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Global Manufacturing Production: An Analysis and Determinants for Mexico's Trade in Value-Added

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Abstract Mexico's participation in the global manufacturing production began with the in-bond or *maquiladora* industry in the mid-60s. Since then, the manufacturing industry has positioned itself in the Global Value Chains (GVCs). However, the analysis of foreign trade in global manufacturing production requires a different measurement that accounts for trade in value-added. In this article, we examine the global manufacturing production as well as the determining factors of trade in value-added for the 2003-2018 period. This analysis becomes relevant for designing an industrial policy focused on improving Mexico's participation in the creation of added value linked to GVC. We corroborate the significance of the U.S. industrial activity as a determinant of the trade in value-added. The Mexican industrial activity becomes a significant determinant as well as the gross fixed capital formation. However, we found that traditional variables, such as foreign direct investment, are not significant. These results led us to believe that more efforts in constructing a theoretical framework are needed to explain the trade in value-added.

Keywords: Trade in Value-Added, GVCs, Mexico, GMM, Exports

JEL Classification: C33, F14, F15

1. Introduction

The emergence of global manufacturing production since the 1970s meant a shift in the understanding of how countries trade. Firms engaged in a high complexity of network structures for the global production of intermediate and final goods. Production processes crossed borders resulting in a link of horizontal, vertical, or diagonal integration (Jones et al., 2019), and as a result, Global Value Chains (GVCs) production transformed international trade. Likewise, the growth of GVCs production required a different measurement of trade flows. The existing empirical literature shows that using gross exports to measure a country's involvement in world trade has led to the double-counting of international trade flows and an overestimation of countries' participation in global network production (Borin & Mancini, 2015; De Backer & Yamano, 2012). Hence, a better approach is to measure trade in value-added. In this field, progress has been made with the estimation of trade accounts using Input-Output (IO) tables and international trade accounts (Johnson and Noguera, 2017, 2012; Foster-McGregor & Stehrer, 2013; Andrew & Peters, 2013; Daudin et al., 2011). Nevertheless, the same attention has not been given to the estimation of the determinants of this type of trade (Olczyk and Kordalska, 2017).

Mexico has been an early participant in global manufacturing production as a result of the in-bond or *maquiladora* industry in the northern border. However, with the North American Free Trade Agreement (NAFTA), the industry's gradual transformation occurred, giving rise to manufacturing sectors where more complex production processes were linked to GVCs[1]. The external sector is essential for Mexican economic growth since 43.7 percent of total gross production is based on export activities (Davila and Valdez, 2018). Therefore, quantifying Mexico's participation in the global manufacturing production cannot be based on gross flow but on the trade in value-added accounts. There are numerous estimates at the aggregate level and by sectors of the economy. However, when it comes to this trade's determinants, there is a lack of empirical studies. Thus, we examine the main characteristics of global manufacturing production and determinants of the Mexican manufacturing industry's value-added trade for the 2003-2018 period. We sought to determine whether the theoretical frameworks that explain the traditional trade pattern have the same explanatory power when it comes to value-added trade.

Furthermore, this paper aims to fill a gap in the empirical literature of quantifying manufacturing exports, which have always been measured at the gross level without considering the increasing presence of GVCs in their production. In this way, it contributes to verifying the participation of trade flows in the new context of global manufacturing production. The examination of global manufacturing production reveals product concentration in a few branches with a high degree of technological sophistication. At the same time, other branches show a low share with low technological content. Along with the global manufacturing production's main characteristics, we estimated a dynamic data panel using the Generalized Method of Moments (GMM) system approach with a three-digit disaggregation by industrial branches according to the North American Industry Classification System (NAICS) for the 2003-2018 period. The estimation includes an external demand variable, such as U.S. industrial activity, because of the significance of that market for global manufacturing products. A relative price variable is included as the real effective exchange rate to determine whether exchange rate policies remain equally effective for value-added trade. In addition to these variables, tariff barriers, domestic industrial production, employment in global manufacturing production, and physical capital are considered.

This research is organized as follows: the second section proceeds with the empirical literature regarding the measurement of trade in value-added, which served as the necessary background for the econometric specification of its determinants for the Mexican manufacturing industry. The third section examines Mexico's participation in the GVC's starting in the 1980s, highlighting the maquiladora industry's contribution and the external manufacturing sector. In the same section, we provide an overview of the Mexican global manufacturing production's main characteristics for the 2003-2018 period. The fourth section describes the methodology and the description of the variables. The fifth section shows the econometric model and the results, and the last section offers a summary, conclusions, and suggests areas for future research.

2. Literature review

Global manufacturing production has required developing new methodologies for measuring trade flows derived from global production chains. The use of IO tables, combined with bilateral trade flows, has shown the direction and destination of imported inputs for the production of exported goods, as well as the use of domestic inputs[2]. The most cited example has been the case of China's trade flows (Koopman et al., 2008; Kee & Tang, 2016; Meng et al., 2017), which has attracted much attention towards demonstrating the need to redefine countries' positions in global manufacturing production.

Accurate measurement of international trade has numerous implications for trade policy. However, in this paper, we focus on the three related to the trade in value-added. The first is the growing divergence between gross and value-added accounts. Deficits or surplusses in the balance of payment accounts should be adjusted by considering the origin of intermediate inputs in final products to be exported. Nagengast and Stehrer (2015) argue that trade in value-added is a better approach since bilateral trade cannot be measured only by the flows between two partners since a third country often influences a significant portion of their trade. Second, the relationship between income and international trade flows is also affected when trade in value-added is counted. Al-Hashimi et al. (2015) estimate that external shocks may be more dangerous for trade in value-added since this trade is concentrated in durable goods sectors whose income elasticity is higher. Therefore, economies in which the manufacturing industry is heterogeneous and concentrated (as is the case of Mexican manufacturing) may be adversely affected unless trade policy measures are applied to level out the effects of adverse demand shocks[3]. Third, the measurement of trade in value-added leads to the detection of technological development levels in which a country is linked to the global production chain. As stated by Lejour et al. (2017), the higher the integration to supply value chains, the higher the technological content in that sector. The authors argue that Latin American countries have the problem of concentrating their production on natural resources. Hence, it is more difficult to climb to higher levels of technological content. Mexico and Brazil are the exceptions due to their significant participation in the export of manufacturing goods. Even when countries in Latin America have more comparative advantages in exporting commodities, it can be favorable and desirable to find domestic services linked to global production that increases value-added. Indeed, Dean (2013) suggests that knowing the contribution of value-added by developing countries helped diversify productive activities into goods that were not considered before and increase trade potential (Dean, 2013).

Empirical evidence about the measurement of value-added based on IO tables is extensive at the macro level; here, we list those focused on using IO tables for the estimation of trade in value-added[4]. For instance, some works discuss this at a multilateral level (Johnson & Noguera, 2017; Foster-McGregor & Stehrer, 2013; Andrew & Peters, 2013; Daudin et al., 2011). Their trade in value-added measures the primary objective of comparing countries' performance regarding their international trade participation. Some studies focused on individual countries (Meng et al., 2017; Tham & Kam, 2017; Borin & Mancini, 2015; Dean, 2013; Ricotta, 2009; Koopman et al., 2008) with the notion of contrasting if trade account imbalances are due to a high incidence of foreign intermediate inputs in export production. There is also an interest in how regions can benefit from participation in GVCs for their trade in value-added (Lejour et al., 2017; Kaplan et al., 2016; Durán & Zaclicever, 2013), in particular for developing countries. Likewise, trade in value-added is more intensive in specific manufacturing sectors (Chen, 2016; Timmer et al., 2015; Abe, 2013) such as the automotive or the electronics industry, where international fragmentation of production has been globalized for decades.

Regarding the empirical evidence for Mexico, some early works highlight the need to adjust trade accounts due to *maquiladora* trade flows in the total exports. For example, De la Cruz et al. (2011) use Koopman et al. 's (2008) methodology to estimate indicators by differentiating the *maquiladora* manufacturing from total exports for 2000, 2003, and 2006. The indicators are compared with multilateral studies where Mexico is included, and they find that value-added content is lower than what has been reported in previous studies. Fujii and Cervantes (2017) also followed the methodology by Koopman et al. to examine the influence of *maquiladora* flows on trade in value-added. They argued that Mexico's insertion into regional GVCs such as NAFTA has not been beneficial regarding high technological content. A deeper disaggregation reveals that most value chains' activities remain a part of those related to the medium or low technological sophistication levels. Castillo and de Vries (2017) followed the approach from Los et al. (2015) to calculate the *maquiladora*'s domestic content. Their results revealed a decrease in domestic value-added share in aggregate *maquiladora* exports from 27 percent in 1981 to 13 percent in 2006. According to these authors, one of the causes of the decline has been Mexico's participation in NAFTA.

Flatness and Rasmussen (2017) use OECD TiVA databases to estimate NAFTA's adverse effects on the U.S. economy for the 1995-2011 period. However, their work does not differentiate the in-bond industry. The authors' estimations indicate a reduction of U.S. products in Mexico's imports, and a similar trend is found for trade with its third partner, Canada. Despite this, the authors find that results are not adverse in some industrial sectors. For instance, in the automotive industry, the trend is somewhat positive and growing. Blecker et al. (2017) argue that an increase in origin rules would be counterproductive for the NAFTA region because of trade diversion, particularly for the automotive industry, which requires a high percentage of imported content. Still, the recent renegotiation of NAFTA, now called the United States Mexico Canada Agreement (USMCA), requires an increase in the regional content, from 62.5 percent to 75 percent[5]. According to Rioux et al. (2015) and Barajas (2019), instead of reinforcing regional content, a better approach would be to link to the Transpacific Trade Partnership (TPP) to gain from the already established GVCs in the region. The Bank of Mexico (2017) uses a different database, WIOD, to estimate trade in value-added to the U.S. and Mexico. Their results confirmed Flatness and Rasmussen's findings of an increase in the value-added for Mexican exports. Nonetheless, it is more evident for a few sectors, such as the electronics and automotive industries.

When analyzing the effects of NAFTA on the U.S. economy, technological change and China's participation in world trade since 2001 are two elements that are not always considered. Rioux et al. (2015) analyze the influence that trade with China has had in the NAFTA region. For instance, Mexico was the primary source of Information and Communication Technologies (ICT) products for the U.S. in 2001. Ten years later, bilateral trade flows in this industry fell by 50 percent due to increased ICT imports from China (Rioux et al., 2015). The ICT industry is an example of a setting in which Mexico has developed links to GVCs. However, Mexico's comparative advantage has shrunk due to the presence of China in this sector. Chiquiar and Tobal (2019) share the conclusion that China's presence in the WTO meant significant competition for Mexican products in the U.S. market. The authors examine Mexico's participation in the GVCs and identify three periods: the years from 1994 to 2001 showed significant growth due to NAFTA; from 2001-2005, a reduction in participation due to the presence of China; and 2006-2017, a recovery period due to the performance of the automotive industry.

Also, when seeking value-added exports at a high technological level, we should consider the beneficial component of spillovers to the rest of the economy. For instance, Laguna (2010) identifies clusters for Mexican manufacturing using the principal components approach. According to his results, auto parts, electronics, textiles, or paper products should receive particular attention from industrial policy, given that these branches are most linked to the rest of the production system and have the most potential for economic spillovers. Laguna (2010) does not differentiate between high and low technology. It would then be necessary to analyze what the trade-off would be in an industrial policy that attempts to integrate the most complex links of a CVG since Mexico is a small country with high import elasticities.

In sum, studies on trade in value-added for Mexican manufacturing have followed the pattern of previous empirical evidence in which the aim was to adjust international trade accounts, allowing for a high component of imported inputs into the production of exportables. None of these studies analyze the critical determinants of value-added trade. This study attempts to fill this gap in the empirical literature.

3. Mexico's Participation in Global Manufacturing Production

In the mid-1960s, Mexico followed the international production-sharing model, known as *offshore production*, taking advantage of industrial relocation processes of production fragmentation to Mexico from the U.S and Asia (Barajas, 2015). Two policy tools began this change for the Mexican industrial development: on the one hand, the in-bond industry preferential tariff regime and, on the other hand, less-regulated Foreign Direct Investment (FDI) laws[6]. Since the beginning of the production sharing process, these two policies allowed the relocation to Mexico of U.S. firms and Asian firms, mainly from Japan and Korea (Davis, 1985; Rioux et al., 2015; Barajas, 2015).

In 1994, Mexico, the U.S., and Canada signed the North American Free Trade Agreement (NAFTA), which consolidated the Mexican industrialization process based on exports. Production sharing platforms gained a particular drive, generating a more significant deepening of Mexico and the U.S.'s economic integration, which can be attributed to trade and investment (De Long, 2017). Before the signing of NAFTA, GVCs were already strengthening, as in the case of auto parts, automotive and electronics, where multinational corporations, subsidiaries, and suppliers participate in complex inter-and intra-firm relations of diverse capital origin, as well as in comprehensive inter-and intra-industrial governance (Dicken, 2011; Gereffi et al., 2005; Johnson, 2014).

Since its inception, Mexico's participation in these export platforms has focused mainly on producing intermediate goods and final consumer goods through the assembly or manufacturing processes. In the 2000s, high-technology manufacturing processes began to increase as a result of the expansion of the automobile, telecommunication, and medical equipment firms, among others. However, the process of regional integration was not smooth; according to Dussel (2018), under NAFTA, intra-regional trade grew significantly but also showed periods of slowdown, which is known as an integration/disintegration process. For instance, after steady growth in the intra-regional trade for the 1990-2000 period (from 38 to 46%), the participation fell to 40 percent in recent years. According to Chiquiar and Tobal (2019), Mexico reduced participation in the GVCs seems to be explained by China's entry into the WTO in 2001.

Under the *maquiladora* industry regime, international and multinational firms operated under a *cost* and not *profit* structure, so the value-added accounted for in Mexico was reduced to the company's total operating cost. The main cost components are labor, operations, and domestic inputs costs. The calculation of these costs became more difficult as the activities of these companies became more complex. Alongside this, their operating regime changed; therefore, calculating trade in value-added also became more difficult (Barajas, 2015; Rioux et al., 2015). Data on the *maquiladora* industry were available at a disaggregated level from 1975 until 2006. After 2006 it became more challenging to differentiate value-added by firms because the *IMMEX* program replaced the maquiladora regime[7]. In this scenario, it has become more difficult for empirical scholars to distinguish the maquiladora industry accounts and monitor their performance in the long term.

As mentioned earlier, the quantification of trade in value-added has been based on the IO tables. International databases, such as GTAP, TiVA, or WIOD, have included Mexico as one of the participating countries linked to the GVCs. For the determination of added value, two empirical frameworks are mainly followed: Hummels et al. (2001) and Koopman et al. (2011). A few studies quantify the domestic content for the maquiladora industry, as is the case of Castillo and de Vries (2017), who only estimate the percentages for that industry and not the total manufacture. The studies that based their calculations on INEGI's database relate to the 2003 IO table as the reference year to carry out their final estimation. In some cases, the estimate was at three- and four-digit disaggregation for the manufacturing industry (i.e., De la Cruz et al., 2011). It would be difficult to compare the different calculations due to the different estimation methodologies; however, results concurred that the Mexican industry had increased the trade in value-added. However, a variable that shows Mexico's participation in global manufacturing production should consider only trade flows from companies engaged in this type of production and include foreign capital participation as conditions to calculate trade in value-added.

Considering the previous empirical evidence, we propose an alternative indicator for quantifying Mexico's participation in global manufacturing production. To this end, we suggest using the value-added variable of exports created by the Mexican Institute of Statistics and Geography (INEGI, Spanish acronym) for the advantages it shows in comparison with other quantifications. While international databases, although based on IO tables, focus on the imported content of exports, INEGI adds two more qualifications - only export firms and a high presence of foreign capital - to be considered part of the global manufacturing production. The data is also disaggregated to three and four digits of the North American Industrial Classification System (NAICS) for all economic sectors. Although INEGI's database does not include data by partners, it should be noted that the United States is the most important trade partner for Mexico in terms of its exports since more than 70 percent is sent to the U.S. market.

According to INEGI's methodology, the Value-Added Global Manufacturing Exports (VAGME) represents the manufacturing industry's domestic contents that participate in the GVCs. It identifies the components of the Mexican manufacturing industry immersed in global production. Furthermore, it includes economic activities that highlight the sequences of the connected production processes distributed in more than one country, depending on the production arrangements. In this process, imported raw materials are transformed into a product with a higher value that will serve as input in a different country (INEGI, 2018).

There are three main criteria or conditions to get to the final VAGME variable. First, there is a selection of export firms whose inputs come mainly from abroad (2/3 parts of inputs as a minimum proportion of their exports). Second, there is an identification of the firms with the most foreign capital (controlled by foreign parent companies and parts of GVCs). For the last stage, there is a classification of exporting firms (not considered in the two previous points) by the type of products they are exporting, where the intermediate goods are defined as part of the global value. The data from trade databases (Harmonized System) has to be matched to the industrial classification (NAICS) using correspondence tables. The variable obtained after using these criteria specified by INEGI offers the advantage of considering foreign capital participation in production for export and isolates companies whose imported inputs are a significant part of the external output.

Study the main characteristics of the global manufacturing production for Mexico for the 2003-2018 period allows us to know more about the performance of the VAGME and its significance in the global manufacturing output. Figure 1 shows the composition of global manufacturing production in 2018. As can be seen, there is a high share of a few branches that have been traditionally significant in developing the external manufacturing sector.

Figure 1 shows that in 2003, three industrial sectors (331: Primary Metals Construction, 334: Computer and Electronic Product Manufacturing, and 336: Transportation Equipment Manufacturing) accounted for 63 percent of the total global manufacturing production. By 2018, their participation increased to 69 percent. The most significant increase was in sector 336, which alone accounts for 40 percent of the total global manufacturing production. After a more in-depth look at branch 336, we found the automotive industry and the automotive industry's parts and components production as the sector's main factors. The Mexican automotive industry has been extensively studied for the economic impacts on the rest of the economy (Unger, 1991; Sosa, 2005; Carbajal et al., 2016). It has also been the sector in which the rules of origin were discussed widely in the last 2018 NAFTA negotiations. Therefore, any trade policy recommendations regarding global manufacturing production cannot be made without considering the automotive industry's role for the rest of the economy. Nevertheless, if we compare this structure with total manufacturing production, the concentration decreases. In 2018, branch 336 shared total output was 32 percent, while branch 331 was 7 percent. The food industry (311) had a significant 14 percent share for the same year. Our estimations seem to confirm a higher industrial concentration and heterogeneity for the activities linked to global manufacturing production.

Table 1 shows a summary of additional indicators for three periods: 2003-2007 (before the recession), 2008-2009 (during the recession), and 2010-2018 (after the recession). More than 70 percent of Mexican exports are sent to the U.S. market; therefore, the downturn initiated in that country impacted the Mexican external sector. If we take the 2003-2007 period as a reference, rises are highlighted in green or light green and drops in orange and light orange. Table 1 highlights several of the characteristics of global manufacturing production. For example, global manufacturing production constitutes about 38 percent of the total manufacturing production; this percentage has remained constant and only increased slightly after the recession. The manufacturing production growth rate of almost 7 percent recovered after a significant fall during the recession (-15 percent); however, the growth rate has not reached the level of the period previous to the falloff.

Although VAGME represents around 50 percent of the total global manufacturing for 2018, its share falls to 12 percent for the same year compared to the overall manufacturing production. However, percentages are higher for the most representative industrial sectors (331, 334, and 336). Table 2 shows that only the VAGME's share for the transport industry (336) has a significant increase from the 2003-2007 period, while the other two sectors have decreased after the recession. Indeed, the recession hit hard the electronics products, since this is a consumer product. The relocation of foreign firms could explain it since they need to find a cheaper location for their production stages.

Regarding the number of jobs, global manufacturing production only accounts for 33 percent of total manufacturing in 2018 and has grown slightly since 2003 (28 percent). When the percentages are disaggregated at the level of the industrial sectors, the outlook changes. In the 2003-2007 period, the number of jobs in the electronics sector (334) of global manufacturing production was 81 percent of the total manufacturing production. That is, most of the jobs in this sector are linked to global manufacturing production. Even though its share decreased to 63 percent by the 2010-2018 period, it is still significant. The other two sectors (331 and 336) have instead increased the percentages during the period studied; particularly, the transportation industry, which accounts for 78 percent of jobs in the last period.

One of the characteristics of global manufacturing production is its low domestic content. Table 1 shows that the percentage of local inputs used in global manufacturing production has been steadily at around 22 percent for the period studied, slightly increasing after the recession. There are differences between the three sectors worth mentioning. While sector 331 shows higher participation than the total (more than double), it decreases slightly in the next two periods. This behavior is different for sector 336, which in the 2003-2007 period, shows a similar share to that of the manufacturing aggregate. It increases in the following two periods; its share thus grew more than 10 points. The electronics industry (334) has traditionally had low domestic content, as seen in the 13 percent share before the recession. This participation is reduced in the following two periods significantly.

In sum, global manufacturing production has a significant share in total manufacturing, which has continued despite the recession. This type of production is mainly concentrated in three sectors that determine the overall average, which reveals a structural heterogeneity in the manufacturing industry that has not changed since promoting export production. This industrial structure is not far from the non-global industry, but with a lesser degree of concentration. Concerning participation in international trade, the VAGME represents a high percentage of global manufacturing production, almost 50 percent during the last period. However, it still does not reach a significant percentage compared to total manufacturing production (12 percent). This distinction is worth noting since gross manufacturing export data does not accurately measure Mexico's international trade participation under the new global manufacturing production framework. We argue that to study and evaluate the external manufacturing sector's performance, we should shift from the analysis of gross exports to the trade in value-added. Hence, an examination of global manufacturing production and the VAGME reveals to what extent Mexico participates in global production chains. Furthermore, identifying the determinants of this trade is necessary for industrial and trade policy strategies that seek to increase the role of Mexican exports in GVCs that have a more significant content of technological knowledge. With this purpose in mind, we focus on the value-added global manufacturing trade to empirically estimate the determinants. In the following section, we explain the methodology and variables to be estimated.

4. The Model

As mentioned earlier, empirical studies of value-added trade are extensive in terms of measurement. There are existing surveys, such as Johnson and Noguera (2017), that cover forty years of quantitative studies and value-added trade analysis. Chiquiar and Tobal (2019) do the same for the Mexican economy. However, when analyzing the determinants of this trade, the empirical literature is scarce since the sample of data for the value-added trade variable was insufficient.

Several common characteristics emerge from the literature review. For example, the main objective of analyzing the determinants is to know if the gross export theoretical framework is useful in explaining the trade in value-added. If this were not the case, then a series of different trade policies would be necessary, rather than those that only promote gross exports. For instance, studies based on the gravitational model, such as Johnson and Noguera (2017), use the gravitational structural model to examine how the trade frictions, the role of distance, and regional agreements explain the changes in the value-added ratio. Choi (2013) integrates the Ricardian and HO models into the gravitational model to test which model best describes bilateral trade in value-added. The authors find that the three models are significant; however, the power of explanation depends on the sample period. Criticisms of gravitation models as explanatory of trade in value-added come from Olczyk and Kordalska (2017), who consider that traditional models such as gravitational models include very few factors that affect this kind of exports. Instead, they follow Landesmann et al. (2015) methodology that includes the traditional variables and explanatory variables from the new trade theory. As can be seen, it was not a measurement problem, but rather a search for a theoretical framework that included the factors of global production segmentation.

Other analyses focus on specific explanatory variables rather than looking for the factors that affect trade in value-added. Lommatzsch et al. (2016) analyze how a country's external competitiveness affects this trade; therefore, they focus on relative prices as the real effective exchange rate (REER). They distinguish the European Union (EU) economies between developed and emerging economies. They argue that the REER variable needs to be modified to a value-added REER as the trade's explanatory variable. Their results are compared with a traditional model and find a significant difference in the relative price variables' explanatory power when it comes to trade in value-added. Caraballo and Jiang (2016) explore the factors that affect the erosion of value-added exports. They follow a semi-parametric approach and verify that the primary determinant of the erosion depends on the raised content of high skilled labor embedded in imports from countries linked in the GVCs. The higher the content, the lower the country's added value that will export the product, whether final or intermediate. A contrast to this evidence is offered by Kee and Tang (2016), who study Chinese exports to explain the trade's growth in value-added. The authors find that the FDI and trade liberalization encouraged the import of intermediate goods that made it possible for Chinese companies to compete in the production of exportable goods. Hence, it would have been possible for domestic content to increase over time.

As mentioned in the above section, the empirical literature for Mexican account analysis focuses on measuring the export variable for global production that contrasts with gross exports. However, there is no equivalent effort for the analysis of its determinants. The search for the determinants would help propose an industrial policy that supports Mexico's position in global manufacturing production. As will be seen in the following sections, the indicators show that this is the case. It is necessary to investigate what variables are present in the explanation of this behavior. This research begins with the same question as previous studies, which are the factors that explain the growth of value-added trade. In determining which theoretical model to follow, we considered specific characteristics that make the Mexican case a particular model. For example, the importance of the U.S. market for Mexican products, which, on average, has been higher than 70 percent for the last twenty years. NAFTA's regional integration agreement has helped achieve greater vertical integration of global production among partner countries. The *maquiladora* industry had been, until 2006, a special tariff exemption regime, but it continues today as a comprehensive system for the export of manufacturing processes. Likewise, Mexican exports' competitiveness is considered in terms of relative prices, real effective exchange rate, and trade liberalization. For all the above, our analysis coincides with Olczyk and Kordalska (2017) to not be based on a standard model of trade, where only a specific number of explanatory variables are considered; therefore, the main export determinants are taken from various trade theories. Still, an additional effort is made to focus on those determinants that sufficiently characterize the specificity of the manufacturing sector. In that regard, we focus our analysis on the VAGME as a dependent variable[8]. This variable represents the value-added exports linked to global production, which has been calculated in previous empirical evidence. Still, no studies explain its determinants, which is significant for developing industrial policies that aim to strengthen Mexico's participation in higher levels of the GVCs.

Since VAGME is the ratio of value-added to global manufacturing production, we propose an expression that includes external factors and internal factors as determinants:

$$vagme_{it} = f(X_{it}) \tag{1}$$

where X_{it} is the vector of explanatory variables.

The proposed specification model of VAGME's determinants includes a lagged dependent variable, and given that the data sample is longitudinal, the GMM is applied to address autocorrelation and unobserved heterogeneity problems. A pool Ordinary Least Square (OLS) or a fixed effect panel fails to correct all the correlation problems between the regressors and the error term, so the estimators are inconsistent and biased. Among the alternatives to solve these problems, several authors have proposed models based on instrumental variables (IV) and, in particular, the GMM system, developed by Arellano and Bond (1991), Arellano and Bover (1995), Blundell and Bond (1998). The Arellano and Bond estimator uses GMM for the estimation of a dynamic model of the form:

$$y_{it=}\delta y_{i,t-1} + \beta x_{it} + u_{it} \quad \text{where } i = 1 \ldots \text{N}, \; t = 1 \ldots \text{T and} \qquad u_{it} = \mu_i + \vartheta_{it} \tag{2}$$

The expression $u_{it} = \mu_i + \vartheta_{it}$ shows two sources of persistence over time: autocorrelation and individual effects due to the heterogeneity among individuals. According to expression (2), μ_i is correlated with $y_{i,t-1}$; we took the first differences to correct it and have the following:

$$\Delta y_{it} = \Delta\delta y_{i,t-1} + \Delta\beta x_{it} + \Delta u_{it} \tag{3}$$

Expression (3) shows that Δy_{it} is correlated with Δu_{it}. The use of instrumental variables is crucial in order for the estimate to be unbiased. Arellano and Bond (1991) use lags in the endogenous and weakly exogenous variables and differences in the strictly exogenous variables. The GMM estimates the relationship between the dependent and independent variables using both equations' information in levels and differences. Blundell and Bond (1998) extended the original idea of Arellano and Bond (1991), assuming that the instrumental variables' first differences are not correlated with the fixed effects. This allows for the introduction of more instruments, which increases the efficiency of the model. This is how a system of two equations is constructed, the original equation and the transformed, known as the "GMM system." Another advantage of the GMM system is that it allows the inclusion of non-stationary variables and the possibility of non-cointegration of the previous ones in the equation[9]. Furthermore, the GMM system does not skew the parameters in small samples or the presence of endogeneity (Bond, 2002).

The validity of the proposed instruments and consistency of estimators must be checked using several tests. The Hansen test is used to examine the joint validity of the selected instrumental variables[10]. Another relevant test is the AR(1) and AR(2) tests for autocorrelation of residuals. The consistency of the GMM estimator is based on the absence of second-order serial correlation. Initially, the equation's residues in the first differences present serial correlation so that the null hypothesis is rejected for AR(1). However, to guarantee the assumption of independence of the original errors, the residues must not exhibit a significant AR(2) (Baum et al., 2003).

As a first approximation to the explanation of the determinants of trade in added value, in this paper, we want to verify if the explanatory variables that are usually used to explain gross exports can also be valid to explain trade in value-added. Therefore, the explanatory variables consider the variables of a standard theoretical model that explains exports and consider the factors of competitiveness, production, and economic integration that we find that, in conjunction, affect the growth of the *vagme*. Thus, expression (1) includes both external and internal factors in the explanation of the *vagme*. The independent variables considered as external factors are the U.S. economic activity (*ivaus*), the foreign direct investment (*ied*), tariffs (*tarr*), and the real effective exchange rate (*reer*). As internal factors, we consider as independent variables the domestic production (*ipmx*), physical capital (*gfcf*), and a variable of employment (*emp*).

The following dynamic panel data is obtained after we pooled and took logarithms of all relevant variables for the empirical estimation of equation (1) that includes both external and internal factors:

$$lvagme_{it} = \beta_0 + \beta_1 lvagme_{i,t-1} + \beta_2 livaus_{it} + \beta_3 lied_{it} + \beta_4 ltarr_{it} + \beta_5 lirer_t + \beta_6 lipmx_{it} + \beta_7 lgfcf_{it} + \beta_8 lemp_t + u_{it} \tag{4}$$

where $i = 1\ldots21$ refers to the number of Mexican manufacturing sectors; $t = 1\ldots15$ refers to the period (2003-2018), and βs are the parameters to estimate. We expect that β_1 through β_3 will show positive signs and the same for β_6 through β_9. We assume that the past performance of the variable *vagme* would positively affect its current value. Since the U.S. and Mexican economies are interdependent, we expect the positive economic growth of U.S. industries to have a positive influence on the *vagme*. Following the works of Alguacil et al. (2002) and Pacheco-López (2005), we expect the sign for the foreign direct investment coefficient β_3 to be positive. An increase in the value of the currency (appreciation) will make exports more expensive; therefore, we expect a negative sign for the β_5 coefficient. Tariff barriers reduce export flows, and we expect a negative β_4 the coefficient for this variable.

Regarding internal variables, we expect domestic industrial production, *ipmx*, to influence the external sector positively and, therefore, over the dependent variable. According to Goldstein and Khan (1986), the higher the production capacity of an economy, the greater its exportable supply capacity. Hence, we include physical capital with the gross fixed capital formation, *gfcf*, as a proxy, which would boost all sectors' production, including the export sector. As another endowment factor variable, we include employment as the number of jobs in global manufacturing production. Jobs linked to global production tend to be highly skilled compared to the rest of the economy; therefore, increases in the number of skilled workers are expected to influence the vagme positively.

5. Empirical Results

In this paper, expression (2) is estimated using the Blundell and Bond (1998) system GMM robust two-step estimator. Blundell and Bond (1998) point out the weakness of the Arellano and Bond (1991) GMM estimator for highly autoregressive panel series and suggest the GMM system estimator. They show that there is an essential gain in efficiency when using lagged differenced dependent variables as instruments.

Table 2 shows the variable definitions, sources of information, and summary of statistics. The set of external variables includes U.S. industrial value-added, *ivaus*, foreign direct investment, *ied*, tariffs, *tarr*, and the real exchange rate, *irer*. The internal variables include Mexican domestic production, *ipmx*, total employment in the global manufacturing sector, *emp*, and gross fixed capital formation, *gfcf*. The data comes from different sources of information, including INEGI, the U.S. Bureau of Economic Analysis (BEA), the World Trade Organization (WTO), and the World Bank's World Development Indicators (WDI).

The panel consisted of 21 Mexican industrial manufacturing branches classified according to the NCAIS for 16 years (2003-2018). Therefore, we have a small panel in which N >T, and there is no need to perform a Unit Root Test for stationarity as the number of years is small (Maddala & Wu, 1999). The GMM estimation is also carried out in two steps, applying the correction for finite samples proposed by Windmeijer (2005), which reduces the standard error default bias.

Three econometric specifications are considered. Model 1 considers productive factors such as capital and employment, in addition to an external demand variable and a proxy for internal production (Expression 5). The second model considers only external variables such as external demand, foreign direct investment, exchange rate, and rates (Expression 6). The third model considers only the productive variables and factor endowment -capital and employment- (Expression 7):

$$lvagme_{it} = \beta_1 lvagme_{i,t-1} + \beta_2 livaus_{it} + \beta_3 lipmx_{it} + \beta_4 lemp_{it} + \beta_5 lgfcf_{it} + u_{it} \quad (5)$$

$$lvagme_{it} = \gamma_1 lvagme_{i,t-1} + \gamma_2 livaus_{it} + \gamma_3 ltarr_{it} + \gamma_4 lirer_{it} + \gamma_5 lied_{it} + u_{it} \quad (6)$$

$$lvagme_{it} = \delta_1 lvagme_{i,t-1} + \delta_2 lipmx_{it} + \delta_3 lemp_{it} + \delta_4 lgfcf_{it} + u_{it} \quad (7)$$

Table 3 shows the results for the expressions (5)-(7), respectively. The table includes the post estimation test as such that AR(1) and AR(2) p values, the number of instruments for each model, and the Sargan and Hansen-J p values[11].

Table 3 shows that for the three specifications proposed, the coefficients for lagged *lvagme* are high and significant, representing the degree of persistence in the current value of *lvagme*. Specifically, for each percentage point of increase in *lvagme* in the previous period, *lvagme* would increase by 81, 64, and 78 percent according to models 1, 2, and model 3, respectively. These results are consistent with previous empirical evidence that includes the lag of the dependent variable as a regressor. The income variable, *livaus*, which represents U.S. industrial activity, is significant and positive when included in models 1 and 2. An increase of one percent in U.S. industrial activity represents a 16 percent increase for *lvagme* and 13 percent for the second model. We chose the industrial production index and not a variable of market demand, such as the U.S. GDP, since VAGME is linked to GVCs. Therefore, it would be expected that industrial activity would dictate export demand for this type of products. However, the coefficient's value is relatively low compared to previous estimates (the external demand variable being the U.S. economic activity). Cermeño and Rivera (2016) summarize previous empirical quantitative estimates for exports and imports, which show high-income coefficients for Mexican exports. Their empirical estimate for the export function is also low. According to the authors, this is due to the low fluctuations in the U.S. economic activity during the studied period (1994-2014).

Since the dependent variable is the aggregate value of global manufacturing production exports as a ratio of global manufacturing production, *vagme*, the industrial production variable, *lipmx*, is included in models 1 and 3. The variable *lipmx* is significant for model 3, where only internal variables such as employment and capital are included. However, it is not significant in model 1. In both cases, coefficients show the expected sign, that is, that growth in industrial activity has a positive impact on the *vagme*. In fact, in model 3, the coefficient is significant and high. A percentage of growth in Mexican industrial activity will lead to a 27 percent change for the *vagme*. From the empirical literature on the relationship of these two variables, there are cointegration models that confirm a long-term relationship between manufacturing exports and GDP, but that does not confirm uni-directionality, that is, that causality comes from one direction (Heras & Gomez, 2015; Rodriguez & Venegas, 2011). Waithe et al. (2010) confirmed a positive relationship between exports and GDP but found an inverse relationship in the long-run when testing the export-led growth hypothesis. According to them, this results from the high import content of exports and the lack of economic links with domestic suppliers. Our results indicate the opposite for exports linked to manufacturing global manufacturing production.

The employment variable *lemp* was included as an explanatory variable since it is in global manufacturing where medium and high skill labor is concentrated. Table 4 shows that the *lemp* variable is significant for the first model. However, any models 1 and 3 show the opposite sign than expected. This can be explained by the low content of labor in the high-tech manufacturing export sectors. Fujii et al. (2016) state that the sectors that make the most significant contributions to exports have low-medium and low employment coefficients, while labor-intensive exports contribute little to exports.

Aside from *lemp,* there is another variable representing the production factors, *lgfcf*. We chose the variable lag since we argue that capital formation would have effects after one period. The variable is significant in the models included (Model 1 and 3) and had the expected sign for the GMM estimate; however, the coefficients are small. An increase in one percent of the *lgfcf* will increase *lvagme* by 9 percent. The two coefficients' results lead us to conclude the importance of the physical capital for the added value of exports. Investments in machinery and equipment, buildings, and plants have a positive effect on value-added over the long term. The result seems reasonable for exports of global manufacturing production that concentrate medium and high technology (automotive and electronics). If exports linked to global manufacturing production are considered as a factor of economic growth, then the results obtained here show that capital formation is a significant variable for a long-term industrial policy to promote these exports.

The variable of trade restriction represented by tariffs, *ltarr*, is significant for Model 2, but it shows the wrong sign. The coefficient would have been expected to be negative since a rise in imported goods' tariffs would hurt the *lvagme*, given the high content of imported inputs in exportable. An alternative explanation for the positive sign would be related to the substitution effect: high tariffs on imported inputs would increase the use of domestic inputs, increasing the value-added component of Mexican exports. According to Blonigen (2001), this is what happened in the Japanese automotive industry that produces imported parts and components coming from the U.S.

On the other hand, the real exchange rate, *lirer,* is significant but has a negative sign. An increase in the real effective exchange rate implies a real appreciation of the currency, which would negatively affect the exports. However, given the high content of imported inputs, an appreciation would make them cheaper. Given the high import content of exports linked to global manufacturing production, the positive sign can reflect this fact. It is worth mentioning that the growing importance of global chains has questioned whether the exchange rate is still valid as a trade policy measure to promote exports. According to Ahmed et al. (2017), the response of exports to exchange rate changes has been reduced. Hence, there was a need to adjust the real exchange rate to global production, that is, a value-added exchange rate (Ahmed et al., 2017). Although the *lirer* is significant, it does reveal that it is quite significant in Mexico's case. A real appreciation of the peso will have a 15 percent positive impact on VAGME.

Another variable postulated was the FDI, as it is the significant participation in export production. However, *lied* was not significant when included in Model 2. According to Unger (2001), during the early nineties, there was a new wave of investments in the sectors of automotive, chemical, steel, computers, and others with the precise goal of exporting, which allowed growth rates to remain high throughout the decade. Even though FDI was a significant source of investment flows for export production during the nineties, its significance is not reflected in the analyzed period. It is worth noting that high levels of FDI happened after NAFTA was signed, while did not have the same growth in the 2000s, at least in the manufacturing industry. Another problem is that the empirical evidence for Mexico focuses on cointegration relationships, rather than an analysis of exports' determinants where FDI is included (Cabral & Alvarado, 2019).

The post-estimation tests for the GMM show that the second-order autocorrelation test does not reject the null hypothesis of non-autocorrelation. Therefore, the moment conditions are valid and consistent. The Hansen test *p*-values are 0.65, 0.30, and 0.38 respectively. Therefore, the instruments used in the estimation are accepted as valid.

The panel cointegration test, FMOLS for the three estimates, is included as proof of the robustness of the results. The null hypothesis indicates the absence of cointegration, and the alternative hypothesis indicates that all panels are cointegrated. There are three tests, Pedroni, Kao, and Westerlund. The results are shown in Table 4, where we can see that in all cases, the null non-cointegration hypothesis is rejected; an exception is given for model 2, where it is only rejected when Westerlund is applied.

In sum, the three specifications presented confirm that one of the traditional variables to explain exports remains central for exports related to global manufacturing production. U.S. industrial activity has a reduced impact on the dependent variable compared to previous empirical evidence, which may be part of the advantages of regional integration or a possible diversification of exports to other destinations, such as China. Mexican industrial production is significant and positive for the *vagme*, which would mean that industrial policies are required to drive domestic value-added growth in manufacturing exports. Likewise, physical capital in the manufacturing sector also has a positive, albeit reduced impact. It must be considered that investment in global manufacturing production expanded throughout the country, particularly in the last twenty years.

6. Summary and Conclusions

The growth of trade in value-added has called attention to redefining the meaning of a country's participation in global manufacturing production. Gross exports and imports are no longer indicators of this participation. Advances in international trade statistics have made it possible to quantify how each country participates in global manufacturing production. Mexico has been an early participant since the mid-1960s through the *maquiladora* industry. In the last decades, the expansion of regional GVCs meant for Mexico to develop the industry sectors where the export production moved beyond the assembly of final products. However, to achieve this change, it is necessary to identify the main determinants to increase the Mexican industry's domestic value-added contribution.

With NAFTA, Mexico consolidated its participation in the GVCs, making a rectification in trade accounts to estimate its participation more urgent. Empirical evidence has shown the indices of participation of Mexico in the trade in value-added. When compared with other IO databases, INEGI's variable in trade in value-added is lower. Likewise, there is a lack of studies addressing the determinants of that trade, the value-added of exports. This paper represents the first approach to filling that gap in the empirical literature by proposing an econometric specification.

Concerning the determinants, we followed economic theory and previous empirical evidence on the determinants of manufacturing exports. We wanted to test if the theoretical models that explain gross exports are still valid to explain value-added exports. We empirically applied dynamic panel data for the 21 Mexican manufacturing branches for the 2003-2018 period. We found that the U.S. industrial activity is significant in explaining the behavior of trade in value-added. Regarding internal factors, we found that domestic industrial production and physical capital are determinants for the value-added of exports. We proposed other variables, such as relative prices; however, it was not significant in all cases. This may mean that it is no longer possible to use the same conceptual framework as gross exports to understand what factors affect trade in added value. Although the new international trade theories consider the fragmentation of production, more work is needed on empirical models that analyze the determinants of this new type of trade.

Our results for Mexico indicate that, in the long run, Mexican trade policy has little room for increasing trade in value-added since this trade is tied to fluctuations of U.S. industrial activity, although not as high as with gross exports. Also, as has been examined, global manufacturing production is concentrated in very few sectors, with the automotive industry being the most representative, and in which there are subsidiaries of the three largest automakers in the United States. Thus, industrial policy should encourage the arrival of FDI that places Mexico in the production stages of more technological knowledge content. Variables that can positively affect trade in value-added exports are domestic industrial production and physical capital. These are the internal factors in our estimation. First, an increase in production capacity would increase the supply of exportable. Second, a more significant domestic industrial activity could create positive spillovers for the rest of the industry, including global manufacturing production. Nevertheless, in both cases, the domestic investment will not be enough; government institutions can take an active role in increasing industrial capacity. Even though FDI was not significant for the study period, we believe a regulated foreign investment like the Chinese model partnerships can increase domestic content in manufacturing exports.

There is a need for further analyses of the determinants, in particular, by sectors with more disaggregation. We show that value-added trade is concentrated in three industries, which do not have more significant links with the rest of the economy. However, in these industries, there are more possibilities to scale in the global value chains. It would be necessary to study the determinants at the sector level and propose a trade and industrial policies that encourage greater participation in activities that generate higher domestic value-added.

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[1] As part of the NAFTA agreement, the maquiladora program was replaced by the Manufacturing, Maquila and Export Service Industry (Industría Manufacturera Maquiladora y de Servicio de Exportación or IMMEX) program in 2006.
[2] The measurement of trade in value-added became extensive once international trade databases started being captured using IO tables. An overview of the differences and similarities between databases can be found in the special issue of *Economic Systems Research* dedicated to global multiregional input–output (GMRIO) tables, models, and analyses (Tukker & Dietzenbacher, 2013).
[3] In the case of Mexican value-added exports, demand shocks coming from the U.S. increased the sector's vulnerability given the asymmetric economic interdependence with the U.S.
[4] The empirical literature is quite extensive for a related subject, vertical specialization, which also has used IO tables for its empirical estimation. See Sotomayor (2016) for a literature review.

[5] For the full text of the new agreement check https://ustr.gov/trade-agreements/free-trade-agreements/united-states-mexico-canada-agreement/united-states-mexico
[6] With the most significant changes in 1973. See Davis, 1985.
[7] For a complete description of the IMMEX Decree, see http://www.2006-2012.economia.gob.mx/industry/foreign-trade-instruments/immex
[8] For a more detailed explanation of the construction of the variable go to INEGI (2018)
[9] Some variables in the sample do not have unit roots in levels.
[10] Since our specifications consider a two-step estimation (GMM estimators asymptotically efficient), we do not consider the Sargan test, which is more suitable for one-step estimation.
[11] For the sake of brevity, we do not report the pool OLS and fixed effects results but are available upon request.

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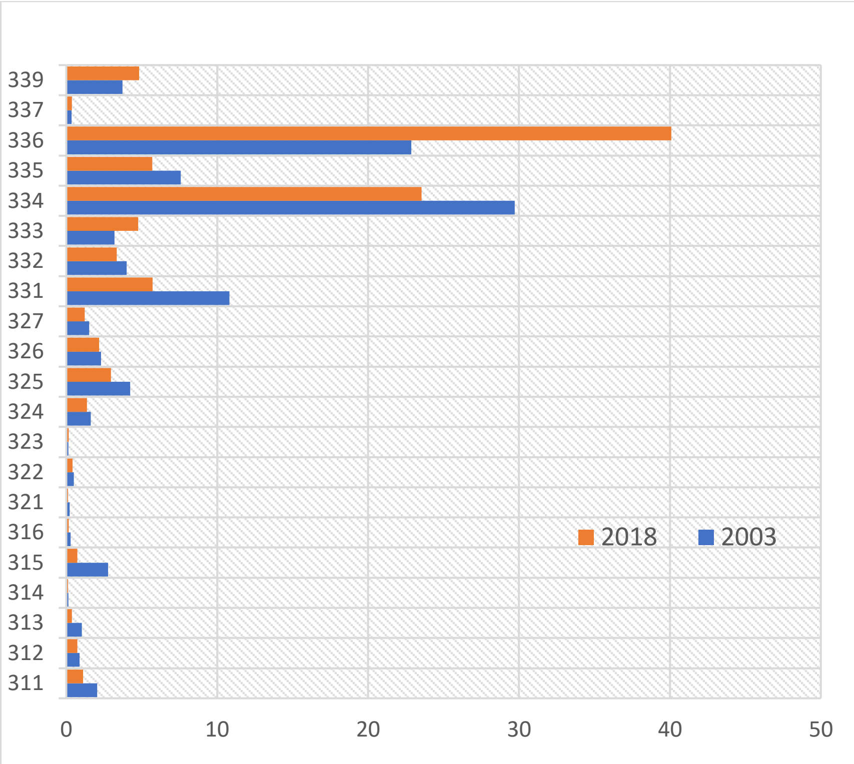
Figure 1: Composition Global Manufacturing Production by Industrial Sectors 3 digits 2003 and 2018 (%)



Source: based on data from INEGI

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Table 1 Main Characteristics Global Manufacturing Production (%)

Variable description	2003-2007	2008-2009	2010-2018
Global Manufacturing Production as % Total Manufacturing Production	38.82	38.94	39.88
Global Manufacturing Production's average rate of growth	6.84	-15.06	3.91
VAGME as % of the Global Manufacturing Production	43.32	49.95	49.76
VAGME's average rate of growth	4.63	-8.50	6.33
VAGME as % of Total Manufacturing Production	10.70	10.70	12.20
331 Primary Metals Construction	*25.28*	*27.40*	*23.66*
334 Computer and Electronic Product Manufacturing	*20.94*	*16.70*	*15.11*
336 Transportation Equipment Manufacturing	*16.64*	*21.65*	*26.54*
Total jobs in Global Manufacturing Production as % of the Total Manufacturing Production	28.17	29.18	33.75
331 Primary Metals Construction	*42.93*	*46.53*	*52.78*
334 Computer and Electronic Product Manufacturing	*80.91*	*75.39*	*63.36*
336 Transportation Equipment Manufacturing	*62.71*	*73.00*	*77.59*
Domestic inputs as % total inputs for the global manufacturing production	21.54	21.53	23.77
331 Primary Metals Construction	*45.16*	*44.20*	*42.22*
334 Computer and Electronic Product Manufacturing	*13.26*	*10.47*	*8.99*
336 Transportation Equipment Manufacturing	*23.27*	*31.16*	*36.20*

Source: based on data from INEGI

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Table 2 Variable definitions and summary of statistics

Name	Definition	Source	Obs.	Mean	Std. Dev.	Min	Max
lvagme	Log share of the value-added of global manufacturing exports as a percentage of total global manufacturing production.	INEGI	336	3.62	0.31	2.7	4.24
livaus	Log U.S. industrial index value-added, 2013 = 100	Bureau of Economic Analysis (BEA)	336	4.71	0.23	3.94	6.07
lipmx	Log Mexican industrial index production, 2013 =100	INEGI	336	4.61	0.13	3.95	4.96
lemp	Log the number of employees for export value-added global manufacturing production.	INEGI	336	10.53	1.24	8.23	13.44
lgfcf	Log share of gross fixed capital formation as a percentage of total domestic production.	INEGI	336	1.64	0.76	-0.83	3.49
ltarr	Log tariffs by sectors, percentages.	World Trade Organization (WTO)	336	1.92	1.09	-1.13	4.06
lirer	Log real effective exchange index, 2013 =100	World Development Indicators (WDI)	336	4.65	0.08	4.54	4.81
lied	Log foreign direct investment dollars constant 2013	INEGI	321	5.4	1.91	-5.07	9.68

Table 3 GMM System Specification Models

Variable	Model 1	Model 2	Model 3
lvagme	0.812***	0.640***	0.776***
livaus	0.163*	0.134*	
lipmx	0.111		0.267**
lemp	-0.055*		-0.055
lgfcf	0.088**		0.097**
ltarr		0.014*	
lirer		0.148*	
lied		-0.009	
Observations	300	300	300
AR1 (p-value)	0.067	0.111	0.071
AR2 (p-value)	0.164	0.32	0.15
No. of Instruments	17	18	14
Sargan (p-value)	0.079	0.126	0.213
Hansen-J (p-value)	0.652	0.303	0.382
*** p<0.05, ** p<0.01, *** p<0.001**			

Table 4 Robustness Test FMOLS

Ho: No cointegration				
Ha: All panels are cointegrated				
		Model 1	Model 2	Model 3
Pedroni	Augmented Dickey-Fuller	-9.58***	-7.32***	-11.18***
Kao	Augmented Dickey-Fuller	-6.44***	-3.17***	-6.55***
Westerlund (*)	Variance Ratio	-1.66**	-1.28	-2.47***

(*) Includes trend