Modernization plans for the Mexican customs system: Have they really worked? A productivity impact assessment

Abstract

Research measuring the efficiency of customs offices is a nascent but growing area of research interest. We examined whether the Mexican government's policies enacted during the period 2011-2017 improved the efficiency of the customs system. Our empirical approach employed a standard metafrontier model to assess the efficiency of all customs offices in Mexico. We examined changes in the best-practice performance, productivity, and technology leadership for three groups of customs offices (border, interior, and maritime) by conducting static and temporal analyses. The static analysis showed that border customs had the most within-group variations. The internal customs group exhibited constant efficiency, whereas the maritime customs group was nearest to the metafrontier. The temporal analysis indicated that border customs offices were the most productive group during the period; however, this group was distant from the metafrontier. Our findings contribute to the growing literature on customs efficiency measurement.

Keywords: efficiency, customs, Mexico, DEA metafrontier, Malmquist Productivity Index.

Introduction

Customs agencies have played a vital role in the historical development of global trade, and they are crucial to the supply-chain management model of the 21st century (World Customs Organization [WCO], 2008). The importance of efficient customs management for international trade and logistics is also included in the "logistics performance index" (LPI), published every two years by the World Bank (Rashidi and Cullinanen, 2019). Therefore, the main logistics priority for all foreign trade stakeholders is to ensure that customs offices facilitate trade transactions. For example, the WCO (2008) aims to contribute to its member countries' development by fostering trade while simultaneously ensuring their borders remain secure.

Research examining ways to make trade more efficient has become increasingly important. Several studies have been conducted to measure and define the positive effects of implementing best practices in international trade (National System of Foreign Trade Information, 2015). For example, Volpe et al. (2014) found a significant decrease in export clearance delays for Uruguayan companies implementing best practices. Furthermore, several multinational initiatives have contributed to the improvement of international trade. For instance, the ratification of the Revised Kyoto Convention (RKC) was associated with a 62-64% decrease in average import times, a 63-64% decrease in import costs, and a 63-69% decrease in export times (Soo Choi, 2017). Similarly, the implementation of the SAFE Framework of Standards (which balanced trade promotion with security by encouraging cooperation between customs agencies and private companies) was significantly correlated with a 65-71% decrease in import times, a 68% decrease in import costs, a 70-78% decrease in export times, and a 71% decrease in export costs (Soo Choi, 2017). The findings from these studies are remarkable because they show that customs-related policies to facilitate trade are not necessarily opposed to those seeking to ensure national security.

Mexico is invested in ensuring the correct management of its customs offices to facilitate international trade. Mexico's Secretariat of Finance and Public Credit and its Tax Administration Service are focused on modernizing the country's customs system (both logistically and technologically) to improve the efficiency of foreign trade transactions. Similar initiatives have also been promoted in other parts of the world such as in Europe (Raus, Flügge and Boutellier, 2009). Such improvements will contribute to the economic growth of the Mexican economy. Customs modernization process can be summarized in three main objectives. The first objective is to facilitate trade while simultaneously ensuring the identification of any operations that could pose a risk for the population and the country's national security. The second objective is to establish trade alliances with potential trade partners (Tax Administration Service, 2016). The third objective is to increase the efficiency and productivity of Mexico's customs system while guaranteeing that tax collection[1], national security, and foreign trade remain unaffected.

From 2011 to 2017, the Mexican government established several initiatives to modernize the customs system. Some notable initiatives include the Customs Modernization Plan (*Plan de Modernización de Aduanas*), Customs S21 (*Aduana S21*), the Single Window for Foreign Trade (*Ventanilla Única de Comercio Exterior Mexicano*), and the Technological Integration Customs Project (*Proyecto de Integración Tecnológica de Aduanas*). Thus, this study examines the success of these initiatives to improve the Mexican customs system, particularly those aimed at improving productivity and efficiency.

[1]Tax collection continues to be one of their main directives since the establishment of customs agencies globally.

Customs agencies play a pivotal role in a country's development, which is why governments worldwide have prioritized improving the effectiveness and efficiency of these agencies. Scholarly research on customs efficiency, however, is scarce. One of the few available studies employed data envelopment analysis (DEA), originally developed by Charnes et al. (1978), as well as the Malmquist productivity index (Caves et al., 1982) to assess changes in productivity between 2014 and 2015 on a sample of customs offices in 18 countries of the Asia-Pacific region, including Mexico (Zamora Torres, 2017). The findings indicate that the most efficient customs systems in 2014 were Brunei and Singapore and, in 2015, New Zealand, Peru, the Philippines, and Chile.

Conversely, for 2014 and 2015, the least efficient customs systems were the United States, Canada, Japan, China, and Mexico. Additionally, the customs systems that showed the greatest technological improvement were Singapore, Peru, South Korea, Russia, Hong Kong, Japan, and New Zealand. Conversely, customs systems with the least technological improvement included Australia, Brunei, Thailand, Malaysia, Indonesia, and Chile.

Benazić (2012) examined the efficiency of Croatia's regional organizational units by implementing DEA. His findings showed that the organizational structure of Croatia's Customs Administration was inefficient. Kilibarda et al. (2017) analyzed the efficiency of the logistics processes of the Serbian customs system by implementing both DEA and principal component analysis (PCA). They selected the workforce as the only input and the number of customs operations (including exports, temporary exports, re-exports, imports, temporary imports, re-imports, warehouse customs deposits, and additional customs procedures) as the output. The authors found that only four out of 14 customs offices had an efficient logistics system and concluded that to improve the efficiency of the customs system, it would be necessary to increase the number of operations carried out and optimize the number of customs officers.

To our knowledge, only two studies have analyzed the impact of policies to improve the efficiency of customs offices. The first study examined the Single Window for Foreign Trade policy in Mexico, aiming to identify specific areas in the Mexican customs system where profit and efficiency increased because of the implementation of this system (Zamora Torres et al., 2013). By simplifying the information exchanged between traders and customs offices, they found significant improvements in the efficiency of foreign trade operations, including a 20% decrease in average customs clearance times. Similarly, Soo Choi (2017) assessed the effects of custom modernization policies in reducing clearance times and costs across 101 countries members of the World Trade Organization. Considering several indicators of customs policy established by the WCO and data from various international organizations, the study showed a significant correlation between customs modernization policies and trade efficiency (Soo Choi, 2017).

Each of Mexico's three types of customs offices (border customs, internal customs, and maritime customs) has its specific characteristics and regulations. However, to assess the efficiency and productivity of Mexican customs offices, this study implements DEA, which requires that the units analyzed be homogeneous from an operational perspective. In particular, we employed a metafrontier model developed by O'Donnell and colleagues (2007) to obtain a more comprehensive understanding of the Mexican customs system. Further, we implemented the Malmquist Metafrontier Index to measure productivity changes and their respective explanatory factors (Oh, 2007).

Our research has significant theoretical and practical implications, as this is the first study to conduct a temporal metafrontier analysis in the field of customs. Furthermore, we also assess the efficacy of the modernization policies enacted by the Mexican government for its customs system. Unlike standard analyses that rely on key performance indicators, we implement a robust methodology that allows for a comprehensive assessment of the efficiency of Mexican customs offices.

Sampling and variables

Sample

Table 1 shows the 48 customs offices studied (from a total of 49 that exist in Mexico) disaggregated by classification, which is determined by their location within the Mexican territory. Our sample contains, by type, 21 borders customs offices, 11 interior customs offices, and 16 maritime custom offices. During our pre-processing of the data, we opted to remove the Acapulco office from the final sample due to data irregularities.

Our study period was from 2011 and 2017 since it corresponds with the period in which the government enacted policies to modernize the sector.

[Insert Table 1 here]

This classification determines key operational differences. Border customs offices are located along the northern and southern borders of the country; northern offices are more numerous (19 offices) due to the large trade volume between Mexico and the United States. Compared with the southern border, customs offices along the northern border have a greater number of dedicated import and export lanes for vehicles, bonded warehouses, and special permits for the import and export of merchandise. Customs offices along the southern border are in the cities of Ciudad Hidalgo in the state of Chiapas and Subteniente López in the state of Quintana Roo (General Customs Administration, 2018). By contrast, interior customs offices are more homogeneous; additionally, they are connected to the major aerial, railroad, and highway routes. As their name implies, maritime customs offices can be found in coastal cities with access to major sea routes and have the capability of inspecting shipping operations; most of them are located within or near port areas (General Customs Administration, 2018).

Variables

Metafrontier methods require modeling the productive process of Mexican customs offices by defining the input and output bundle. Inputs and outputs are usually selected based on prior literature and/or the characteristics of the production process. These are, however, conditioned by available information. As noted earlier, only a handful of studies have focused on assessing customs offices' efficiency, limiting the information on the types of variables we can use to define the input/output bundle. Table 2 shows the inputs and outputs that have been used in prior scholarly research.

[Insert Table 2 here]

The most commonly used input in the scholarly literature on customs efficiency is the number of employees. Other inputs include the operational resources, which are commonly expressed as available resources or in monetary terms. Outputs depend primarily on the characteristics of the productive units being studied, as these variables result from operational processes. In this case, the productive units being analyzed are customs offices, whereas the outputs were obtained based on the main objectives of the customs system: national security and tax collection (WCO, 2019).

The inputs selected for this study represent three categories interlinked to the customs offices' productive process: infrastructure, human resources, and requirements and declarations. We selected the first and second inputs because they are frequently used in the field-relevant literature, whereas the third was selected because customs offices in Mexico are government-controlled. Mexican customs offices require that users provide declarations about their operations and meet certain requirements. Import/export requests are financial documents in which the importer or exporter, to ensure compliance with foreign trade tax regulations, declares to the customs office any merchandise to be imported or exported. Thus, import/export requests are directly linked to the processing volume involved in the operation. The inputs selected for our model are described below:

- *Employees*: the number of full-time employees working at any customs office. Employees are the most valuable asset of a customs office's administrative capability, as the quality of the service it provides to its users depends entirely on its employees (Benazić, 2012).
- *Bank branches and modules*: the number of bank branches and modules authorized to receive foreign trade payments through official payment forms. These include only banking institutions authorized to receive, process, and certify the various forms used for foreign trade transactions, including requests, declarations, and payments inside customs offices.
- *Import requests*: the number of import requests processed in each customs office.
- *Export requests*: the number of export requests processed in each customs office.

The outputs were grouped into two categories: tax collection and customs clearance. These variables were chosen based on the second priority of the World Customs Organization's

2019-2022 Strategic Plan (2019), which aims to ensure fair tax collection and to protect all members of society. These are described below:

- *Import value*: the total monetary value (in MXN) of the goods imported to each customs office.
- *Export value:* the total monetary value (in MXN) of the goods exported from each customs office.
- *Collected tax:* the total monetary value (in MXN) of taxes collected by each customs office.

The input and output variables were obtained directly from the Tax Administration Service.

[Insert Table 3 here]

Overall, we examined 48 customs offices. Table 3 reports the descriptive statistics for 2011, and Table 4 reports the descriptive statistics for 2017.

[Insert Table 4 here]

Methods

O'Donnell et al. (2007) proposed a methodology to conduct efficiency comparisons when units can be grouped according to specific technologies and when the data analyzed are cross-sectional. They posit that, first, it is necessary to measure their efficiency relative to the other units in their group (thereby establishing a local frontier). Second, it is necessary to measure efficiency relative to a global frontier comprising all observations (which make up a metafrontier). The efficiency score relative to the metafrontier can be decomposed into two elements: The first element measures the distance to the local frontier (technical efficiency), and the second one measures the gap between the local frontier and the metafrontier (which represents the technological gap). Additionally, Oh and Lee (2007) proposed the Metafrontier Malmquist Productivity Index, which measures temporal changes in productivity in groups with different technologies (Caves et al., 1982). The steps to calculate this index are as follows:

$$T = \{(x, y): x \geq 0; y \geq 0; x \text{ may produce } y\} \quad (1)$$

where y and x are the non-negative vectors of the observed inputs and outputs of dimension $M \times 1$ and $N \times 1$, respectively. The metatechnology set (T) has all input-output combinations that are technologically feasible, assuming that it meets the four main requirements established by Färe and Primont (1995).

The set of production possibilities associated with T for any vector of inputs x is given by

$$P(x) = \{y: (x, y) \in T\} \quad (2)$$

In terms of measuring efficiency, technology is represented by using the output-oriented distance function as

$$D(x, y) = inf_{\theta}\ \{\theta > 0 : (y/\theta)\ \in P(x)\} \quad (3)$$

This function provides the maximum value that a customs office could radially expand its output vector, given its input vector. A customs office may be considered technically efficient if $D(x, y) = 1$. For this study, we chose an output-oriented model because customs offices are part of a government agency whose objective is to affect as many commercial transactions as possible. Further, Zamora Torres and Navarro Chávez (2014) highlighted an increasing need among governments to rationalize the inputs used due to the financial situation of most countries.

For this study, it is necessary to consider the existence of sub-technologies representing the production possibilities of the different customs office groups. Specifically, let's assume that customs offices can be divided into K technologically homogeneous groups (in our study, $K = 3$). One can thus avoid customs offices in a given group (which has its resources, regulations, or environmental restrictions) being compared with customs offices from other groups with different operational characteristics. According to O'Donnell et al. (2007), however, it is preferable to compare the efficiency of a given customs office group to the metafrontier. Hence, it will be possible to identify the effect a given group's operational or structural characteristics may have on overall efficiency. The available input-output combinations for customs offices in group k define their group technology as:

$$T^k = \{(x, y) : x \geq 0; y \geq 0; x \text{ may be used by customs offices in group } k \text{ to produce } y\} \quad (4)$$

The specific technologies of the K groups are represented by the following production possibility sets and their respective distance functions:

$$P^k(x) = \{y: (x, y) \in T^k\}, \quad k = 1, 2, \ldots, K; \quad \text{and} \qquad (5)$$

$$D^k(x, y) = inf_\theta\{\theta > 0 : (y/\theta) \in P^k(x)\}, \quad k = 1, 2, \ldots, K \qquad (6)$$

The limits of sets $P^k(x)$ are known as group frontiers and should fulfill the following properties (O' Donnell et al., 2007):

1. If $(x, y) \epsilon T^k$ for every k, then $(x, y) \epsilon T$;

2. If $(x, y) \epsilon\, T$, then $(x, y)\ \epsilon\ T^k$ for any k;
3. $T = \{T^1 \cup T^2 \cup \ldots \cup\ T^K\};$ and
4. $D^k(x, y) \geq D(x, y)$ for every $k = 1, 2, \ldots, K$.

These properties result from the fact that the specific output sets of group $P^k(x), k = 1, 2, \ldots, K$ are subsets of the production possibilities set $P(x)$.

As mentioned earlier, a given observation (x, y) is technically efficient relative to the metafrontier only if $D(x, y) = 1$. Further, the output-oriented technical efficiency measure of a given unit (x, y) relative to the metatechnology can be defined as

$$TE\ (x, y) = D(x, y) \tag{7}$$

Similarly, technical efficiency relative to the frontier of group k can be defined as

$$TE^k(x, y) = \ D^k(x, y) \tag{8}$$

Property 4 indicates that the distance function of group k, $D^k(x, y)$ cannot have a value lower than the function of output metadistance, $D(x, y)$. In this way, the metafrontier envelops the frontier of group k. When there is inequality between the distance function of group k and the metadistance function, a measure of the proximity of group $k's$ frontier to the metafrontier can be obtained. Subsequently, for each customs office belonging to group k, the technological gap ratio (TGR) can be defined as:

$$TGR^k(x, y) = \ \frac{D(x,y)}{D^k(x,y)} = \frac{TE(x,y)}{TE^k(x,y)} \leq 1 \tag{9}$$

$TGR^k(x,y)$ provides a measure of the distance from group $k's$ local frontier to the metafrontier. The lower the value, the greater group $k's$ structural disadvantage.

The measures mentioned above allow us to calculate the efficiency levels of a cross-sectional sample. When panel data are available, the Malmquist Index is commonly used to carry out a temporal analysis of productivity changes (Prasada et al., 2003; McMillan & Chan, 2004). Subsequently, assume that we have information for $i = 1, \dots, I$ customs offices for the period $t = 1, \dots, T$. Additionally, assume that each customs office produces M outputs, $y \in R_+^M$, using N inputs, $x \in R_+^N$, and can be grouped in K typologies.

The production possibility set for group k in period t is defined as $P_k^t = \{(x^t, y^{t)} | x^t$, which can produce $y^t\}$ (Pastor & Lovell, 2005; Tulkens & Vanden Eckaut, 1995). Lastly, we defined the set of global production possibilities of all groups as $P^G = conv\{P_1^I \cup P_2^I \cup \dots \cup P_K^I\}$. In this way, a single production reference set includes observations for the entire period and all groups.

According to Caves et al. (1982), the Malmquist metafrontier is defined as

$$M^G(x^t, y^t, x^{t+1}, y^{t+1}) = \frac{D^G(x^{t+1}, y^{t+1})}{D^G(x^t, y^{t)}} \qquad (10)$$

where $D^G(x,y) = \inf\{\phi > 0 | (x, y/\phi) \in P^G\}$ is the output-oriented distance function over the global technology set. Additionally, to identify the components that contribute to the increase of productivity, $M^G(x^t, y^t, x^{t+1}, y^{t+1})$ can be decomposed as follows:

$M^G(x^t, y^t, x^{t+1}, y^{t+1})$

$$= \frac{D^G(x^{t+1}, y^{t+1})}{G^G(x^t, y^t)}$$

$$= \frac{D^G(x^{t+1}, y^{t+1})}{G^G(x^t, y^t)} \times \{\frac{D^t(x^t, y^t)}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^G(x^{t+1}, y^{t+1})}{G^G(x^t, y^t)}\}$$

$$= \frac{D^G(x^{t+1}, y^{t+1})}{G^G(x^t, y^t)} \times \{\frac{D^t(x^t, y^t)}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^I(x^{t+1}, y^{t+1})}{G^I(x^t, y^t)}\}$$

$$\times \{\frac{D^I(x^t, y^t)}{D^I(x^{t+1}, y^{t+1})} \times \frac{D^G(x^{t+1}, y^{t+1})}{D^G(x^t, y^t)}\}$$

$$= \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^I(x^{t+1}, y^{t+1})/D^t(x^{t+1}, y^{t+1})}{D^I(x^t, y^t)/D^t(x^t, y^t)}$$

$$\times \frac{D^G(x^{t+1}, y^{t+1})/D^I(x^{t+1}, y^{t+1})}{D^G(x^t, y^t)/D^I(x^t, y^t)}$$

$$= \frac{TE^{t+1}}{TE^t} \times \frac{BPG^{I,t+1}}{BPG^{I,t}} \times \frac{TGR^{t+1}}{TGR^t}$$

$$= EC \times BPC \times TGC \tag{11}$$

where TE^S , $s = t, t+1$ represents the evaluated unit's level of efficiency relative to its group's contemporary frontier as defined in (8). A value of 1 indicates that the unit is efficient, whereas smaller values indicate that the productive unit is inefficient. Therefore, the efficiency change (EC) component measures the change in efficiency levels for a given period. If a value greater (or smaller) than 1 indicates that there has been an increase (or decrease) in efficiency levels, $BPG^{I,S}$ (best practice gap) measures the distance from the group's contemporary frontier relative to its intertemporal frontier. Thus, BPC represents the change in this component throughout the period; if its value is greater (or smaller) than 1, this means that the frontier (comprising best practices) in period $t+1$ is closer (or further away) from the intertemporal frontier, compared with period t. In other words, it would indicate a technological improvement (or a technological deterioration) in the group during the analyzed period. Lastly, TGR^s measures the technological gap between group $j's$ technology level and the potential technology level determined by the global technology level (Battese et al., 2004). Subsequently, customs offices with $TGR = 1$ will be part of the global frontier, leading to the implementation of new technologies. In this way, the group with the most $TGR = 1$ customs offices can be assumed to be the leading group. Therefore, TGC represents a measure of change in technological leadership (Oh & Lee, 2009).

Frontier models are often used to calculate the distance functions $D^t(x^t, y^t)$, $D^{t+1}(x^{t+1}, y^{t+1})$, $D^I(x^t, y^t)$, $D^I(x^{t+1}, y^{t+1})$, $D^G(x^t, y^t)$, and $D^G(x^{t+1}, y^{t+1})$, which are necessary for the calculation and the breakdown of $M^G(x^t, y^t, x^{t+1}, y^{t+1})$. These models can be either parametric models, such as stochastic frontier analysis (SFA; Battese & Coelli, 1995), or non-parametric models, such as DEA (Charnes et al., 1978).

We opted for a non-parametric DEA model for two reasons. First, it can accommodate multiple inputs and outputs to model productive processes. Second, as opposed to parametric models, DEA does not require the prior functional specification of the production function. Thus, we can obtain distance functions for the decision-making unit (DMU) k' belonging to group k in each period $s = t, t+1$ from solving the following linear program[2] for customs office k':

$[D^s\left(x^{k',s}, y^{k',s}\right)]^{-1} = max\ \phi_c^{k',s}$s.t.:

[2] We conducted all calculations in R using a code developed by the authors.

$$\sum_{k \in R_j} \lambda^k y_m^{k,s} \geq \phi_c^{k',s} y_m^{k',s}, \quad m = 1, \dots, M$$

$$\sum_{k \in R_j} \lambda^k x_n^{k,s} \leq x_n^{k',s}, \quad n = 1, \dots, N$$

$$z^{k,s} \geq 0, \qquad (12)$$

where $\lambda^k$is a vector of intensity that determines the weight of each DMU when building the virtual reference unit in the efficient frontier for k'.

Having determined the optimal value of $\hat{\phi}_c^{k',s}$, $D^I(x^{k',s}, y^{k',s})/D^{k',s}(x^{k',s}, y^{k',s}), s = t, t+1$ will be obtained from the optimization of the following lineal program:

$$[D^I(x^{k',s}, y^{k',s})/D^{k',s}(x^{k',s}, y^{k',s})]^{-1} \ = max\phi_I^{k'}$$

s.t.:

$$\sum_{k \in R_j, s \in \tau} \lambda^{k,s} y_m^{k,s} \geq \phi_I^{k'} \hat{\phi}_c^{k',s} y_m^{k',s}, \quad m = 1, \dots, M$$

$$\sum_{k \in R_j, s \in \tau} \lambda^{k,s} x_n^{k,s} \leq y_n^{k',s}, \quad n = 1, \dots, N,$$

$$z^{k,s} \geq 0 \ \tau = \{1, 2, \dots, T\} \qquad (13)$$

Lastly, having determined the optimal value of $\hat{\phi}_I^{k'}$, the global distance function $D^G(x^{k',s}, y^{k',s})/D^I(x^{k',s}, y^{k',s}), s = t, t+1$ can be obtained as follows:

$$[D^G(x^{k',s}, y^{k',s})/D^{k',s}(x^{k',s}, y^{k',s})]^{-1} = \max \phi_G^{k'}$$

s.t.:

$$\sum_{k \in R, s \in \tau} z^{k,s} y_m^{k,s} \geq \phi_G^{k'} \hat{\phi}_I^{k'} y_m^{k',s}, \quad m = 1, \ldots, M$$

$$\sum_{k \in R, s \in \tau} z^{k,s} x_n^{k,s} \geq x_n^{k',s}, \quad n = 1, \ldots, N$$

$$z^{k,s} \geq 0, R = R_1 \cup R_2 \cup \ldots R_J, \quad \tau = \{1, 2, \ldots, T\} \tag{14}$$

Results

In this section, we present the results of our analyses. First, we report on the static analyses; that is, the relative efficiency levels for 2011 and 2017. Next, we present the temporal results accounting for the evolution of productivity during the study period and the explanatory components.

Static analysis results

Table 5 shows the efficiency levels for the years 2011 and 2017. The *group frontier* column shows the efficiency levels of each customs office relative only to other offices within their own group. The *metafrontier* column shows the entire sample's efficiency levels of the customs offices. The coefficient represents the potential output level reached in both cases, given the inputs used. For example, the 2011 coefficient for the Subteniente López customs office was 0.786 in the *group frontier* column, which means that its real output is 78.6% of the potential due to its input levels and the performance of other offices of the same type. The *technological gap* column shows the quotient between the two columns mentioned above, allowing us to measure the effect of the analyzed office belonging to a specific group on its efficiency level. In other words, it quantifies the structural impact on a group's efficiency. The closer the value is to 1, the lower the structural impact of a group on efficiency.

In general, the results show a slight improvement in efficiency during the period of study for border and maritime customs offices (8.6% and 1.1%, respectively). Conversely, interior customs offices' efficiency decreased slightly during the same period, even though they exhibited the highest average efficiency levels in 2011 and 2017 (in this group, customs offices are closer to their group frontier, on average). The technological results show that, in both years, maritime customs offices exhibited the largest group structural advantage, followed by interior customs offices. The group with the greatest structural disadvantage was border customs offices; however, this group showed improvement during the study period, as its average technological gap increased nine percent from 0.298 to 0.327.

[Insert Table 5 here]

For 2011, the most efficient border customs offices, relative to their own group, were the following: Ciudad Juárez, Naco, Nuevo Laredo, Piedras Negras, Ciudad Acuña, Sonoyta, and Colombia. Conversely, the least efficient border customs offices were the following: Agua Prieta, Subteniente López, Ojinaga, Puerto Palomas, and Ciudad Miguel Alemán. During 2011, most of the interior customs offices were efficient, except for the Querétaro, Chihuahua, and Guanajuato offices. The maritime customs offices in Ciudad del Carmen, Coatzacoalcos, Salina Cruz, Tuxpan, Lázaro Cárdenas, Altamira, and Dos Bocas exhibited a value of 1 for both the group frontier and the metafrontier; the best units in this group led the metafrontier, despite the low average efficiency of the rest of the units in the group.

For 2017, the most efficient border customs offices were the following: Agua Prieta, Subteniente López, Ciudad Juárez, Naco, Nuevo Laredo, Piedras Negras, Ciudad Acuña, Sonoyta, and Colombia. Conversely, the least efficient were the following: Ojinaga, Puerto Palomas, San Luis Río Colorado, Ciudad Hidalgo, Tecate, and Ciudad Camargo. It is worth noting the marked increase in the number of efficient border customs offices. Just as in 2011, in 2017 most of the interior customs offices were efficient, except for those in Querétaro and Guanajuato. The interior customs group exhibited steady efficiency values throughout the study period, remaining the most efficient group in both years. The most efficient maritime customs offices in 2017 were the following: Ciudad del Carmen, Coatzacoalcos, Manzanillo, Salina Cruz, Tuxpan, Veracruz, and Altamira, which were also part of the metafrontier for both years, except for the Dos Bocas office, the efficiency of which decreased during the study period, which drove it further away from the metafrontier. The offices in Guaymas and La Paz were the most inefficient (thereby the furthest from the metafrontier). This group's technological gap was the least affected from a structural standpoint for both years.

Temporal analysis

As DEA models estimate the efficiency coefficients based on the distance to the production frontier, a comparison of the static results only shows whether the units' distance relative to the efficient frontier changed for that particular year. As noted earlier, the efficiency frontier is not static and moves from year to year. Therefore, to estimate the effects of Mexico's technological modernization policies it was necessary to conduct a temporal analysis that allowed us to identify the relative movement of the frontiers from one year to the next. Also, a temporal analysis allowed us to assess whether best practices improved during the period of study and whether there had been any technological improvements. Furthermore, we were able to assess how much variation in efficiency levels can be attributed to the units' movements within the frontier and actual movements in the efficiency frontier.

Next, we present the results of the temporal analysis of productivity changes and their explanatory factors. Table 6 shows average changes in productivity and their explanatory components by group.

[Insert Table 6 here]

Customs offices' global productivity decreased 1% on average (productivity change [PC] = 0.990) from 2011 to 2017. Even though efficiency increased 5.7% (efficiency change [EC] = 1.057), all groups' best-practices performance worsened by 4.5% (best practice gap change [BPC] = 0.965). The decline in groups' intertemporal frontiers improved the levels of efficiency that we observed during the study period. Further, the average technical gap ratio change (TGC) was 0.971, which indicates that, on average, the groups' global best-practices performance worsened. This suggests that, globally, modernization policies exhibited no clear effect, as the improvements in efficiency that we observed could stem from a worsening of units' best-practices performance. However, upon analyzing groups in detail, we found that the only group exhibiting increased productivity was the border customs offices group (8.7%), which is linked primarily to a 10.6% increase in efficiency (EC = 1.106). On average, this group's best-practices performance, however, worsened slightly (BPC and TGC < 1). This suggests that the improvements in efficiency were more important than the reference frontier's decline. This improvement could be attributed to different factors, including the introduction of various technological innovations between 2011 and 2017.

Conversely, the interior customs group exhibited a 10% decrease in productivity, whereas the maritime customs group showed a 6.4% decrease. Interior customs' decreased productivity was caused primarily by decreased structural efficiency (this group's TGC worsened by 10%). Maritime customs agencies' decrease in productivity stems from the decline of the group frontier, which indicates that this group's best-practices performance worsened (perhaps going so far as to evidence a technological regression). This contributed to an average efficiency improvement of 3% for this group, as reductions in best practices help reduce the remaining units' distance relative to the group frontier. Thus, overall, no significant improvements in these two groups could be traced back to the enactment of modernization policies.

Maritime customs offices showed the largest change in technological leadership (0.2%), suggesting that they are the leading group in the metafrontier. Conversely, interior customs offices were the group farthest from the metafrontier, exhibiting a 10.3% decrease during the study period. Small TGC values indicate that a given group is far from the global technology frontier. We ran a Kruskal-Wallis test to verify whether TGC differences we found in our analyses were significant, which confirmed that they were statistically significant.

Figure 1 shows the kernel density functions estimated for the three groups' TGC values. Most maritime customs offices' group values were near 1, indicating that this component remained stable throughout the study period. Conversely, internal customs offices performed poorly as a group, as exhibited by its lower group values.

[Insert Figure 1 here]

Table 7 shows the customs offices' efficiency change, best practice gap change, technological gap ratio change, and productivity change.

[Insert Table 7 here]

In the breakdown of the productivity index, some customs offices consistently exhibited a value of 1, including those of Nuevo Laredo (from the border customs group), Mexico City (from the interior customs group), Ciudad del Carmen, Coatzacoalcos, and Lázaro Cárdenas (all from the maritime customs group). Additionally, the office in San Luis Río Colorado (from the border customs group) doubled its efficiency level between 2011 and 2017.

Conclusions

Customs offices are of paramount importance for a country's economic growth and national security as all international commercial transactions go through them. The Mexican government sought to improve the country's customs system by enacting various modernization policies. These include the Customs Modernization Plan, the Single Window for Foreign Trade, and the Customs Technological Integration Project. These policies aim to improve the performance of Mexican customs offices, thereby expecting to benefit the Mexican government and its workers and their users. Additionally, this modernization process has implications for the country's overall welfare because the customs system directly adds to the economy's growth through tax collection and should contribute to improving national security in Mexico. Therefore, assessing the change in efficiency of customs offices following the enactment of modernization policies is important to understand whether these policies achieved the overall intended objectives.

The results of our study show that, overall, the change in productivity was not as expected. There was a one percent decrease in productivity during the period examined. Regardless, there was a 5.7% increase in efficiency; however, it should be noted that this increase was attributed to a decline in customs offices' best-practices performance. Therefore, our findings do not support the modernization policies introduced during the study period, as they were unsuccessful in increasing Mexican customs offices' productivity until 2017. The only group whose productivity improved was the border customs group, showing a 10.6% increase. This result suggests that the policy impact was greater on border customs offices. A potential explanation may be because border customs offices deal with a greater volume of transactions, which implies that they have a greater potential for improvement with the implementation of policies to bolster their productivity. Additionally, these offices receive an important percentage of the overall taxes collected by customs offices, making them a key target for these types of policies. Further, although Mexico would benefit from diversifying its trade operations, it appears that this has not been achieved. In fact, our findings show that maritime offices were the leading group in the metafrontier.

The border customs group showed the best results for the efficiency frontier; however, this group did not lead in the metafrontier. Thus, border customs offices' administrators should undertake periodical evaluations to devise ways to improve their performance. Any future customs policies should consider their organizational needs to help them improve their performance. It is worth noting that Mexico's most important foreign trade partners are the United States and Canada, accounting for 83.59% of Mexico's foreign trade operations (Economy Secretariat, 2019). Since border customs offices are the main points of access of these two trading partners, it is important that these customs offices remain efficient.

Conversely, interior customs offices consistently exhibited the lowest performance overall. Therefore, to increase their productivity, we suggest that future research identify key areas requiring improvement.

This study makes several contributions to the scholarly literature. First, to our knowledge, this is one of the few studies focusing on assessing the productivity of customs offices. Second, it is the first to implement the model developed by Oh and Lee (2007) for this purpose. As noted earlier, these policies were enacted to modernize the customs services aimed at improving efficiency, bolstering economic growth, and strengthening national security. By providing estimates of improvements (or declines) in efficiency over time, we offer insights on the effects of customs modernization policies implemented by the Mexican government.

There are, however, limitations that are worth noting. First, it would be advisable to consider and include additional variables to refine the productive process model of customs offices. Unfortunately, this process would require accessing data that are generally not available to the public. Therefore, this limits the inferences we can make from our results. Further, in future studies, we could analyze a larger sample and include offices from other countries, which could help us increase the generalizability of our findings and assess the performance of the Mexican system more comprehensively. Various factors determine how public institutions function, including a country's economy, its trade policies, government spending, and cultural factors. Thus, having a more comprehensive database could help us include additional variables to generate more effective models to assess customs offices' efficiency.

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