the model.

CGE models are an important tool of empirical analysis for the policymakers towards simulating the effects of economic policies. One of the main features of the CGE models is its capacity to allow the analysis for all the linkages between sectors of an economy. Hence, these could be interlinkages between industries, or between household expenditures and incomes, imposing endowments and resource constraints.

The CGE model is developed in the sense of Johansen (1960) and utilizes a version of the SAM as database. The set of equations that constitute the model that is implemented here can be found in the Appendix at the end of the paper. The model is formulated as a system of nonlinear simultaneous equations, which are derived from the agents' optimization behaviour. This set of equations is solved by using MATLAB.

Once the equations are established, the following step is to calibrate the model. Calibration is the method of estimation of coefficients and exogenous variables in a CGE model. This procedure is based on the information provided by the SAM. The purpose of the calibration is testing the parameters in order to know if the values of the parameters are consistent with the base year.

The process of calibration was developed by Johansen (1960) and consists of setting the base year —1950— of the economy in the past, and after that, simulates real changes in the exogenous variables for the years to date to determine if the endogenous variables are similar to the historical observations available for the years around 1950. In order to calibrate the model is necessary to extract parameters directly from the SAM when is possible (Table 2). Thus, by estimating the parameters and assigning values to exogenous variables, is possible to verify if the model reproduced an equilibrium solution for the main macrobalances, congruous with the SAM data.

After this, the next step will be to work on the issue of Indirect Transportation Costs. This will be assuming the indirect transportation cost is an "iceberg-type", in the same sense that is described by Krugman (1980).

The logic that follows the model can be explained as follows. Since it was formulated as a model for international trade it involves the existence of two markets, domestic H and foreign F. If the domestic market produces a good x with a value of $V_{XH}$ and a portion of this good is consumed in the shipping process, the value of the good that would arrive to the foreign market is $\tau_X V_{XH}$. Where $1 - \tau_X$ is the part of the good that was consumed during transport from one market to another. With the aim of determining the relative prices in the domestic market $P_{XH}$ and foreign market $P_{XF}$, it must be noted that the value $V_{XH}$ is the price $P_{XH}$ multiplied by the amount of good that is shipped from the domestic market $M_{XH}$. However, due to the fact of transit of goods from one country to another, the total amount received in the foreign market $M_{XF}$ will be only $\tau_X M_{XH}$. Thus, the foreign price $P_{XF}$ really paid by the foreign market is given by $P_{XF} = P_{XH} / \tau_X$. A feature of this formulation is that transportation cost per good has no variation in respect of the amount of good delivered.

## Table 2. SAM to calibrate the CGE model

| | | *Activity* | | *Factor* | | *Indirect Tax* | | *Final Demand* | | | *External* | *Total* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | *Sector 1* | *Sector 2* | *Capital* | *Labour* | *IDT* | *TRF* | *HOH* | *GOV* | *INV* | *R.O.W* | |
| Activity | Sector 1 | $p_i^{q0} X_{i,j}^{\ 0}$ | | | | | | $p_i^{q0} X_i^{p0}$ | $p_i^{q0} X_i^{g0}$ | $p_i^{q0} X_i^{v0}$ | $p_i^{e0} E_i^0$ | |
| | Sector 2 | | | | | | | | | | | |
| Factor | Capital | $p_h^{f0} F_{h,j}^{\ 0}$ | | | | | | | | | | |
| | Labour | | | | | | | | | | | |
| Indirect Tax | IDT | $T_j^{z0}$ | | | | | | | | | | |
| | TRF | $T_j^{m0}$ | | | | | | | | | | |
| Final Demand | HOH | | | $p_h^{f0} FF_h$ | | | | | | | | |
| | GOV | | | | | $\Sigma_j T_j^{z0}$ | $\Sigma_j T_j^{m0}$ | $T^{d0}$ | | | | |
| | INV | | | | | | | $S^{p0}$ | $S^{g0}$ | | $\varepsilon^0 S^f$ | |
| External | R.O.W | $p_h^{m0} M_j^0$ | | | | | | | | | | |
| Total | | | | | | | | | | | | |

Source: Author's calculations.

Thus, the export price quoted in foreign currency terms (Equation 16 in the Appendix

$$p_i^e = \varepsilon p_i^{We} \quad \forall i \tag{16}$$

is modified to include the ITC,

$$p_i^e = (\varepsilon p_i^{We})(1 - \tau_e) \quad \forall i \tag{16a}$$

where $\tau_e$ is the indirect transportation costs that, following the iceberg concept, will be the fraction of the original unit that melts away on route; $p_i^e$ is export price in terms of domestic currency; $p_i^{We}$ is export price in terms of foreign currency (exogenous) and $\varepsilon$ is the foreign exchange rate. By modifying this equation, the result implies a multiplier effect in the external sector.

This approach could provide a size of the ITC involved in trade process. The direct way to do that will be to estimate the amount of the cost parameter by defining the share of GDP used on deliver goods. This is in addition to the share of GDP involved in the transportation industry.

## Estimation and Results

In addition to the time series of SAMs previously described, it is necessary to find a good data set for model calibration: the value for $\tau_e$. In this regard, various studies conducted show wide variations in their results. Hummels (2001) provides insight about the time delays on international trade by estimating the economic cost of using the maritime shipping instead air cargo. The data used are the U.S. imports of manufactured goods, finding that an additional day in the transportation time is equivalent to a 0.8% tariff.

Fox et al. (2003) describe the situation of the U.S.-Mexico border by estimating the border crossing costs. Such costs are for the case of the southbound trade in a range from 1.8 to 6% and for the northbound trade between 1 to 1.5%. To estimate the model, they supposed a reduction in trade value of 1% for the southbound and 5% in the opposite way. Thus, they calculate the economic benefits of the removal of those barriers would be around US$3.2 billion with an increase in the bilateral trade flows of about US$7 billion.

Walkenhorst and Yasui (2003) conducted a study about the cost of border barriers. The authors supposed a trade facilitation that leads to a reduction in costs by 1% of the value of world trade, giving as result a welfare gain of US$40 billion worldwide.

Using the data collected by El Colef (2007) in order to determine the value of $\tau_e$, the survey estimate a total cost of US$62.5 per truck for each hour spent waiting to pass through to the U.S. border. Table 3 shows the cost due to waiting times in the U.S. border, the exports and annual costs are in US$ millions. The average wait times are in hours. A quick look at the table allow us to see that the border waiting time does not seem to be directly related to the amount of exports or the number of trucks crossing through it.

**Table 3. Transportation costs due to border delays**

| *Port of Entry* | *Trucks by year* | *Average waiting time* | *Annual costs* | *Exports by truck* |
|---|---|---|---|---|
| Tijuana | 745 974 | 3.0 | 139.87 | 18 060 |
| Cd. Juarez | 773 265 | 2.2 | 106.32 | 23 528 |
| Laredo | 1 526 623 | 2.9 | 276.70 | 44 088 |
| Nogales | 288 164 | 1.1 | 19.81 | 8 038 |
| Total | 3 334 026 | 2.6 | 542.71 | 93 714 |

Source: El Colef (2007).

Thus, the next step is to estimate the share of the costs of delay on the total exports in percentage that are displayed in Table 4.

**Table 4. Border delay costs as a share of exports**

| *Port of Entry* | *Delay costs share* |
|---|---|
| Tijuana | 0.77 |
| Cd. Juarez | 0.45 |
| Laredo | 0.63 |
| Nogales | 0.25 |
| Total | 0.58 |

Source: Author's calculations.

Since we only have one point in the time representing a half of the two-way trade remaining to be determined the rest of the volume of trade, and given the huge variation that exists from one port of entry to another, the calibration of $\tau_e$ will be carried out using three different values: 0.5, 0.75 and 1%. With these values capturing not only the costs due to delays at the border crossing but also the losses attributable to the distance covered by the product until the final destination, that is the whole "iceberg" is attempted.

After running the CGE model, including the ITC variable, a summary of the economic impact of the results of this experiment is provided by Table 5.

The losses from freight movement are substantial and increased over the period, the total impact for 2008 reached about US$1.9 billion in the most conservative scenario and reaches US$3.8 billion in the estimation with higher costs. The trend that the ITC exhibit is similar to costs of bilat-

**Table 5. Indirect Transportation Costs**

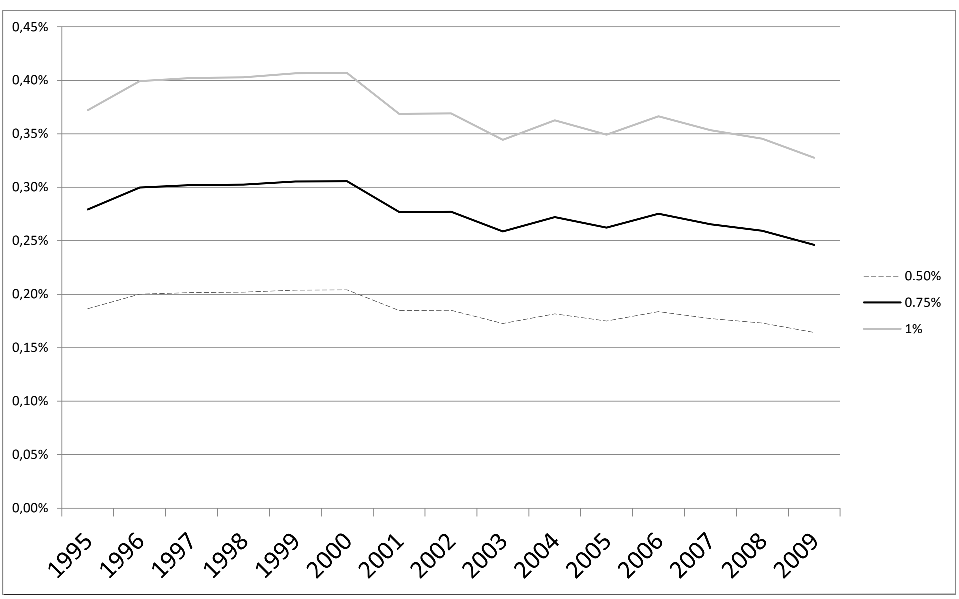
| *Year* | *Value of τ* | | |
|---|---|---|---|
| | *0.5%* | *0.75%* | *1%* |
| 1995 | 534.5 | 800.7 | 1 066.3 |
| 1996 | 666.1 | 997.9 | 1 328.9 |
| 1997 | 809.5 | 1 212.7 | 1 614.9 |
| 1998 | 850.5 | 1 274.2 | 1 696.7 |
| 1999 | 980.8 | 1 469.3 | 1 956.7 |
| 2000 | 1 185.8 | 1 776.4 | 2 365.6 |
| 2001 | 1 149.8 | 1 722.5 | 2 293.8 |
| 2002 | 1 201.1 | 1 799.4 | 2 396.2 |
| 2003 | 1 209.1 | 1 811.4 | 2 412.2 |
| 2004 | 1 380.5 | 2 068.2 | 2 754.1 |
| 2005 | 1 485.8 | 2 225.9 | 2 964.2 |
| 2006 | 1 749.2 | 2 620.5 | 3 489.6 |
| 2007 | 1 835.1 | 2 749.2 | 3 661.0 |
| 2008 | 1 895.0 | 2 838.9 | 3 780.4 |
| 2009 | 1 449.2 | 2 171.1 | 2 891.1 |

Source: Author's calculations.

eral trade flows, growing over the entire period and displaying a drop for 2009. Moreover, if the ITC is analysed by share of the GDP (in percentage), the results presented in Figure 2 show a decreasing trend for the entire period, as the ITC dropped around 12%.

Dividing the whole period into two samples, we have that for 1995 to 2000 the ITC raised in 9%, after this year, the ITC the exhibits a downward trend, dropping by around 20%. Thus, while the costs grow as bilateral trade increased, as can be seen GDP and trade do not share similar rates of growth, for this reason although in absolute terms the cost growth, when they are measured in terms of its output share these show a declining trend. These findings are consistent with the expected trade facilitation after the entry into force of a trade agreement due to removal of tariff and non-tariff barriers.

**Figure 2. itc as share of gdp**




Source: Author's calculations.

## Conclusions

Trade facilitation and trade flows are related in a direct way: trade increases as trade facilitation is improved. At this point, trade facilitation implies a reduction both in tariff and non-tariff barriers. However, despite that transportation costs play an important role in international trade, its participation in the trade facilitation has been little studied.

While there are other sources of inefficiencies that can act as trade barriers, the distance and the border crossing delays are a major contributor to the price differential existent between the United States and Mexico. These constraints lengthen delivery times, thus generating additional costs both the exporter and transport sector.

This paper provides insight into the economic implications of the indirect transportation costs arising from the movements of goods between the United States and Mexico. Using the information collected regarding to waiting times at the most important land ports of entry for bilateral trade, indirect transportation costs of transport are estimated under the iceberg-form.

From the methodological point of view, this paper is differentiated from existing literature by using a Computable General Equilibrium model based on Social Accounting Matrices. Thus, this type of approach is used considering the advantages with respect to its level of disaggregation and its capacity analysis. In terms of implementation, this paper provides the advantage of the amplitude of the study period by using Input-Output Tables for a 15 years period as main source of information. Also, an extensive analysis on different ports of entry to determine iceberg size within the model is used.

Thus, it can be observed that the existing literature on this topic agree with the results obtained. Since the Indirect Transportation Costs declined over the time, this can lead to two conclusions. First, this can result from the entry into force of the NAFTA with which bilateral trade restrictions are reduced. The treaty implied that within a maximum period of 15 years most sectors would be tax free. In the specific case of the transport industry, the full opening would be reached by year 2000. Is in this year when it can be observed that initiates a downward trend in costs, which is consistent with the trade agreement signed. While the above results show a decrease of the ITC in terms of GDP, in absolute terms these continue to increase due to the increasing flow of bilateral trade as well as the bottlenecks that imply given the limited capacity of the border crossing ports. Second, it may be a result of the decline that has had international transport costs according to some studies. Here, it is worth to notice the important role that trade facilitation efforts by various international organizations to minimise these border crossing frictions.

## Appendix

### *Equations of the cge model*

The first step is to incorporate the intermediate goods and the composite good as part of the analysis. The composite good is obtained by aggregating the capital and labour through the production function of the composite good, which is a Cobb-Douglas form function (Equation 2). Thus, this problem is related with the production of the composite good that will be used as input for the gross domestic output. This can be realised as follows:

$$\max_{\mathrm{Y}_j,\, \mathrm{F}_{h,j}} \pi_j^y = p_j^y Y_j - \sum_h p_h^f \, \mathrm{F}_{h,j} \tag{1}$$

Subject to:

$$Y_j = b_j \prod_h F_{h,j}^{\beta_{h,j}} \quad \forall j \tag{2}$$

That is, the profit-maximisation problems for the *j-th* firm subject to the composite goods where:

$\pi_j^y$: profit of the *j-th* firm producing composite factor Y*j*
$Y_j$: composite factor used by the *j-th* firm
$F_{h,j}$: the *h-th* factor used by the *j-th* firm
$X_{i,j}$: intermediate input of the *i-th* good used by the *j-th* firm
$p_j^y$: price of the *j-th* composite factor

$p_h^f$: price of the *h-th* factor

$\beta_{h,j}$: share coefficient in the composite factor production function (exogenous)

$b_j$: scaling coefficient in the composite factor production function (exogenous)

And we have in addition the factor requirements of the firm,

$$F_{h,j} = \frac{\beta_{h,j} p_j^y}{p_h^f} Y_j \qquad \forall h,j \tag{3}$$

the intermediate inputs requirements, which depend directly on the volume of production $Z_j$,

$$X_{i,j} = ax_{i,j} Z_j \qquad \forall i,j \tag{4}$$

the composite factor used by the *j-th* firm as function of the output,

$$Y_j = ay_j Z_j \qquad \forall j \tag{5}$$

where $ax_{i,j}$: input requirement coefficient of the *i-th* intermediate input for a unit output of the *j-th* good (exogenous) and $ay_j$ the input requirement coefficient of the *j-th* composite good for a unit output of the *j-th* good (exogenous); and finally, the price of the *j-th* gross domestic output or unitary cost of production $p_j^z$

$$p_j^z = ay_j p_j^y + \sum ax_{i,j} p_i^q \qquad \forall j \tag{6}$$

where $p_i^q$ is the price of the *i-th* composite good.

In the second place, it is necessary introduce the government into the model. The public sector is important by the following reasons: first, the influence through the taxes on income and prices; second, the government expenditure plays a crucial role in the economy consumption; and finally, the trade tariffs are considered.

The next equations are the taxes system, in which, is assumed that the government levied the household income at a fixed tax rate (Equation 7), an ad valorem tax on output (Equation 8) and an ad valorem import tariff on international trade (Equation 9)

$$T^{d} = \tau^{d} \sum_{h} p_{h}^{f} FF_{h} \tag{7}$$

$$T_{j}^{z} = \tau_{j}^{z} p_{j}^{z} Z_{j} \qquad \forall j \tag{8}$$

$$T_{i}^{m} = \tau_{i}^{m} p_{i}^{m} M_{i} \qquad \forall i \tag{9}$$

where:

$T^{d}$: direct tax (exogenous)
$T_{j}^{z}$: production tax on the *j-th* good (exogenous)
$T_{i}^{m}$: import tariff on the *i-th* good (exogenous)
$\tau_{i}^{m}$: direct tax rate
$\tau_{j}^{z}$: production tax rate on the *j-th* good (exogenous)
$\tau_{i}^{m}$: import tariff rate on the *i-th* good (exogenous)
$FF_{h}$: endowments of the *h-th* factor for the household (exogenous)
$M_{i}$: imports of the *i-th* good
$X_{i}^{g}$: government consumption of the *i-th* good
$p_{i}^{m}$: price of the *i-th* imported good

The following equation is the government expenditure equation which assumes that all the taxes revenues are spent in consumption, which means that there is no public deficit. This expenditure $X_{i}^{g}$ is realised in fixed ratios between each of the goods:

$$X_{i}^{g} = \frac{\mu_{i}}{p_{i}^{q}} \left( T^{d} + \sum_{j} T_{j}^{z} + \sum_{j} T_{j}^{m} \right) \qquad \forall i \tag{10}$$

Where $\mu_{i}$ is the share of the *i-th* good in government expenditure (exogenous).

The investment and saving are considered as follow. The household savings and the government fiscal balance can be defined in terms of its average propensities to save:

$$S^p = ss^p \left( \sum_h p_h^f FF_h \right) \tag{11}$$

$$S^g = ss^g \left( T^d + \sum_j T_j^z + \sum_j T_j^m \right) \tag{12}$$

where:

$S^p$: household savings
$S^g$: government savings
$ss^p$: average propensity for savings by the household (exogenous)
$ss^g$: average propensity for savings by the government (exogenous)

The relation between investment and savings is defined by the economic identity I=S, thus the investment derives from the savings of households and government plus the current account balance,

$$X_i^v = \frac{\lambda_i}{p_i^q} (S^p + S^g + \varepsilon S^f) \qquad \forall i \tag{13}$$

where:

$X_i^v$: demand for the *i-th* investment good
$S^f$: current account deficits in foreign currency terms (exogenous)
$\varepsilon$: foreign exchange rate
$\lambda_i$: expenditure share of the *i-th* good in total investment (exogenous)

Since the recent addition of the government and investment and savings inside the model, some previous equations need to be modified. Thus, the new household and government demands functions are:

$$X_i^p = \frac{\alpha_i}{p_i^q} \left( \sum_h P_h^f FF_h - S^p - T^d \right) \qquad \forall i \tag{14}$$

$$X_i^g = \frac{\mu_i}{p_i^q}\left(T^d + \sum_j T_j^z + \sum_j T_j^m - S^g\right) \qquad \forall i \tag{15}$$

The last important characteristic of this standard CGE model is the presence of the external sector, this extension makes possible to switch from a closed model to an open one. Therefore, is assumed that the export and import prices quoted in foreign currency terms are exogenous, that is, a small country without enough market shares to be able to influence in the world prices:

$$P_i^e = \varepsilon p_i^{We} \qquad \forall i \tag{16}$$
$$P_i^m = \varepsilon p_i^{Wm} \qquad \forall i \tag{17}$$

where: $p_i^{We}$ and $p_i^{Wm}$ are the export and import prices, both in terms of foreign currency and exogenous, and $P_i^e$ is the export price in terms of domestic currency.

Additionally, the Balance of Payments is assumed in equilibrium, where $E_i$ are the exports of the *i-th* good.

$$BOP = \sum_i p_i^{We} E_i + S^f - \sum_i p_i^{Wm} M^i \tag{18}$$

Since the standard CGE model includes the consumption both domestic and imported goods, we have to assume that exist difference between good produced in the domestic economy and the ones that are imported. At this point, we use Armington's assumption. The Armington composite goods have a nested consumption structure, since assumes that the imported goods are not consumed or used directly. Instead of this, the composite good comprises imports and the corresponding domestic goods, whose proportions are determined by the elasticity of substitution. The Armington composite good is defined as follow:

$$Q_i = \gamma^i \left(\delta m_i M_i^{\eta i} + \delta d_i D_i^{\eta i}\right)^{\frac{1}{\eta i}} \qquad \forall i \tag{19}$$

where:

$D_i$: the *i-th* domestic good

$Q_i$: the *i-th* Armington composite good

$\gamma^i$: scaling coefficient in the Armington composite good production funcion (exogenous)

$\delta m_i$, $\delta d_i$: input share coefficients in the Armington composite good production function (exogenous)

$\eta_i$: parameter defined by the elasticity of substitution (exogenous) ($\eta i = (\sigma i - 1)/\sigma i$, $\eta i \leq 1$)

$\sigma i$: elasticity of substitution in the Armington composite good production function and the demand functions for imports and the domestic good:

$$E_i = \left[\frac{\theta_i^{\Phi_i} \xi e_i (1 + \tau_i^z) p_i^z}{p_i^e}\right]^{\frac{1}{1-\Phi i}} z^i \qquad \forall i \tag{20}$$

$$D_i = \left[\frac{\theta_i^{\Phi_i} \xi d_i (1 + \tau_i^z) p_i^z}{p_i^d}\right]^{\frac{1}{1-\Phi i}} z^i \qquad \forall i \tag{21}$$

The last point on international trade is to split the production process between imported and domestic goods. This production is described by a constant elasticity of transformation (CET) function, where, according on the relative price between exports and domestic goods, the supply for each of these markets changes:

$$Z_i = \theta_i (\xi e_i^{\Phi_i} + \xi d_i D_i^{\Phi_i})^{\frac{1}{\Phi i}} \qquad \forall i \tag{22}$$

where:

$Z_i$: gross domestic output of the *i-th* good

$\tau_i^z$: production tax rate on the *i-th* gross domestic output (exogenous)

$\theta_i$: scaling coefficient of the *i-th* transformation (exogenous)

$\xi e_i$, $\xi d_i$: share coefficients for the *i-th* good transformation (exogenous)

$\Phi_i$: parameter defined by the elasticity of transformation (exogenous)

Finally, impose the market-clearing conditions to assure the equilibrium in all the markets. The first equation is for the Armington composite goods and the second one is the factor market-clearing condition:

$$Q_i = X_i^p + X_i^g + X_i^v + \sum_j X_{i,j} \qquad \forall i \tag{23}$$

$$FMCC = \sum_j F_{h,j} - FF_h \qquad \forall h \tag{24}$$

Equation 24 is the factor market-clearing condition, that is, total demand for *h-th* factor by firms must be equal to total endowments of *h-th* factor, assumed to be given in the economy.

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