

López Noria, Gabriela

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Automobile Industry: Evidence from the First 20 Years
of NAFTA**

Gabriela López Noria

Banco de México

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The Impact of Trade Liberalization on the Mexican Automobile Industry: Evidence from the First 20 Years of NAFTA*

Gabriela López Noria[†]
Banco de México

Abstract: This paper examines the impact of trade liberalization under NAFTA on the productivity of the Mexican automobile industry. Using a panel of establishments for the period 1994-2014, in a first stage a Cobb-Douglas production function is estimated by the Levinsohn and Petrin's (2003) method (in an alternative exercise by that of Akerberg, Caves and Frazer, 2015) to obtain a productivity measure. In a second stage, a model is estimated by System GMM to analyze the effect of trade openness on the estimated productivity. The main results indicate that there exists a positive association between trade liberalization and productivity for medium size establishments, but not for small or large establishments. This finding is consistent with that of other authors, who find that trade liberalization results in higher productivity for some firms, but not for all of them (e.g. Lileeva and Trefler, 2010; Bustos, 2011).

Keywords: International Trade Agreements; Liberalization; NAFTA; Tariff; Automobile; Vehicles; Cobb Douglas; Production Function; Productivity

JEL Classification: F130; L620; D240

Resumen: Este documento investiga el impacto de la liberalización comercial bajo el TLCAN sobre la productividad de la industria automotriz mexicana. Utilizando un panel de establecimientos para el periodo 1994-2014, en una primera etapa se estima una función producción Cobb-Douglas por el método de Levinsohn y Petrin (2003) (y en un ejercicio alterno por el de Akerberg, Caves y Frazer, 2015) para obtener una medida de productividad. En una segunda etapa, se corre un modelo por MGM en Sistema para analizar el efecto de la apertura comercial sobre la productividad estimada. Los resultados principales indican que se aprecia cierta asociación positiva entre la liberalización comercial y la productividad para los establecimientos medianos, pero no para los pequeños o grandes. Este resultado es consistente con el de otros autores que encuentran que la liberalización comercial resulta en mayor productividad para algunas empresas, pero no para todas (e.g. Lileeva y Trefler, 2010; Bustos, 2011).

Palabras Clave: Acuerdos de Comercio Internacional; Liberalización; TLCAN; Tarifa; Automóvil; Vehículos; Cobb Douglas; Función Producción; Productividad

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[†] Dirección General de Investigación Económica. Email: glopezn@banxico.org.mx.

1 Introduction

The Mexican automobile industry (MAI) has been one of the top ten vehicle producers and exporters in the world for several years now. According to the International Organization of Motor Vehicle Manufacturers, the MAI was ranked position 8 by the number of vehicles it produced from 2011 to 2013, position 7 from 2014 to 2017, and position 6 in 2018 (see Table 1).¹ In terms of its vehicle exports to the world, UN Comtrade² registered that the MAI was ranked position 5 in 2011 and position 4 from 2012 to 2018 (see Table 2). In addition, Figure 1 shows that the MAI's exports increased dramatically following NAFTA's implementation in 1994.

Table 1: Leading Global Automobile Producers
(Millions of Units)

	2011	2012	2013	2014	2015	2016	2017	2018
1	China-18.4	China-19.3	China-22.1	China-23.7	China-24.5	China-28.1	China-29.0	China-27.8
2	USA-8.7	USA-10.3	USA-11.1	USA-11.7	USA-12.1	USA-12.2 33	USA-11.2	USA-11.3
3	Japan-8.4	Japan-9.9	Japan-9.6	Japan-9.8	Japan-9.3	Japan-9.2	Japan-9.7	Japan-9.7
4	Germany-6.1	Germany-5.6	Germany-5.7	Germany-5.9	Germany-6.0	Germany-6.1	Germany-5.6	India-5.2
5	South Korea-4.7	South Korea-4.6	South Korea-4.5	South Korea-4.5	South Korea-4.6	India-4.5	India-4.8	Germany-5.1
6	India-3.9	India-4.2	India-3.9	India-3.8	India-4.1	South Korea-4.2	South Korea-4.1	Mexico-4.1
7	Brazil-3.4	Brazil-3.4	Brazil-3.7	Mexico-3.4	Mexico-3.6	Mexico-3.6	Mexico-4.1	South Korea-4.0
8	Mexico-2.7	Mexico-3.0	Mexico-3.1	Brazil-3.1	Spain-2.7	Spain-2.9	Spain-2.8	Brazil-2.9
9	Spain-2.4	Canada-2.5	Thailand-2.5	Spain-2.4	Brazil-2.4	Canada-2.4	Brazil-2.7	Spain-2.8
10	France-2.2	Thailand-2.4	Canada-2.4	Canada-2.4	Canada-2.3	Brazil-2.2	France-2.2	France-2.3

Source: International Organization of Motor Vehicle Manufacturers.

Table 2: Leading Global Road Vehicles Exporters
(Billions of Dollars)

	2011	2012	2013	2014	2015	2016	2017	2018
1	Germany-242.2	Germany-230.5	Germany-237.1	Germany-253.9	Germany-236.9	Germany-239.4	Germany-251.8	Germany-257.4
2	Japan-146.1	Japan-160.9	Japan-146.8	Japan-140.6	Japan-132.4	Japan-140.4	Japan-144.7	Japan-152.4
3	USA-115.0	USA-127.2	USA-129.6	USA-131.9	USA-123.7	USA-120.7	USA-126.0	USA-126.1
4	Rep. of Korea-66.8	Mexico-69.9	Mexico-76.7	Mexico-85.5	Mexico-90.0	Mexico-87.8	Mexico-101.5	Mexico-115.2
5	Mexico-62.6	Rep. of Korea-69.7	Rep. of Korea-72.3	Rep. of Korea-72.9	China-68.6	Canada-63.4	China-73.7	China-83.5
6	China-59.5	China-62.0	China-64.8	China-71.5	Rep. of Korea-68.5	China-62.8	Rep. of Korea-61.4	Rep. of Korea-60.6
7	France-52.5	Canada-59.9	Canada-58.4	Canada-59.1	Canada-59.7	Rep. of Korea-62.2	Canada-61.4	Canada-58.9
8	Canada-51.8	France-45.9	United Kingdom-49.0	United Kingdom-52.7	Spain-49.7	Spain-53.9	Spain-55.4	Spain-57.2
9	Spain-50.3	United Kingdom-45.4	Belgium-48.4	Spain-51.6	United Kingdom-48.8	United Kingdom-50.0	United Kingdom-52.0	France-54.6
10	Belgium-43.9	Spain-42.2	Spain-48.4	France-46.1	France-42.5	Belgium-45.0	France-49.5	United Kingdom-53.1

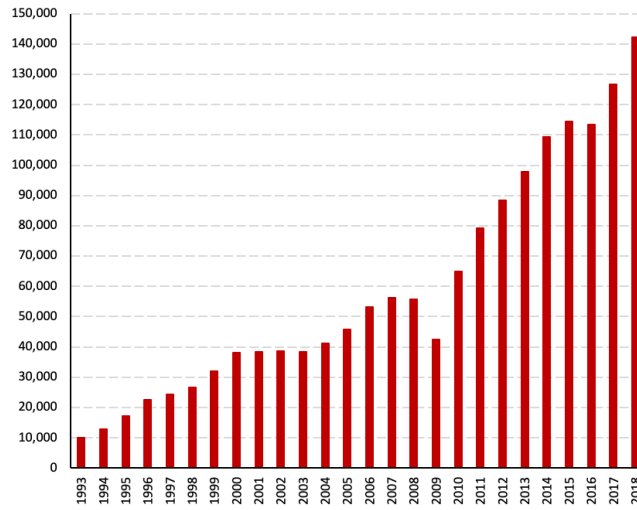
Source: UN Comtrade — International Trade Statistics Database.

The MAI is recognized worldwide by the quality of its manufacturing and since 2000 it has transformed itself to produce more sophisticated vehicles in terms of technology and value added (Promexico, 2013).

¹International Organization of Motor Vehicle Manufacturers.

²UN Comtrade — International Trade Statistics Database.

Figure 1: Mexico's Exports (Vehicles, Buses and Auto-parts)
(Millions of Dollars)



Source: Banco de México.

This success in both quantity and quality can be explained by the following main factors.

- 1) The MAI is almost a 100 years old (i.e. Ford established its first assembly lines in Mexico in 1925), which is reflected in its maturity and strength as an industry.³
- 2) The MAI has undergone an important stage of industrial restructuring and modernization. Until the mid-1970s, this industry was characterized by outdated machinery and its production was oriented to the domestic market. Nowadays, it is known worldwide as one of the most dynamic and competitive vehicle production and exporting platforms.
- 3) Mexico has a strategic geographic location. It shares a border of more than 3,000 kilometers with the United States (US), the biggest buyer of vehicles in the world and it has access both to the Pacific Ocean and the Atlantic Ocean, which favors trade with Asia and Europe, respectively.
- 4) Mexico has 12 free trade agreements with 46 countries, among them the North American Free Trade Agreement (NAFTA), signed up with the US and Canada in 1993 and implemented the following year.⁴ NAFTA covers the biggest free trade area in the world and vehicles are the largest trade component among its trading partners.⁵
- 5) The MAI is globally recognized for having skilled

³For a brief history of the development of this industry see Section 2.

⁴See ProMexico (2017) for more details. It was replaced by the United States-Mexico-Canada Agreement, which entered into force on July 1, 2020.

⁵According to ProMexico (2016), Mexico's share in US imports of vehicles grew from 10% in 1995 to 26%

and competitive labor force (Covarrubias Valdenebro, 2014). 6) Mexico's experience as a producer and exporting platform of vehicles, as well as its low labor costs and multiple free trade agreements, have attracted foreign investors into the MAI. FDI flows into the MAI increased from 2,658.0 million dollars in 2010 (18.7 percent of total FDI inflows into the Mexican manufacturing sector) to 6,608.3 million dollars in 2018 (42.1 percent of total FDI inflows into the Mexican manufacturing sector).⁶

At a national level, the MAI is considered one of the driving forces of the Mexican economy. In 2010 and 2018, it accounted for 2.0 percent and 3.0 percent of Mexico's GDP, respectively. In addition, Table 3 shows that the MAI increased its share in the manufacturing sector's GDP from 7.9 percent in 1993 to 20.4 percent in 2018, becoming the most important contributor to the manufacturing sector in this latter year.⁷

Table 3: Share of Individual Mexican Industries in the Manufacturing Sector's GDP
(Percentage)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Manufacturing Industries	100	100	100	100	100	100	100	100	100	100	100	100	100
Food Industry	18.6	18.6	18.4	18.1	17.3	16.4	17.1	16.8	18.3	19.2	20.6	20.2	21.1
Automobile Industry	7.9	8.0	8.7	10.2	10.1	10.7	11.1	11.7	11.0	11.6	11.4	11.2	11.4
Industry of Chemical Products	10.0	9.2	9.6	8.9	8.3	8.5	8.7	8.5	9.1	9.7	9.6	10.2	10.0
Oil and Products Derived from Oil	2.1	2.2	2.3	2.2	2.3	2.2	2.0	2.1	2.1	2.2	2.2	2.1	2.3
Production of Electric Devices for Domestic Use	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.7	0.7	0.7

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Manufacturing Industries	100	100	100	100	100	100	100	100	100	100	100	100	100
Food Industry	18.8	20.1	20.7	23.9	22.6	23.0	22.2	23.4	22.3	20.8	20.8	20.2	19.9
Automobile Industry	11.6	11.8	11.2	10.3	12.7	13.7	14.7	15.5	16.7	18.1	19.3	20.4	20.4
Industry of Chemical Products	10.4	10.4	10.8	11.1	10.4	9.7	10.2	10.5	8.4	7.8	7.8	6.1	5.9
Oil and Products Derived from Oil	2.1	2.1	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.2	2.3	2.3	2.3
Production of Electric Devices for Domestic Use	0.7	0.6	0.5	0.5	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Source: INEGI, Cuentas Nacionales.

Note: The first three industries are sub-sectors disaggregated at a 3 digit level according to SCIAN classification, while the last two sub-sectors are disaggregated at a 4 digit level.

The MAI is also one of the largest employers in Mexico. In 2010 and 2018, it generated 13.9 percent and 22.2 percent, respectively, of the total employment in the manufacturing sector.⁸

in 2015 and, currently this country is the main supplier of vehicles to the US, followed by Canada and Japan.

⁶The data source is the Mexican Ministry of Economics.

⁷The data source is the National Institute of Statistics and Geography (INEGI in Spanish), National Accounts (Cuentas Nacionales in Spanish).

⁸The data source is INEGI's Monthly Manufacturing Survey (Encuesta Mensual de la Industria Manufacturera in Spanish).

The MAI's outstanding performance both globally and in Mexico makes this industry an important case study. In this paper, I provide some evidence on the impact of NAFTA on the MAI's productivity, using establishment level data for the first 20 years of the trade agreement (1994-2014).⁹ The empirical analysis is performed in two stages. In the first stage, a Cobb Douglas production function is estimated by the Levinsohn and Petrin (2003) approach (in an alternative exercise, the first stage specification is estimated instead by the Akerberg et al. (2015) methodology) in order to control for simultaneity and selection problems. From these first stage estimates, I derive a total factor productivity (TFP) measure as a residual and use it as a dependent variable in the second stage estimation. In the second stage, I estimate a model by System Generalized Method of Moments (GMM) that includes the lagged dependent variable; trade openness proxies (i.e. tariff on imported vehicles and the ratio of sales to the foreign market to the value of production); a measure of technological adoption; establishment characteristics such as age and size; the real exchange rate; the Herfindahl Hirschman Index (HHI); and some interaction terms between the trade openness proxies, the real exchange rate, and the HHI with size dummies, as explanatory variables. System GMM is employed in this second stage estimation in order to allow for a lagged dependent variable on the right hand side of the equation and to control for possible cases of endogeneity between the TFP measure and the independent variables. The main results show that there seems to be a positive association between trade liberalization under NAFTA, measured by a reduction of tariffs on imported vehicles, and medium size establishments' total factor productivity.¹⁰ No correlation between trade openness and productivity is found in the case of small and large establishments. These results are consistent with the theoretical and empirical models of Bustos (2011) and Lileeva and Trefler (2010), which are extensions of the standard

⁹Empirical studies on the trade-productivity link have proliferated in the last decade due to two main reasons: 1) there is a great interest in studying whether a change in trade policy has had an effect on industries' or firms' productivity gains; and 2) there is a greater availability of both trade and industry or firm level data, which has allowed more studies on this topic to emerge (see De Loecker, 2011).

¹⁰These results cannot be necessarily interpreted in terms of causality due to the following reason: the trade openness proxy (i.e. tariffs on imported vehicles) varies across time in a linear way, which is equivalent to introducing a time trend in the estimated regression. Hence, these findings might suggest that productivity at the MAI increased during the period analyzed, but cannot show that this effect was necessarily due to the tariff reduction. Therefore, results in this document are presented in terms of an association/correlation and not of causality.

Melitz's (2003) model of firm heterogeneity. Regarding the impact of exports on total factor productivity, there are mixed results. In the first exercise, where total factor productivity is derived using the Levinsohn and Petrin (2003) approach, no association is found between exports and productivity. However, in the alternative exercise, where total factor productivity is obtained using the Akerberg et al. (2015) methodology, a positive correlation between exports and productivity is found for all establishments.

Despite the importance of the MAI for the Mexican economy, empirical analyses on this industry are scant and mainly descriptive.¹¹ This paper contributes to the literature on this industry in different ways. 1) It updates previous analyses (either descriptive or empirical) on the MAI since it covers the period 1994-2014. 2) The TFP, at an establishment level, is estimated by econometric techniques that allow me to control for potential simultaneity and selection problems. To my knowledge, no previous analyses on the Mexican automobile sector have ever used these econometric techniques to estimate the TFP. 3) Rather than using the two-stage least squares approach as in López-Córdova (2003) for the case of Mexico to estimate the second stage equation, I employ System GMM. This econometric technique permits to consider a dynamic component in the model and to control for possible cases of endogeneity.

The rest of the paper is organized as follows: Section 2 briefly describes the emergence and development of the MAI. Section 3 surveys the literature on the effect of trade openness on productivity. Section 4 presents the empirical strategy, the data, and the results, while Section 5 concludes.

2 The Mexican Automobile Industry

The MAI's emergence and development was mainly due to both foreign and domestic investments and to the Mexican government's implementation of Automotive Decrees until the end of the 1980's.

¹¹See for example Moreno-Brid (1996); Hualde (1998); Mortimore and Barron (2005); Carrillo (2000); Studer-Noguez (2002); ProMexico (2016), among others.

During the first quarter of the 20th century, all the vehicles sold in Mexico were imported since there were no vehicle assembly plants or auto parts factories. The first vehicle assembly companies started operations in Mexico between 1925 and 1960. Some of them were a 100 percent foreign or domestic owned companies and some of them were both, foreign and domestic. Ford Motor Company established its first assembly line in Mexico in 1925. General Motors and Fábricas Automex (which was a partly domestic owned company at the beginning and that later became Chrysler) followed up and opened their doors in 1935 and 1938, respectively. Promexa, a 100 percent domestic owned company in its origins, became Volkswagen, a 100 percent foreign owned company, in 1963. Nissan Mexicana was constituted as a completely foreign owned company in 1961. It later started manufacturing vehicles in Aguascalientes and in Cuernavaca in 1966 and 1992, respectively.

Diesel Nacional (1951),¹² Planta Reo de México (1949),¹³ Representaciones Delta (1955), Impulsora Mexicana Automotriz (1967),¹⁴ and Vehículos Automotores Mexicanos (1946)¹⁵ were domestic owned companies that used to operate in Mexico, but ceased activities during the 1960s and 1980s, except for Diesel Nacional, which is now known as DINA. Mexico has also been the platform of other firms producing medium-sized and heavy trucks and buses such as the Big-Three (Ford, Daimler Chrysler and General Motors), Kenworth, Mexicana de Autobuses, Oshmex, Scania, Volvo, and Víctor Patron (Robert, 2000). The MAI is comprised as well by the auto parts sector, which is mainly focused on exporting to the US.¹⁶ However, in this document I just concentrate on analyzing assembly plants of vehicles and trucks.

Currently, the Big Three plus Volkswagen and Nissan account for more than 95 percent of Mexico's vehicle production and exports. Table 4 shows a detailed timeline of the MAI. In terms of regulation, the MAI used to be ruled by development programs called Automotive Decrees. Their main aim was to control production, sales, imports of vehicles (and

¹²See *Dina* (2018) for more details.

¹³See *Retrobuses* (2017) for more details.

¹⁴See *Excelencias del Motor* (2017) for more details.

¹⁵See *Vehículos Automotores Mexicanos* (2017) for more details.

¹⁶Mexican Ministry of Economics (2012).

auto parts) and, ownership of car plants.¹⁷ The 1962 Auto Decree, for example, prohibited imports of finished vehicles and established a 60% local value - added requirement on vehicles assembled in Mexico as well as a 40% limit on foreign ownership in auto parts plants. This regulation raised the production of motor vehicles, but the machinery became outdated, product quality decreased, and national firms faced higher production costs than their foreign counterparts.

The 1977, 1983 and 1989 Auto Decrees, on the other hand, promoted competitiveness in this industry, increased exports, and allowed for imports of new vehicles subject to the firms' trade surplus coefficients, respectively. These latter decrees emerged as a result of trade deficits in autos, the 1982 balance of payment crisis, and as Mexico's first attempts to dismantle the import-substitution program and, therefore, to liberalize the economy. Table 5 presents a brief description of these Auto Decrees.

In the 1980's, market integration between Mexico and the US strengthened due to the maquiladora program, i.e. manufacturing operations taking place in Mexico in order to assemble imported components into exportable goods. The MAI took advantage of this program particularly to produce motor vehicle parts (Klier et al., 2017).

During the 1990s, Mexico continued with its trade liberalization process under NAFTA and the MAI became ruled by this trade agreement. Table 6 presents the rules the MAI has followed since NAFTA's inception.

¹⁷Moreno-Brid (1996).

Table 4: Timeline of the MAI

Year	Description of the MAI
1908	Vehicles arrived into Mexico.
1925	Ford opened the first vehicle assembly plant in Mexico.
1935	General Motors followed Ford and established its first vehicle assembly plant in Mexico.
1938	Fábricas Automex, a privately owned Mexican firm and Chrysler licensee, was established in this year.
1946	Vehículos Automotores Mexicanos, a 100% domestic company, started operations.
1949	Planta Reo de Méxco, a 100% domestic company, started operations.
1951	Diesel Nacional, a 100% domestic state owned company, started operations.
1961	Nissan was constituted a completely foreign owned company in this year.
1962	Chrysler bought 33% of Fábricas Automex. Representaciones Delta is a 100% percent domestic company.
1963	Volkswagen bought Promexa, a previously 100% domestic firm. Plantas Reo de México ceased operations.
1964	Representaciones Delta ceased operations.
1966	Nissan started manufacturing vehicles in Aguascalientes.
1967	Volkswagen started operations in Puebla. Impulsora Mexicana Automotriz, a 100% domestic company, started operations as well.
1968	Chrysler increased its share of Fábricas Automex to 45%.
1969	Impulsora Mexicana Automotriz ceased operations.
1972	Chrysler finally bought Fábricas Automex.
1978	Renault acquired 40% equity of Diesel Nacional, a previously 100% domestic state owned firm. Diesel Nacional is now known as Dina.
1986	Ford opened an assembly plant in Hermosillo. This year is considered the beginning of the modern Mexican vehicle industry.
1992	Nissan started manufacturing vehicles in Cuernavaca.
mid-1990s	BMW, Honda, Mercedes-Benz started manufacturing vehicles in Mexico.
1998	Chrysler and Daimler-Benz merged.
Current time	The Big Three plus Volkswagen and Nissan account for more than 95% of Mexico's vehicle production and exports.

Source: Robert (2000) and Studer-Noguez (2002).

Table 5: Mexican Auto Decrees

Auto Decrees	Objective	Requirements Established by the Decree	Results
1962	To create a national auto industry. It was a step forward on adopting import-substitution policies.	It established a 60% local value-added requirement on vehicles assembled in Mexico, as well as a 40% limit on foreign ownership in auto parts plants. It prohibited imports of finished vehicles.	Production increased, but machinery became outdated, product quality decreased, and national firms faced higher production costs than their foreign counterparts.
1977	Following the 1976 devaluation, the government's main priority was to fix the balance of payments, so it ordered manufacturers to balance trade by 1982.	50% or more of an automaker's exports had to come from domestic parts suppliers. Price controls and production quotas were eliminated. It allowed up to 20% of automakers' exports to be produced in maquiladoras.	The decree encouraged investment by multinationals. In 1977, GM announced its expansion and built new plants in the following years. Ford, Volkswagen, Chrysler and Nissan followed it soon afterwards.
1983	To reduce the trade deficit.	It established a 60% Degree of Integration (DIN) for autoparts and a global DIN of 80% for each company. Firms were only able to produce one line and five models.	Production fell and manufacturers experienced losses. A trade surplus emerged but not because of an increase in exports, but due to a lower domestic demand.
1989	To promote the industry's development, to dismantle the imports-substitution program, and to increase its share in the global economy. There were three decrees in this year: the Autotransportation Decree, the Auto Popular Decree, and the Automotive Decree.	The Autotransportation Decree focused on the production of buses, trucks and other vehicles. The Auto Popular decree had as main objective to provide consumers with a "reasonably priced vehicle". The Automotive Decree had as main aim to liberalize the MAI.	Certain rules for domestic content were reduced, and imports of vehicles were allowed but they were limited.

Source: Robert (2000) and Mexican Ministry of Economics (2012).

Table 6: Rules under NAFTA for the Mexican Automobile Industry

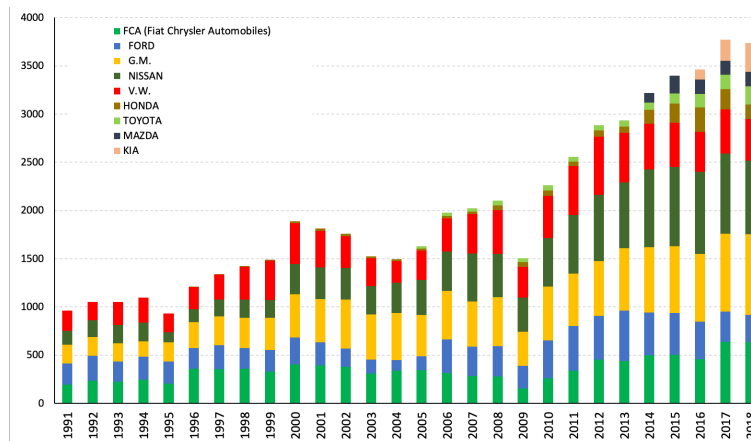
Tariffs on vehicles and light trucks originated in the US and Canada		Amount of Exports Required for every \$1.00 worth of Vehicles and Light Trucks Imported		Local Content Requirements and Market Share Restrictions		Imports of Used Vehicles		Import Licenses	
Before NAFTA	After NAFTA	Before NAFTA	After NAFTA	Before NAFTA	After NAFTA	Before NAFTA	After NAFTA	Before NAFTA	After NAFTA
20%	On January the 1st, 1994, Mexican tariffs were reduced to 10%.	\$2.00	On January the 1st, 1994, this amount was reduced to \$0.80.	Local Content Requirements and Market Shares were present.	NAFTA provided for their elimination within a 10 year period in vehicles from the US and Canada which meet the NAFTA rule of origin.	Prohibited in Mexico, except for certain border zones (Northern zones of Mexico, free zones of Baja California, partial zones of Sonora and Baja California Sur, and the border city of Cananea in Sonora).	Prohibited in Mexico, except for certain border zones (Northern zones of Mexico, free zones of Baja California, partial zones of Sonora and Baja California Sur, and the border city of Cananea in Sonora).	Import licenses were required for heavy and light vehicles.	Import licenses were required for heavy and light vehicles.
	Tariffs on <i>vehicles</i> were phased out in equal decrements over the following 10 years. Tariffs on <i>light trucks</i> were phased out in equal decrements over the following 5 years.		This amount was reduced over a period of 10 years until it was eliminated in 2004.					Eliminated after 1999 for the case of heavy vehicles, and after 2004, for the case of light vehicles.	

Source: Office of Automotive Affairs in the United States.

As it can be seen, NAFTA led to an elimination of tariffs, of domestic content requirements, and of markets share restrictions. New plants were built and existing ones were re-structured so that they could be integrated into the North American system.

Twenty-six years after NAFTA's implementation, tariffs, local content requirements, and import licenses in this industry have been completely eliminated. At present, Mexicans can import new vehicles from the US or Canada and, assembly firms are not subject to trade balance requirements in order to import vehicles. Furthermore, the MAI is now characterized by a high degree of specialization in its labor force; by its distribution process known as *just in time* and; by the dynamism of its exports that have led Mexico to become a net vehicle exporter. In this sense, firms such as General Motors and Nissan have considered Mexico a leading place for vehicle assembly; while firms such as Chrysler, Ford, and Volkswagen have chosen this country as the only platform to export vehicles. Figure 2 confirms that Chrysler, Ford, General Motors, Nissan and Volkswagen have been the largest producers of vehicles in Mexico during the analyzed period.

Figure 2: Production per Vehicle Assembler
(Thousands of Units)



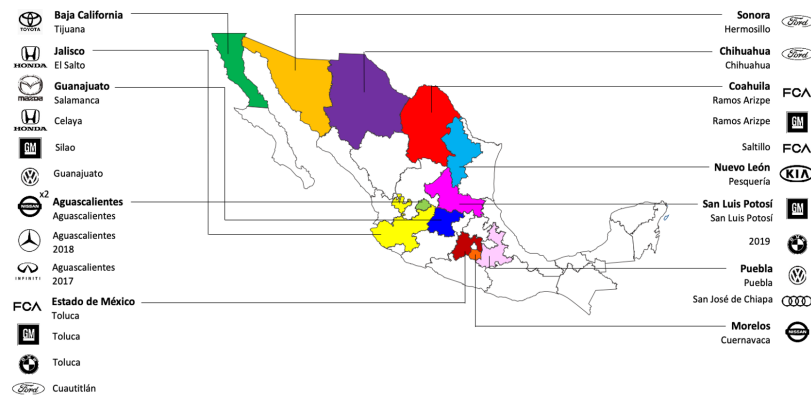
Source: Asociación Mexicana de la Industria Automotriz.

Nonetheless, other international automakers such as Mazda have also “added production capacity in Mexico”: their output represents “a substitution of imports to North America

from Asia” (Klier et al., 2017). In addition, leading German auto producers, such as VW’s Audi, BMW, and Daimler’s Mercedes-Benz, have also established in Mexico in order to export vehicles without having to face trade barriers. This has been possible due to Mexico’s numerous free trade agreements (Klier et al., 2017).

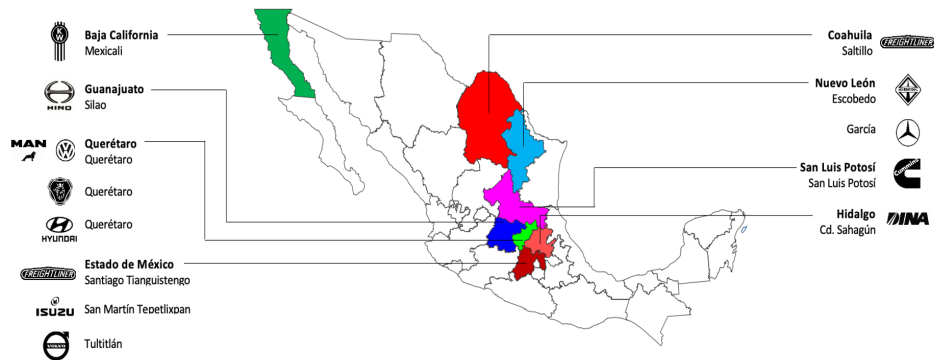
Figures 3 and 4 show the location of the assembly lines of light vehicles and heavy trucks in Mexico. The assembly lines of light vehicles are mainly located in the North and Centre of Mexico, while the assembly lines of heavy trucks are located in three Northern states and the Centre.

Figure 3: Assembly Lines of Light Vehicles in Mexico



Source: ProMexico (2016).

Figure 4: Assembly lines of Heavy Trucks in Mexico



Source: ProMexico (2016).

Most vehicle producers are located in Central Mexico since the majority of potential consumers live in Mexico City or in its surroundings. In addition, the MAI's clustering depends as well on the "ease of access to the country's transportation network": a large fraction of vehicles are exported to the US and Canada by rail (Klier et al., 2017).

3 Literature Review

The theoretical and empirical literature on the trade-productivity link has identified several channels through which industries, firms, plants or establishments may experience productivity gains following a trade liberalization episode.

First, trade could affect productivity through the reallocation of market shares channel. Higher competition, as a result of trade reforms, could lead inefficient firms to exit the market, while enabling efficient firms to survive and, therefore, to expand their market shares. This channel assumes firm heterogeneity and fixed costs of exporting. Melitz's (2003) theoretical model shows that opening an economy to trade leads the most productive firms to enter the export market; while the least productive firms, to shut down their production process. Similarly, in the modeling framework of Bernard et al. (2003), existing productivity differences between plants determine whether they become exporters or not. Trade openness could further enhance the gap between plants, since the most productive ones continue to grow, while the least productive exit the market (Bernard and Jensen, 2004). On the empirical front, Hay (2001) investigates the impact of the 1990 trade liberalization process in Brazil on the productivity of manufacturing firms and finds that it generated large productivity gains along with a fall in market shares. For the case of Chilean manufacturing plants, Pavcnik (2002) finds that surviving firms are more productive than exiting firms after trade reforms and that the import-competing sector is on average more productive than the non-traded goods sector, which contributed to the reshuffling of resources in the Chilean economy. Bernard and Jensen (2004) test the learning by exporting hypothesis for the case of manufacturing plants in the US. They find that exporters are nearly 9 percent more productive than firms that never export and that the reallocation effects from less to more productive plants account for more than 40

percent of TFP growth. López-Córdova (2003) show that the main driver of productivity in the Mexican manufacturing sector over the period 1993-2000 is the reallocation of resources caused by increased import competition. While exporting was not found to have a positive effect on productivity, it did promote the reallocation of resources to more productive firms.

Productivity gains may also emerge as a result of lower input tariffs and, therefore, greater access to intermediate inputs and capital goods with technological knowledge embodied in them. For example, Schor (2004), using Brazilian firm level data, shows that there is a negative relationship between input tariffs and productivity, but the effect of a reduction in nominal tariffs on productivity is found to differ across firms. Fernandes (2007) shows that trade liberalization had a positive effect on plant productivity in Colombia. The effect is stronger for larger plants and those in less competitive industries. According to the author, the findings are due to within plant increases of imports of intermediate inputs, skill intensity and machinery investment, as well as to the reallocation of resources from less to more efficient plants. Amiti and Konings (2007) analyze the effect on productivity of a reduction of tariffs on final goods and a reduction of tariffs on intermediate inputs. Using data for Indonesia, the authors show that productivity increases when tariffs are reduced, particularly tariffs on intermediate inputs. Similar conclusions are found by Topalova and Khandelwal (2011) for the case of India. İşcan (1998) analyzes the effect of the 1986 Mexican trade liberalization program on the productivity of 47 manufacturing sectors over the 1970-1990 period. The main findings are that productivity increased as a result of an extensive use of imported inputs and that export share variables may be capturing “unobserved effects of sectoral differences in technological opportunities and foreign ownership”. De Hoyos and Iacovone (2013) estimate the effect of trade liberalization due to NAFTA on Mexican manufacturing labor productivity over the period 1993-2002. The authors show that an increase in import competition as well as greater access to imported intermediate inputs had a positive effect on productivity. They also find that exporting does not induce productivity growth.

Export activities may also play a role in promoting productivity. For example, the learning-by-doing hypothesis (Lucas, 1988 and 1993) suggests that domestic firms, by establishing buyer-seller relationships with foreign markets, gain new knowledge and technical expertise

that improve their productivity levels (De Loecker, 2006 and 2013). In addition, firms engaging in export activities may also face higher competition in foreign markets, which increases their incentives to innovate and, therefore, to improve their competitiveness (De Hoyos and Iacovone, 2013). For the case of Slovenia, De Loecker (2013) finds evidence of productivity gains as a result of export entry, while De Loecker (2007) shows that productivity gains are higher if firms export to high income regions.

Trade can also affect within-firm productivity. In traditional trade models, lowering barriers to entry exposes domestic producers to foreign competition and, consequently, to an increase in the elasticity of demand for their own product. This reduces their market power and forces them to expand their output at lower average costs (Pavcnik, 2002; Amiti and Konings, 2007). Under this economies of scale channel (Krugman, 1987), firms are assumed to have a common technology and face identical demand conditions (Tybout, 2001), so they expand or contract together with trade reforms. Increased competition as a result of trade openness may also reduce managerial slack and x-inefficiency (Schmidt, 1997; Meyer and Vickers, 1997; Raith, 2003). The intuition behind this is “that the efficiency of a firm is, *caeteris paribus*, a positive function of the managers’ efforts and, this, in turn, is triggered by the exposure to foreign competitors” (De Hoyos and Iacovone, 2013). Using manufacturing plant level data for India, Sivadasan (2009) investigates the effect of the FDI and trade liberalization processes from the early 1990s on productivity. The main findings show that productivity gains are mainly driven by within plant improvements in productivity (i.e. the plants have incentives to reduce slack and/or adopt new technologies), rather than by the re-allocation of resources from inefficient to efficient plants. Trade liberalization may also raise domestic firms’ incentives to innovate and to invest in new technologies as a response to the entry threat of foreign competitors (Grossman and Helpman, 1991; Gokcekus, 1997). Aghion et al. (2005) develop a model to investigate how firms react to the entry threat of liberalization and find that technologically advanced firms and those located in regions with pro-business institutions are more likely to invest in new technologies and production processes. As a result, performance inequality raises.

A common feature of this literature is that, in most of the cases, the analyses are per-

formed in two stages.¹⁸ In the first stage, a semi-parametric approach (i.e. Olley and Pakes (1996) or the Levinsohn and Petrin (2003) econometric technique) is used to estimate a Cobb-Douglas production function and, therefore, to obtain a TFP measure as a residual. In the second stage, the estimated TFP measure is then regressed on proxies for trade liberalization, on establishment's characteristics, on plant and industry fixed effects, on geographical characteristics, among other regressors. This second stage regression is generally estimated by fixed effects (e.g. Hay, 2001; Amiti and Konings, 2007; Schor, 2004; Fernandes, 2007), two-stage least squares (e.g. López-Córdova, 2003), or GMM (e.g. Topalova and Khandelwal, 2011). Nonetheless, some authors have alternatively used the difference in difference approach to estimate the second stage specification (e.g. Pavcnik, 2002; Sivadasan, 2009).

The present paper follows the common approach in the literature and, therefore, uses a two-stage estimation procedure to study the impact of trade liberalization on the productivity of establishments in the MAI. Nonetheless, there are some differences with some of the papers. First, the Cobb-Douglas production function is estimated by the Levinsohn and Petrin (2003) approach and by the Akerberg et al. (2015) method, which enables me to derive two different TFP measures. Second, this paper differs from Pavcnik (2002) in that the second stage specification is estimated as a dynamic model (i.e. a lagged dependent variable is included as a regressor). While Fernandes (2007) also incorporates the lagged dependent variable in the second stage specification, she estimates the model by fixed effects. This can generate a bias in the estimated coefficients due to the correlation between the lagged dependent variable and the unobserved time-invariant plant-specific effects. Instead, my analysis resembles that of Topalova and Khandelwal (2011) since I use the System GMM approach to estimate the second stage specification.¹⁹ This econometric technique permits to consider

¹⁸Except, for example, İşcan (1998) and De Hoyos and Iacovone (2013), that use a direct approach. The former investigates, for the period 1970-1990, the impact of the trade liberalization program Mexico implemented in 1986 on the productivity of 47 manufacturing sectors. The author estimates two output growth equations by the GMM approach. The latter uses Mexican manufacturing plant level data over the period 1993-2002 to estimate by the difference-in-difference approach the effect of the trade liberalization process under NAFTA on labor productivity (measured as value added per unit of hourly labor). Fernandes (2007) implements both a direct approach by introducing a trade policy measure in the estimated production function and, an indirect or two stage approach.

¹⁹Similar to Topalova and Khandelwal (2011), I also include electricity expenditures as independent variable in the first stage specification.

a dynamic component in the model without generating biased coefficients and, to control for possible cases of endogeneity.

The contributions of this paper are three-fold. First, it updates previous analyses (either descriptive or empirical) on the MAI since it covers the period 1994-2014. In addition, the MAI's TFP is estimated by using both the Levinsohn and Petrin (2003) approach and the Akerberg et al. (2015) approach. To my knowledge, no previous analyses on the Mexican automobile sector has ever used these econometric techniques in order to estimate this industrial sector's TFP and, at the same time, to control for potential simultaneity and selection problems that may exist in the first stage specification. Finally, rather than using the two-stage-least squares approach as in López-Córdova (2003) for the case of Mexico to estimate the second stage equation, this paper employs the System GMM econometric technique, which permits to consider a dynamic component in the model and to control for possible cases of endogeneity.

4 Empirical Analysis

Following the literature, the empirical analysis is conducted in two stages.

4.1 First Stage: Estimation of a Cobb-Douglas Production Function

In the first stage, a Cobb-Douglas production function is estimated in order to obtain a MAI's TFP measure as a residual. This Cobb-Douglas production function has the following form:

$$y_{i,t} = \beta_0 + \beta_l l_{i,t} + \beta_k k_{i,t} + \omega_{i,t} + \vartheta_{i,t} \quad (1)$$

Where:

$y_{i,t}$, $l_{i,t}$ and $k_{i,t}$ represent establishment's i at time t output, labor and capital in logarithms, respectively. Output is measured as the value of production;²⁰ labor is proxied by the number of workers;²¹ and capital is measured by the value of fixed assets in book value.²² The value of fixed assets is equal to the sum of the value of depreciated buildings, machinery and equipment, transportation equipment, computer equipment, office equipment and furniture, and other fixed assets. The value of production is deflated using an industry specific producer price index, while the value of the capital stock is deflated with an index of capital formation for manufacturing industries. Both indexes are obtained from *INEGI*.²³

The data used to measure output, labor and capital in equation (1) constitute an original unbalanced panel of 45 establishments, observed during the period 1994-2014, and obtained

²⁰Since physical output is generally not observed, the majority of the empirical studies have used deflated sales, deflated output, or deflated value added to proxy for output in the production function. However, De Loecker (2011) argues that the deflation undertaken, (generally by using an industrywide producer price index) to eliminate the price effects could have two implications. First, the estimated production function coefficients could be biased if inputs are correlated with prices. Second, the estimated parameters could contain price and demand variation, which could “introduce a relationship between measured productivity and trade liberalization simply through the liberalization impact on prices and demand”. In order to purge the productivity response to trade liberalization from price and demand variation, De Loecker (2011) suggests introducing a demand system (where elasticities of demand differ by product segment (e.g. there are five segments in the textile sector: interior, clothing, technical textiles, finishing, and spinning and preparing)) into a production function framework (this can be applied to single product producers or multiproduct producers). This strategy gives rise to a revenue production function (the demand system permits to obtain an expression for price, which is combined with the production function to get an expression for total deflated revenue ($R=Q \cdot P$, where R is revenue, Q is output and P is price)), which includes product and product group effects to control for unobserved demand shocks and, is estimated by Olley and Pakes (1996) or Levinsohn and Petrin (2003), which helps control for unobserved productivity shocks. De Loecker (2011) strategy shows that productivity gains from trade liberalization are much lower when demand and price effects are controlled for. De Loecker's strategy cannot be implemented in this paper since it requires detailed information on input usage, number of products produced, the products produced, segment of the industry in which the firm is active, etc., and this type of data is not publicly available due to confidentiality reasons. In this sense, this paper has followed the majority of the literature and has used the value of production to proxy for output.

²¹The empirical literature has generally measured labor with the number of employees, see, for example, Levinsohn and Petrin (2003), Schor (2004), De Loecker and Konings (2006), Sivadasan (2009), and Fernandes (2007).

²²De Loecker and Konings (2006) measure capital as total fixed assets in book value as well.

²³As regards price deflators, Topalova and Khandelwal (2011) mention the following: “Ideally one would use firm-specific price deflators (De Loecker, 2009). Unfortunately, as is the case in most firm-level data sets, such information is not available, and so we must rely on industry-specific deflators”. Hence, the existent empirical studies on the estimation of production functions at a firm level have used the following price deflators: industry specific price deflators (e.g. Pavcnik, 2002; De Loecker, 2007; Topalova and Khandelwal, 2011); wholesale price indices (e.g. Sivadasan, 2009); price indices from Central Banks (e.g. Levinsohn and Petrin, 2003; Fernandes, 2007) or GDP deflators (e.g. Van Biesebroeck, 2005).

from INEGI's Annual Manufacturing Survey (*Encuesta Anual de la Industria Manufacturera* in Spanish).²⁴ Nonetheless, missing values, inconsistencies, and the fact that some establishments remained in the industry for very few years (i.e. one or two years) reduced the sample to 30 establishments.

$\omega_{i,t}$ is an establishment specific, time varying productivity shock, that is known to the establishment, but not to the econometrician. It is a state variable and, hence, a determinant of the establishments' decision rules regarding inputs' choices (which induces a simultaneity problem) and, the establishments' liquidation or exiting behavior (which induces a selection problem). It evolves over time according to an exogenous Markov process (Olley and Pakes, 1996): it depends on its value at time $t - 1$ and on an unexpected shock with mean equal to zero.

$\vartheta_{i,t}$ is an unexpected establishment specific, time varying productivity shock, unknown to the establishment and the econometrician. This term does not have an effect on the establishments' decision rules. According to Sivadasan (2009), this term "captures all other deviations from the hypothesized production function, arising from classical measurement error, optimizing errors, etc.", as well as idiosyncratic shocks to production (De Loecker, 2011).

Ordinary Least Squares (OLS) estimates of equation (1) are expected to be biased for two main reasons. First, profit-maximizing establishments decide which input combination to choose and the quantities they will use based on their productivity level. Second, profit-maximizing establishments decide whether to stay or exit the market based as well on their productivity level. Therefore, $\omega_{i,t}$ induces both a simultaneity and a selection problem.

Fixed effects estimates of equation (1) could only tackle the simultaneity problem if ω_i is assumed to be establishment-specific and time invariant. However, the assumption of time invariant productivity seems unreliable when the econometrician is trying to investigate the effects of a structural reform such as a trade liberalization process (Pavcnik, 2002; Schor, 2004). In addition, the GMM approach cannot be used in this stage since it may tackle the

²⁴The respondents of the Annual Manufacturing Survey answer the questions regarding the value of the capital stock, taking into account the depreciation of all the fixed assets mentioned.

simultaneity problem, but not the selection problem stemming from the establishments' exit (Pavcnik, 2002).

In order to solve for both the simultaneity and selection problems in this paper, equation (1) is estimated by the Levinsohn and Petrin (2003), henceforth L-P, approach.^{25,26} This methodology is based on Olley and Pakes (1996), henceforth O-P, approach, but adds a free intermediate input ($\tau_{i,t}$) to the Cobb-Douglas production function. Therefore, equation (1) becomes:

$$y_{i,t} = \beta_0 + \beta_l l_{i,t} + \beta_k k_{i,t} + \tau_{i,t} + \omega_{i,t} + \vartheta_{i,t} \quad (2)$$

The L-P method uses an intermediate inputs demand function (i.e. $\tau_{i,t} = \tau_{i,t}(\omega_{i,t}, k_{i,t})$), instead of an investment function as in the O-P approach, to identify the firm's productivity shock $\omega_{i,t}$. The intermediate inputs demand function needs to be monotonically increasing in $\omega_{i,t}$ for all $k_{i,t}$ in order for it to be inverted.²⁷ By inverting it, the productivity shock $\omega_{i,t}$ is expressed as a function of $\tau_{i,t}$ and $k_{i,t}$ (i.e. $\omega_{i,t} = \omega_{i,t}(\tau_{i,t}, k_{i,t})$) and, therefore, substituted out from equation (2). This mechanism permits to obtain consistent estimates of the Cobb-Douglas production function.

An advantage of the L-P approach is that firms generally register a positive use of intermediate inputs (i.e. electricity, materials or fuels), which allows the monotonicity condition to hold. In the case of this document, I use the cost of electricity, instead of materials or fuel, as an intermediate input to estimate equation (2).²⁸ Electricity enters equation (2) in

²⁵See Levinsohn and Petrin (2003) for more details.

²⁶Van Biesebroeck (2005), Amiti and Konings (2007), and De Loecker (2011, 2013) have implemented this approach in order to analyze the effect of trade on productivity.

²⁷Conditional on $k_{i,t}$, the higher $\omega_{i,t}$, the higher the demand for intermediate inputs and, therefore, the higher the level of production. A firm with a high productivity shock will produce more than one that has the same $k_{i,t}$ level, but lower productivity.

²⁸In choosing this intermediate input as a proxy variable for the unobserved productivity shock I followed two considerations suggested by Levinsohn and Petrin (2003). 1) The number of observations with zero values was counted for materials and electricity in order to verify which input had the least, but a very similar number of zero values was found in both cases. This is important since the observations with zero values could reflect "kinks in the factor demand curves arising (for example) from adjustment costs, which can violate the monotonicity condition" (Levinsohn and Petrin, 2003). 2) However, as mentioned also in Levinsohn and Petrin (2003), "inputs measured with less error" are generally preferred, specially in non-parametric estimations, and

logarithms.

In contrast, the O-P approach is based on investment data, which is costly to adjust, so firms only make intermittent investments. This is reflected in positive and zero – investment observations, but the latter are truncated from the estimation since the monotonicity condition only holds for positive observations.

I use Stata’s command *levpet*, written by Levinsohn and Petrin (2003), to empirically implement the L-P approach and therefore to obtain consistent estimates of the production function coefficients.²⁹ The syntax of the *levpet* command requires to use the labor input as a free variable (i.e. inputs chosen in the same period as they are consumed (Manjón and Mañez, 2016); capital as a state variable (i.e. inputs chosen before they are consumed (Manjón and Mañez, 2016); and electricity, materials and/or fuel as a proxy variable for the unobserved productivity shocks. As mentioned before, I use electricity as the proxy variable.

Finally, I employ these estimates to calculate a measure of the MAI’s TFP as a residual (i.e. $y_{i,t}$ minus the estimates of Equation (1)), which is used in the second stage estimation.

4.2 Second Stage: Estimation of the Impact of NAFTA on the MAI’s TFP

In the second stage, the TFP measure previously obtained is regressed on its lag, a proxy for trade openness under NAFTA, on a measure of technological adoption, on establishments’ characteristics, on the real exchange rate and, on the Herfindahl-Hirschman Index. Hence, the estimated equation in this second stage is:

this is the case for electricity. Measurement errors emerge “if inputs are stored period to period and changes in inventories of inputs are not directly observed”. Electricity cannot be stored for long periods of time and, therefore, its use is “highly correlated with the year to year productivity terms”. Instead, materials (as well as fuel) are easy to store and, “hence, new purchases of these inputs may not exactly track inputs used in production”. Hence, following these two criteria presented by Levinsohn and Petrin (2003), I decided to use data on electricity as a proxy in the estimated specifications by the L-P method.

²⁹For more details on this command see Petrin et al. (2004).

$$\begin{aligned}
TFP_{i,t} = & \beta_0 + \beta_1 TFP_{i,t-1} + \beta_2 TradeOpeness_t + \beta_3 TechnologicalAdoption_{i,t-1} \quad (3) \\
& + \beta_4 Establishments' Characteristics_{i,t} + \beta_5 ExchangeRate_t + \beta_6 HHI_t + \\
& \beta_7 TradeOpeness_t * SizeDummies + \beta_8 ExchangeRate_t * SizeDummies \\
& + \beta_9 HHI_t * SizeDummies + \mu_i + \varepsilon_{i,t}
\end{aligned}$$

Where:

i and t are sub-indexes for establishment and time, respectively.

$TFP_{i,t-1}$ – Simple dynamics is added to the model by including the lagged dependent variable on the right hand side of equation (3). The lagged dependent variable is included in the model in order to allow for persistence.

$TradeOpeness_t$ – This variable is proxied by using tariff barriers imposed by Mexico in the past on vehicle imports from the US and Canada. Tariffs on vehicles were reduced from 20 to 10 percent on January 1, 1994 and phased out in equal decrements over the following 10 years.³⁰ This variable varies only across time. This gradual elimination of import tariffs under NAFTA is expected to have increased the competitive pressures to which establishments were exposed (De Hoyos and Iacovone, 2013) and, therefore, to have led them to become more efficient in order to survive.

As mentioned in Section 3, some studies have additionally analyzed the impact of intermediate input tariffs on productivity (e.g. Schor, 2004; Amiti and Konings, 2007; Topalova and Khandelwal, 2011) and have found that access to cheaper intermediate inputs have had a larger impact on firm productivity than pro-competitive effects from lower output tariffs. In the case of the MAI, this analysis is not conducted since tariffs on auto-parts and accessories

³⁰ According to HufBauer and Schott (1993), tariffs on imported vehicles were 20 percent in 1993, but decreased to 10 percent once NAFTA was implemented in 1994. During the next 10 years, the tariff phase out schedule continued as follows: 9 percent in 1995, 8 percent in 1996, 7 percent in 1997, 6 percent in 1998, 5 percent in 1999, 4 percent in 2000, 3 percent in 2001, 2 percent in 2002, 1 percent in 2003, and 0 percent from 2004 onwards. See HufBauer and Schott (1993) and Robert (2000) for more details on the vehicle tariffs phase-out schedule.

were 9 percent in 1993 and 0 percent from 1994 onwards, which makes it very challenging to provide evidence on the intermediate input tariffs - productivity link.

Nonetheless, trade openness has also been measured using the ratio of sales to the foreign market to the value of production, henceforth, $Exports_{i,t}$ in the estimated specifications. This regressor varies across time and establishment. I use this as an alternative trade proxy since it is a standard measure in the literature on productivity and growth. See, for example, Levine and Renelt (1992), Harrison (1996), İscan (1998), and López-Córdova (2003).³¹

Technological Adoption $_{i,t-1}$ – Following Salgado-Banda and Bernal-Verdugo (2011), this variable is measured as the ratio of expenditures on technology transfers and royalties to value added. Value added is calculated as the value of production minus the value of materials (i.e. raw materials, containers, and fuels). The data used to build this variable are obtained from INEGI's Annual Manufacturing Survey, vary across time and establishments, and are expressed in 2012 thousand pesos. This variable has been included into equation (3) since firms adopting new technology or information to improve its own technology tend to experience a positive productivity shock (Gokcekus, 1997).

Establishments' Characteristics $_{i,t}$ stand for age and size. These variables are included in order to control for heterogeneity between establishments.

Age $_{i,t}$ is calculated as the number of years an establishment from the MAI has answered INEGI's Annual Manufacturing Survey. This variable is a proxy for age.

Following Schor (2004) and Fernandes (2007), *size* categories are built as dummies based on the 50th and 75th percentiles of the labor variable (i.e. number of workers) when the establishments are one year of age. These size categories are the following:

1. Small if the establishment has less than 1071 employees.
2. Medium if the establishment has more than 1071 employees but less than 2666 employees.
3. Large if the establishment has more than 2666 employees.

³¹The analysis could have used an alternative trade openness measure such as ((sales to the foreign market + imports)/value of production), but it did not since the questionnaire of INEGI's Annual Manufacturing Survey does not permit to retrieve information on imports.

$ExchangeRate_t$ is the peso US dollar real exchange rate and it is included in order to control for macroeconomic shocks common to all establishments. By introducing this explanatory variable, the impact of NAFTA on the MAI's TFP is disentangled from that of the 1994 Tequila crisis.³²

In order to analyze if more concentrated industries are less productive as stated in the literature, the Herfindahl-Hirschman Index (HHI_t) for the MAI is also included in specification (3).

μ_i – This term controls for unobserved time-invariant establishment specific effects.

$\varepsilon_{i,t}$ – This term represents the specification's error term.

Time fixed effects are excluded from specification (3) since variables such as the tariff, the real exchange rate, or the HHI, that vary across time but not across establishments, have been taken into consideration. I cannot include both, the time fixed effects and these other variables, since a problem of perfect collinearity would emerge.

The age variable and the exchange rate are expressed in logarithms. The rest of the variables are either a ratio, an index or a dummy.

Table 7 presents some summary statistics on the variables described.

Equation (3) presents two issues to be addressed: 1) the lagged dependent variable is correlated with the error term due to the presence of unobserved time-invariant establishment specific effects and 2) some explanatory variables (e.g. tariffs, exports and technological adoption) might be a function of productivity, rather than a determinant of it. Hence, its estimation by traditional panel data techniques which do not control for these problems (i.e. Ordinary Least Squares) generates inconsistent and biased estimates of the unknown parameters. Therefore, equation (3) is estimated by System GMM, which permits to restore consistency of the parameters' estimates and to control for possible cases of endogeneity. In addition, the GMM estimator "turns out to be efficient within the class of instrumental variable estimators" (p. 115, Nucci and Possolo, 2010). Following Arellano and Bover (1995) and Blundell and Bond (1998 a and b), equation (3) is estimated by System GMM using STATA's *xtabond2* command written by David Roodman (2006).

³²A reduction in the exchange rate indicates there is an appreciation.

Table 7: Summary Statistics

Variable	Obs	Mean	Std. Dev.
Value of production ^{1,2}	377	18,800,000	23,500,000
Number of employees	377	2,573	2,977
Value of capital ^{1,2}	376	3,604,790	5,821,067
Value of materials ^{1,2}	375	6,934,175	9,494,789
Value of electricity ^{1,2}	377	55,630	90,436
Sales to Foreign Market ^{1,2}	377	15,200,000	21,700,000
Technological adoption (ratio)	375	0.02816	0.05955
Tariffs on Imported Vehicles (%)	377	2.63	3.26
Exchange rate (Peso - US dollar)	377	10.1360	2.4090
Capital Index (base year=2012)	377	69.4340	23.1863
Producer Price Index (base year=2012)	377	61.1409	25.0570
Herfindahl Hirschman Index	377	1216.587	96.06734

1. Expressed in 2012 thousand pesos.

2. These variables come from INEGI's Annual Manufacturing Survey. Regarding the statistics presented, only the mean and the standard deviation are shown since they do not refer to an individual establishment (as the median, the minimum or the maximum value) and, hence, they are not violating INEGI's confidentiality principle.

The Hansen test of over-identifying restrictions, which is a test for the exogeneity of the included set of instruments; the Arellano-Bond tests for first and second order serial autocorrelation in the first-differenced residuals, as well as robust standard errors, to account for general forms of heteroskedasticity and serial correlation in the error term, are computed and registered together with the results.³³

4.3 Results

Table 8 presents the first stage results from estimating equation (2) by the L-P approach. As described in Section 4.1, the Cobb-Douglas production function is estimated using the *levpet* Stata's command with labor as a free variable, capital as a state variable, and electricity as a proxy for the unobserved productivity shock.

³³The null hypothesis in the Arellano Bond test for first order serial correlation AR(1) in the first-differenced residuals establishes that there is no serial correlation and should be rejected for a correct specification of the model. In addition, the null hypothesis in the Arellano Bond test for second order serial correlation AR(2) in the first-differenced residuals establishes as well that there is no serial correlation and should not be rejected for a correct specification of the model. Finally, the null hypothesis in the Hansen test should not be rejected either since it establishes the instruments are exogenous.

Table 8: First Stage: Estimation of a Cobb-Douglas Production Function
(Levinsohn - Petrin Approach)

	Dependent Variable: Value of Production
	(1)
Independent Variables:	
Free Variable: Labor	0.4312*** (0.1550)
State Variable: Capital	0.2039 (0.1663)
Proxy for unobserved productivity shock: Electricity	0.7318*** (0.2463)
Observations	373
Productivity Measure Obtained as a Residual	$TFP_{Levinsohn-Petrin}$

Notes: Robust standard errors in parentheses.

*** $p < .01$, ** $p < .05$, * $p < .1$.

As it can be seen, all estimated coefficients are positive and both, the labor coefficient and the electricity coefficient are statistically significant.³⁴ The coefficient on electricity is the highest, followed by that of labor and capital. This is in line with the literature on the trade-productivity link (e.g. Schor, 2004; Amiti and Konings, 2007), even the magnitudes of the coefficients are similar to those presented in the literature (e.g. Amiti and Konings, 2007; De Loecker and Konings, 2006). These estimated coefficients are then used to obtain a TFP measure as a residual (i.e. $TFP_{Levinsohn-Petrin}$).

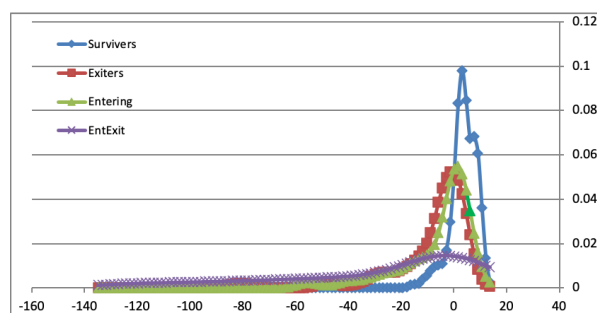
Figure 5 presents a histogram of the estimated TFP measure (i.e. $TFP_{Levinsohn-Petrin}$) by groups of establishments: survivors (i.e. establishments that remain in the sample for the entire 1994-2014 period), exiters (i.e. establishments that left the industry in any year after 1994), entering (i.e. establishments that entered the industry in any year after 1994 but remained in the sample for the rest of the period), and entexit (i.e. establishments that entered the industry in any year after 1994 but left before 2014). It shows that survivors (diamond line) are the most productive group of establishments, while exiters (square line) and the entexit establishments (circle line) are the least productive. These results are consistent with Melitz's (2003) model and the selection effects emphasized there. They might suggest that

³⁴The capital coefficient is not statistically significant. One explanation for this result could be that establishments do not adjust capital year by year, but they do it intermittently (due to adjustment costs). That is, this input's lack of variability might be preventing the effect of capital on production from being identified.

higher levels of competition under NAFTA led inefficient establishments to exit the MAI, while enabling surviving establishments to raise their market share.

It may also be the case that the trade liberalization process under NAFTA led to within establishment improvements in productivity by urging producers to adopt more efficient technologies or to use the same type of technology, but with less x-inefficiency (i.e. “gap between actual productivity and the maximum productivity achievable” (De Hoyos and Iacovone, 2013), in order to reduce costs.

Figure 5: Histogram of the Estimated TFP Measure by Groups of Establishments (L-P Method)



Note: This figure was constructed by the author with data on the Mexican automobile industry.
Source: INEGI's Annual Manufacturing Survey.

Finally, it may be the case that firms engaged in export activities faced higher competition under NAFTA, which increased their incentives to innovate and, therefore, to improve their competitiveness.

In order to test if NAFTA induced an increase in the MAI's productivity through either one or more of these channels (i.e. resource reallocation, reduction of x-inefficiency or innovation in order to improve its competitiveness), equation (3) is therefore estimated by System GMM using the TFP measure obtained in the first stage.

Tables 9 and 10 show the results of the second stage estimation using the tariff and exports variables as trade openness measures, respectively. The specifications in these Tables include the lag of the technological adoption variable, age, the exchange rate, and the HHI as additional regressors, as well as interaction terms of the trade openness variables, the exchange rate, and the HHI with size dummies.

The interaction terms permit to investigate if there is an heterogeneous response of the establishments to tariff reductions, exports increases, exchange rate movements (i.e. appreciation or depreciation), or an increase (decrease) in industry concentration. Furthermore, since the technological adoption effect on total factor productivity may not be immediate, it enters with a lag in both Tables.

The results in Table 9 show that the three models presented are correctly specified since they pass the Arellano-Bond tests for first and second order autocorrelation in the first differenced residuals, as well as the Hansen test. They also show that, while the estimated tariff coefficient is not statistically significant in any of the three specifications, the interaction term between this same variable and the medium size dummy is negative and statistically significant in the second and third regressions (columns (2) and (3)). These findings can be interpreted as follows: there is a positive association between trade liberalization under NAFTA, measured by the gradual removal of tariffs under this free trade agreement, and medium size establishments' TFP. Specification (2), for example, shows that the estimated coefficient on the interaction term between the tariff and the medium size category is negative and statistically significant (-0.9047). It implies that a reduction of one standard deviation in tariffs on imported vehicles would lead to an increase of 2.95 percentage points in the medium size establishments' total factor productivity.

These findings on the positive association between trade liberalization and productivity gains for just medium size establishments are consistent with the following theoretical and empirical models based on Melitz's (2003) assumption of heterogeneous initial productivity.

Bustos (2011) finds that a reduction in variable trade costs as a result of MERCOSUR (i.e. a reduction in Brazil's tariffs) led Argentinian firms in the middle range of the productivity distribution to enter the export market and upgrade technology; while firms in the lower or upper range of this same distribution, to remain almost unaffected. More precisely, the reduction in tariffs led firms that "were below the exporting threshold before liberalization but above it afterwards" (i.e. they cross a threshold) to enter the export market and, those firms that were "below the technology adoption threshold before liberalization, but above it afterwards" (i.e. they cross a threshold) to technology upgrade. Instead, the reduction of tariffs

had a smaller impact on firms in the upper and lower range of the productivity distribution, since the former were above the thresholds before (or regardless of) liberalization, while the latter were below those thresholds even after the trade liberalization process (i.e. they did not cross any thresholds after liberalization). The reason for this result is the mechanism emphasized by the theoretical model: only the firms that cross the exporting threshold, as well as the technology upgrading threshold, due to the increase in exporting revenues as a result of lower variable trade costs or trade integration, enter the export market and upgrade technology.

In addition, Lileeva and Trefler (2010) present a theoretical model of exporting and investing in productivity-enhancing activities, considering heterogeneity in initial productivity and in productivity gains from investing. The authors show that “improved access to foreign markets”, as a result of tariff reductions, “raises productivity for some firms but not all”. Some firms that before the reduction of tariffs neither exported nor invested are now engaging in both exporting and investing and experiencing productivity gains. Some firms that before the increased access to foreign markets neither exported nor invested are now exporting but not investing and are not experiencing productivity gains. Finally, those firms that before the tariff reductions used to only export, are now investing and experiencing productivity gains. Using data on Canadian firms, under the context of the Canadian - US free trade agreement, the authors also show that those firms that were induced to export to the US as a result of lower tariffs experienced labor productivity gains. These productivity gainers then adopted advanced manufacturing technologies, incurred in higher rates of product innovation, and “increased their domestic sales relative to nonexporters”. According to the authors, this exporter-nonexporter productivity growth differential reflects negative selection in initial productivity, which means that productivity gains were larger for the initially least productive plants and decreased until reaching zero for the initially most productive plants.

Table 9: Second Stage: Estimation of the Impact of NAFTA
on the MAI's TFP Trade Variable: Tariff
(System GMM Approach)

	Dependent Variable		
	$TFP_{Levinsohn-Petrin}$		
	(1)	(2)	(3)
Independent Variables:			
Lagged $TFP_{Levinsohn-Petrin}$	0.9778*** (0.1037)	0.9900*** (0.0893)	1.0004*** (0.1066)
Tariff	-0.2004 (0.3483)	0.4090 (0.3631)	0.4143 (0.3790)
Dummy Small	-1.2524 (3.5970)	32.8534 (32.6031)	-16.8998 (196.9314)
Dummy Medium	-0.6266 (0.7683)	49.0642** (17.7656)	-30.2931 (74.5711)
Tariff*Dummy Small	-0.0060 (0.4625)	-0.8252 (0.7991)	-0.8838 (0.8347)
Tariff*Dummy Medium	0.2915 (0.2789)	-0.9047** (0.3700)	-0.9210** (0.3966)
Lagged Technological Adoption	-8.8344 (21.6709)	-8.2676 (21.2712)	-7.7211 (21.9323)
Age	0.4125 (1.4599)	0.2744 (1.5043)	0.2452 (1.6304)
Exchange Rate	-1.9925 (4.6342)	8.3850 (6.0536)	7.8708 (6.0352)
Exchange Rate*Dummy Small		-13.7903 (13.7722)	-14.1583
Exchange Rate*Dummy Medium		-20.2126** (7.3831)	-19.2860**
HHI	2.5884 (7.5858)	2.9885 (7.2788)	-2.3954 (3.6340)
HHI*Dummy Small			7.1715 (27.3187)
HHI*Dummy Medium			10.8672
Constant	-13.6623 (57.1901)	-41.7597 (55.5217)	-2.2786 (27.0674)
Observations	340	340	340
Number of establishments	29	29	29
AR(1) in first differences:	-1.6742	-1.6528	-1.7813
AR(1) in first differences p-value:	0.09409	0.09838	0.07486
AR(2) in first differences:	0.04196	0.02031	0.09928
AR(2) in first differences p-value:	0.9665	0.9838	0.9209
Hansen test of overid. restrictions:	2.2791	2.3029	2.2080
Hansen test of overid. restrictions p-value:	0.3200	0.3162	0.3315

Robust standard errors in parentheses.

p < 0.1 *, p < 0.05 **, p < 0.01 ***

As regards Table 10, no conclusion can be derived on the effect of trade liberalization, proxied by exports, on the MAI's TFP, since the coefficients are not statistically significant and the estimated specifications do not pass the Arellano-Bond test for first order autocorrelation in the first differenced residuals.

Table 10: Second Stage: Estimation of the Impact of NAFTA
on the MAI's TFP Trade Variable: Exports
(System GMM Approach)

	Dependent Variable		
	<i>TFP_{Levinsohn-Petrin}</i>		
	(1)	(2)	(3)
Independent Variables:			
Lagged <i>TFP_{Levinsohn-Petrin}</i>	0.8529*** (0.2414)	0.8556*** (0.2514)	1.0448*** (0.1426)
Exports	0.8527 (1.5457)	0.5972 (1.1586)	0.4691 (1.6668)
Dummy Small	-1.9416 (4.0756)	16.0833 (17.1504)	-101.0593 (161.0600)
Dummy Medium	1.2640 (1.6952)	16.3495 (10.5228)	-33.0374 (75.8277)
Exports*Dummy Small	-2.9657 (6.4094)	-1.7956 (6.2717)	-4.1762 (9.4962)
Exports*Dummy Medium	-2.4368 (2.0751)	-1.9580 (1.8677)	-2.0457 (1.7285)
Lagged Technological Adoption	7.9440 (25.1408)	3.9621 (21.4756)	4.2782 (35.0850)
Age	-0.6779 (1.0653)	-1.0720 (1.1811)	0.2936 (1.5932)
Exchange Rate	3.6779 (3.6441)	8.0047 (4.8231)	1.4016 (4.4144)
Exchange Rate*Dummy Small		-7.9503 (8.3052)	-0.6506 (7.5439)
Exchange Rate*Dummy Medium		-6.6232 (4.5988)	-5.0756 (4.6562)
HHI	-1.0288 (6.0883)	-1.8293 (6.3814)	-2.0527 (3.6892)
HHI*Dummy Small			14.6328 (21.4196)
HHI*Dummy Medium			6.5032 (11.2000)
Constant	0.3333 (40.3992)	-2.9675 (42.7450)	10.4527 (24.8550)
Observations	340	340	340
Number of establishments	29	29	29
AR(1) in first differences:	-1.5217	-1.4985	-1.6050
AR(1) in first differences p-value:	0.1281	0.1340	0.1085
AR(2) in first differences:	-0.06559	-0.08159	0.1184
AR(2) in first differences p-value:	0.9477	0.9350	0.9058
Hansen test of overid. restrictions:	11.587	11.808	4.2078
Hansen test of overid. restrictions p-value:	0.6394	0.6218	0.3786

Robust standard errors in parentheses.

p < 0.1 *, p < 0.05 **, p < 0.01 ***

4.4 Alternative Exercise: Using the Akerberg et al. (2015) Approach to Estimate the First Stage Specification

In this Section, the Akerberg et al. (2015) method is used to estimate the Cobb-Douglas production function in the first stage; while System GMM, to estimate the second stage specification.

While the L-P method is a standard approach in the literature to estimate production functions and, therefore, provides a benchmark against which to compare alternative results, Akerberg et al. (2015) argue that the labor coefficient may not be identified in the L-P method, since this input, in reality, is a state variable (i.e. a variable input whose current choice has an impact on its future cost) and should, therefore, be an argument of the demand function for the proxy variable (i.e. intermediate input's demand function in the L-P approach). According to Akerberg et al. (2015), its inclusion in the demand function for the proxy variable will prevent the labor coefficient to be identified in this method's first stage, but it will definitely be identified in its second stage. However, the first stage of the Akerberg et al. (2015) approach is still important since an estimate of an unknown function that combines the constant of the production function, the coefficient of the state variable, and the inverse of the demand function for the proxy variable (which now considers labor as an argument) is required to approximate the unobserved productivity (Manjón and Mañez, 2016). Once this estimate of the unknown function is obtained in the first stage, then all the parameters of the production function become identified in the second stage.

To perform the analysis, the *acfest* command developed by Manjón and Mañez (2016) is used to estimate the Cobb-Douglas production function in the first stage.³⁵ The syntax of the *acfest* command requires to use the labor input as a free variable, capital and age as state variables, and investment or materials as a proxy for the unobserved productivity

³⁵Regarding this command, Manjón and Mañez (2016) mentions the following: “Yasar et al. (2008) implemented the Olley and Pakes (1996) procedure in Stata, whereas Petrin et al. (2004) did the same for the Levinsohn and Petrin (2003) procedure. However, to date, the proposal of Akerberg et al. (2015) is not available in Stata. In this article, we discuss its implementation as a new e-class command named *acfest*”. Therefore, I follow Manjón and Mañez (2016) to estimate the second stage specification in this alternative exercise.

shocks. In this case, materials, rather than investment, are chosen as a proxy.³⁶ The syntax of the *acfest* command also states that other intermediate inputs (e.g. fuel or electricity) can optionally be included in the estimated specification, additional to that used as the proxy for the unobserved productivity shocks. As in Section 4.1, following Levinsohn and Petrin’s (2003) considerations, electricity has been chosen as an additional intermediate input and included in an alternative specification.³⁷

An important difference that stands out between the L-P method and the Akerberg et al. (2015) approach is that the latter includes age as a state variable in the production function. In order to explain why this occurs I recall what was mentioned in Section 4.1 and that for simplicity I present here:

“First, profit-maximizing establishments decide whether to stay or exit the market based on their productivity level. Second, profit-maximizing establishments decide which input combination to choose and the quantities they will use also based on their productivity level. Hence, $\omega_{i,t}$ induces both a selection and a simultaneity problem, respectively”.

According to Olley and Pakes (1996), in order to control for the selection problem induced by the establishments’ liquidation decisions, an exit rule should be generated. Precursor models to Olley and Pakes (1996) (e.g. Evans, 1987; Hopenhayn and Rogerson, 1993; Ericson and Pakes, 1995) and, consequently, Olley and Pakes (1996) themselves, consider age as a primary component of this exit rule.³⁸ The reason for this is that the probability of exiting an industry decreases with age (Hopenhayn and Rogerson, 1993) and this is consistent with Jovanovic’s (1982) theory of “firm growth in which entrepreneurs learn about their abilities over time” (Evans, 1987) (e.g. they first learn about their productivity levels and, then they decide whether to stay or exit the industry). Therefore, the oldest the establishments, the lower the probability of exiting and, consequently, the selection problem starts fading

³⁶When choosing among materials and investment as a proxy in this alternative exercise, I followed Section 4.1 that states that the monotonicity condition only holds for positive observations of intermediate inputs. Since firms only make intermittent investments (which is reflected in positive and zero-investment observations), the probability of finding more zeros in the investment data than in the materials data is higher and, therefore, I have decided to use materials as a proxy.

³⁷For more details on this command see Manjón and Mañez (2016)).

³⁸Evans (1987) examines the relationship between firms’ dynamics and firms’ age, while Hopenhayn and Rogerson (1993), and Ericson and Pakes (1995) develop models of uncertainty and entry and exit.

away. This explains why age has been included in the production function of this alternative exercise.

Table 11 shows the first stage results using the Akerberg et al. (2015) method. These estimated coefficients are then used to obtain two TFP measures as residuals: TFP_{ACF1} and TFP_{ACF2} (note that a different number of regressors are used to derive them).

Table 11: First Stage: Estimation of a Cobb-Douglas Production Function
(Akerberg-Caves-Frazer (ACF) Method)

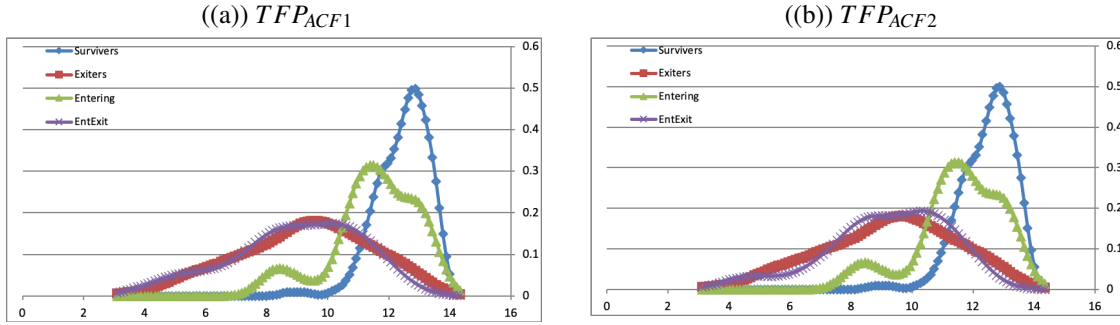
	Dependent Variable: Value of Production	
	(1)	(2)
Independent Variables:		
Free Variable: Labor	0.02195 (0.1209)	0.04122 (0.0939)
State Variable: Capital	-0.007507 (0.0265)	-0.0008001 (0.0228)
State Variable: Age	0.002009 (883.5287)	0.001413 (549.2102)
Proxy for unobserved productivity shocks: Materials	0.9974*** (0.0895)	0.9839*** (0.0786)
Additional Intermediate Input: Electricity		-0.004550 (0.0474)
Observations	310	310
Sargan Test: p-value	0.5887	0.4370
Wald Test: p-value	1	1
Productivity Measure Obtained as a Residual	TFP_{ACF1}	TFP_{ACF2}

Notes: Robust standard errors in parentheses.

*** $p < .01$, ** $p < .05$, * $p < .1$.

Figure 6 presents some histograms of the estimated TFP measures (i.e. TFP_{ACF1} and TFP_{ACF2}) by groups of establishments. Compared to Figure 5 in Section 4.3 that uses the L-P approach, we can see that both charts lead to similar results: the survivors' group (diamond line) is the most productive, while the exiters' group (square line) and the entexit's group (circle line), are the least productive. Therefore, while the L-P and the Akerberg et al. (2015) methodologies differ as was explained before, the estimated TFP measures are comparable.

Figure 6: Histograms of the Estimated TFP Measures by Groups of Establishments (ACF Method)



Note: This figure was constructed by the author with data on the Mexican automobile industry.
Source: INEGI's Annual Manufacturing Survey.

As in Section 4.3, the second stage estimation is conducted by System GMM. Tables 12 and 13 present the results of the second stage estimation using tariffs and exports as trade openness measures, respectively.

The findings in these Tables show the following. First, all the estimated regressions in Table 12 pass the specification tests, except for specification (3) where TFP_{ACF2} is the dependent variable. In general, it can be seen that with the Akerberg et al. (2015) method it is harder to find a positive association between trade (measured by a reduction of tariffs on imported vehicles) and productivity. Only columns identified as (1) show this positive correlation and, even if significant, an order of magnitude smaller than the L-P estimate (e.g. in column 1 where TFP_{ACF1} is the dependent variable, the estimated coefficient on the interaction term between the tariff and the medium size category (-0.0705) implies that a reduction of one standard deviation in tariffs on imported vehicles would lead to an increase of 0.23 percentage points in the medium size establishments' total factor productivity).

Table 13 also shows that all the estimated regressions pass the specification tests, except for model (2) where TFP_{ACF2} is the dependent variable. The main findings in this Table suggest that there is a positive and a statistically significant association between exports and TFP. In particular, specification (1) with TFP_{ACF1} as a dependent variable shows that the estimated exports' coefficient is positive and statistically significant (0.5642). It implies that an increase of one standard deviation in exports results in an improvement of 0.2085 percentage

points in the industry's TFP.

Overall, a common finding in Sections 4.3 (where the first stage analysis is conducted using the L-P method) and 4.4 (where the first stage analysis is conducted using the Akerberg et al. (2015) approach) is the following: medium size establishments' TFP seem to be positively associated with trade liberalization, measured by a reduction of tariffs on imported vehicles, though the results are sensitive to the regressors used. In addition, no association between trade openness and productivity is found in the case of small and large establishments.

The results from Sections 4.3 and 4.4 differ in the sense that exports, proxied by the ratio of sales to the foreign market to the value of production (this variable varies across time and establishments) are not associated with TFP in Section 4.3, but they are in Section 4.4. This latter finding suggests that trade liberalization under NAFTA, measured by exports, is positively correlated with TFP.

Table 12: Second Stage: Estimation of the Impact of NAFTA on the MAI's TFP
Trade Variable: Tariff
(System GMM Approach)

	Dependent Variable					
	TFP_{ACF1}			TFP_{ACF2}		
	(1)	(2)	(3)	(1)	(2)	(3)
Independent Variables:						
Lagged TFP_{ACF1}	0.8338*** (0.1062)	0.8180*** (0.1113)	0.7701*** (0.1692)			
Lagged TFP_{ACF2}				0.8147*** (0.1341)	0.8573*** (0.1252)	0.7515*** (0.1495)
Tariff	0.0427 (0.0261)	0.0136 (0.0296)	-0.0231 (0.0434)	0.0351 (0.0285)	0.0125 (0.0283)	-0.0332 (0.0416)
Dummy Small	-0.3903 (0.4769)	-2.6631 (1.7789)	7.9690 (10.6747)	-0.5954 (0.4651)	-2.8414 (1.9428)	6.5172 (9.7561)
Dummy Medium	-0.0557 (0.1080)	-2.8025 (2.0357)	2.1025 (9.3674)	-0.0811 (0.1044)	-2.5103 (1.9144)	1.6194 (8.4147)
Tariff*Dummy Small	-0.0922 (0.0558)	-0.0398 (0.0753)	-0.0154 (0.1177)	-0.0736 (0.0723)	-0.0133 (0.0905)	-0.0326 (0.1112)
Tariff*Dummy Medium	-0.0705*** (0.0243)	-0.0103 (0.0407)	-0.0109 (0.0405)	-0.0784*** (0.0280)	-0.0094 (0.0328)	-0.0029 (0.0388)
Lagged Technological Adoption	1.0229 (2.0910)	1.3763 (1.7901)	0.6763 (2.6111)	1.8200 (2.0992)	1.7543 (1.9410)	0.0749 (2.3333)
Age	0.0021 (0.1454)	-0.0148 (0.1462)	-0.1161 (0.2380)	-0.0603 (0.1571)	-0.0270 (0.1516)	-0.1952 (0.2377)
Exchange Rate	0.5321 (0.4222)	0.0846 (0.4982)	-0.1156 (0.7014)	0.6225 (0.4438)	0.1385 (0.5155)	0.0418 (0.6776)
Exchange Rate*Dummy Small		0.8805 (0.7575)	1.1782 (1.1052)		0.9832 (0.8793)	1.0260 (1.0407)
Exchange Rate*Dummy Medium		1.1061 (0.8170)	1.0678 (1.0197)		0.9934 (0.7707)	1.0764 (0.9415)
HHI	-1.0893** (0.4645)	-1.0901** (0.4843)	-0.6632 (0.6036)	-1.1240* (0.6017)	-1.0813* (0.5615)	-0.7511 (0.6151)
HHI*Dummy Small			-1.6301 (1.3390)	8.9733 (5.7233)		-1.3786 (1.2551)
HHI*Dummy Medium			-0.6640 (1.2690)			-0.6056 (1.1670)
Constant	8.5556** (3.6177)	9.9139** (4.4663)	8.2290 (6.0492)		9.2510* (5.2769)	8.9377 (5.8944)
Observations	341	341	341	340	340	340
Number of establishments	30	30	30	29	29	29
AR(1) in first differences:	-1.9936	-1.9295	-1.6998	-1.9082	-1.9827	-1.7101
AR(1) in first differences p-value:	0.04620	0.05367	0.08917	0.05636	0.04740	0.08726
AR(2) in first differences:	0.2080	0.1207	0.3612	0.1164	-0.01135	0.4376
AR(2) in first differences p-value:	0.8352	0.9039	0.7180	0.9073	0.9909	0.6617
Hansen test of overid. restrictions:	17.234	15.956	10.248	16.835	16.006	8.1639
Hansen test of overid. restrictions p-value:	0.5071	0.4561	0.1146	0.7724	0.8879	0.08575

Note: Robust standard errors in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 13: Second Stage: Estimation of the Impact of NAFTA on the MAI's TFP
Trade Variable: Exports
(System GMM Approach)

	Dependent Variables					
	TFP_{ACF1}			TFP_{ACF2}		
	(1)	(2)	(3)	(1)	(2)	(3)
Independent Variables:						
Lagged TFP_{ACF1}	0.7395*** (0.1702)	0.7305*** (0.1939)	0.7617*** (0.2013)			
Lagged TFP_{ACF2}				0.7337*** (0.1705)	0.7067*** (0.1957)	0.6594*** (0.2069)
Exports	0.5642*** (0.1492)	0.7131*** (0.2539)	0.6983** (0.2551)	0.5660*** (0.1479)	0.6656** (0.2553)	0.7346*** (0.2118)
Dummy Small	-0.9711 (0.8618)	-3.3111 (2.3714)	10.5166 (8.1663)	-0.9966 (0.8537)	-3.8034 (3.2631)	-8.1286 (22.0838)
Dummy Medium	-0.2311 (0.2749)	-2.9537 (1.8709)	6.9143 (10.5043)	-0.2358 (0.2750)	-2.7615 (1.8799)	-16.5187 (47.4226)
Exports*Dummy Small	0.5655 (1.2522)	0.2023 (1.1796)	0.1845 (1.2867)	0.5589 (1.2089)	0.3138 (1.1121)	0.4095 (1.2133)
Exports*Dummy Medium	0.1245 (0.2825)	0.1115 (0.3185)	0.0266 (0.3073)	0.1218 (0.2791)	0.1203 (0.2931)	0.1891 (0.3702)
Lagged Technological Adoption	0.3852 (5.7969)	1.6125 (4.8017)	1.0936 (5.6211)	0.3030 (5.6872)	0.3613 (4.7825)	-0.0384 (6.2237)
Age	-0.1656 (0.1262)	-0.0091 (0.1456)	-0.0002 (0.1465)	-0.1951 (0.1332)	-0.1081 (0.1660)	-0.0356 (0.1558)
Exchange Rate	0.7783 (0.6481)	-0.1942 (0.6455)	-0.1387 (0.6548)	0.8843 (0.6895)	0.2115 (0.7156)	-0.3595 (0.6439)
Exchange Rate*Dummy Small		1.1134 (0.8362)	0.9012 (0.8355)		1.2532 (1.1774)	1.5766 (1.3865)
Exchange Rate*Dummy Medium		1.1543 (0.8022)	0.9517 (0.7341)		1.0646 (0.8116)	1.9528 (1.2874)
HHI	-1.3994*** (0.4280)	-1.0859** (0.5006)	-0.2106 (0.6254)	-1.4225*** (0.4255)	-1.1062** (0.4866)	-1.7854 (2.5915)
HHI*Dummy Small			-1.8624 (1.1919)			0.4968 (2.6846)
HHI*Dummy Medium			-1.3104 (1.4397)			1.6308 (6.2608)
Constant	11.4162*** (3.6173)	11.1211** (4.4353)	4.3771 (5.6938)	11.4771*** (3.5488)	10.9036** (4.5319)	17.4342 (21.2729)
Observations	341	341	341	340	340	340
Number of establishments	30	30	30	29	29	29
AR(1) in first differences:	-1.9060	-1.8328	-1.8899	-1.8882	-1.8990	-1.7909
AR(1) in first differences p-value:	0.05665	0.06683	0.05877	0.05900	0.05757	0.07332
AR(2) in first differences:	0.4997	0.3733	0.4710	0.5117	0.4758	0.1872
AR(2) in first differences p-value:	0.6173	0.7089	0.6376	0.6089	0.6342	0.8515
Hansen test of overid. restrictions:	4.3148	13.104	12.773	4.1383	10.822	16.824
Hansen test of overid. restrictions p-value:	0.1156	0.1083	0.1199	0.1263	0.09404	0.3970

Note: Robust standard errors in parentheses. *** $p < .01$, ** $p < .05$, * $p < .1$.

5 Conclusions

This paper studies the impact of NAFTA on the total factor productivity of establishments in the MAI over the period 1994-2014.

The empirical analysis is conducted in two stages. In the first stage, a Cobb-Douglas production function is estimated by the Levinsohn and Petrin (2003) approach in order to control for potential simultaneity and selection problems. A TFP measure is then obtained as a residual and, in a second stage, regressed by System GMM on trade openness variables (e.g. tariffs on imported vehicles or exports), on a measure of technological adoption, on establishments' characteristics, on the real exchange rate, on the HHI, and on some interaction terms between the tariff, the real exchange rate, and the HHI with size dummies. The main results show that there seems to be a positive association between trade liberalization under NAFTA (measured by a reduction of tariffs on imported vehicles) and medium size establishments' TFP. No association between trade and productivity is found in the case of small and large establishments. As regards the impact of exports on the MAI's TFP, the findings are not statistically significant.

The results on the positive association between trade liberalization under NAFTA (proxied by a reduction of tariffs on imported vehicles) and productivity for just medium size establishments are consistent with the theoretical and empirical models of Bustos (2011) and Lileeva and Trefler (2010), which are extensions of the standard Melitz's (2003) model of firm heterogeneity.

In an alternative exercise, this paper uses the Akerberg et al. (2015) approach to estimate the first stage specification and, therefore, to obtain a TFP measure as a residual; while System GMM, to estimate the second stage specification, as before. In this case, the findings on the positive association between exports and the MAI's TFP are robust, but not those on the correlation between tariffs and the MAI's TFP.

Overall, while the results present some evidence of a positive association between trade liberalization and TFP in establishments of a particular size, they are sensitive to the TFP estimation method, the variables used to proxy trade openness, and the extra controls included.

Hence, proving the trade-productivity link for the MAI's case remains a challenge.

This paper improves on previous studies in that it controls for both the simultaneity and selection problems in the first stage specification and, for the correlation between the lagged dependent variable and the error term and the endogeneity problems in the second stage specification. However, there still remain some important limitations that could be important avenues of improvement in future work. First, we cannot implement De Loecker's (2011) suggestion of introducing a demand system into the production function framework in order to purge the productivity response to trade liberalization from price and demand variation, since it requires detailed information on input usage, number of products produced, the products produced, segment of the industry in which the firm is active, etc., and this type of data is not publicly available due to INEGI's confidentiality reasons. Second, the effect of intermediate inputs tariffs on productivity cannot be analyzed in this paper since tariffs on auto-parts and accessories were 9 percent in 1993 and 0 percent from 1994 onward, which makes it very challenging to provide compelling evidence on this link.

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