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Antonio Estache
Beatriz Tovar de la Fé
Lourdes Trujillo

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Antonio Estache

The World Bank, Washington, D.C., USA and

ECARES, Universite Libre de Bruxelles, Belgium

Beatriz Tovar de la Fé

Grupo de Investigación en Economía de las Infraestructuras y el Transporte

Universidad de Las Palmas Gran Canaria

Lourdes Trujillo

Grupo de Investigación en Economía de las Infraestructuras y el Transporte

Universidad de Las Palmas Gran Canaria

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Abstract

Mexico's port system was centrally managed by public firms until 1993 reforms liberalized and decentralized it to regional port authorities to improve its efficiency. This paper measures the changes in, and sources of, efficiency since the reforms. We rely on a Malmquist index to calculate and decompose changes in productivity, in terms of infrastructure, for Mexico's 11 main ports between 1996 and 1999. The results suggest that TFP in Mexican ports rose by an average of 4.1 percent a year in 1996–99. They also suggest that the fourth year, because some ports saw their scale efficiency deteriorate as a result of the effects of the East Asia crisis. We finally show that with one exception, all the ports maintained or improved their pure technical efficiency during the sample period. We conclude by arguing that these types of results could be used by any port regulator to improve the effectiveness and fairness of its regulatory decisions.

Introduction

Recent papers by Guasch and Kogan (2001, 2003) support the common wisdom that ports and roads—through their effects on the levels of inventories that businesses have to maintain—are among the main determinants of international competitiveness. The papers show that while U.S. businesses typically hold inventories equal to about 15 percent of GDP, in many developing countries inventories are up to three times that size simply because transport infrastructure is unreliable, inefficient, or insufficient. The authors estimate that additional inventory holdings impose a cost on these countries' economies of more than 2 percent of GDP. This figure indicates the importance of—and great hopes tied to—port reform around the world, and provides a benchmark for the potential welfare gains that can be achieved through port reform in developing countries.

Although this type of benchmark is useful to policymakers concerned about competitiveness, few have tried to monitor the gains from the reforms they have implemented to improve competitiveness. Worse, even fewer seem to have recognized that for these competitiveness gains to be realized, the efficiency gains achieved through port reform will eventually have to be shared with users, ideally as part of scheduled tariff adjustments, just as in reform of major utilities. Indeed, competitiveness will improve only if the efficiency gains are shared with users.

In the last couple of years, if recognition of the need to ensure eventual pass-through of some efficiency gains has been increasing among port regulators, few (with the possible but notable exception of Australia) have shown a major commitment to quantifying these gains when preparing tariff revisions. But this quantification is crucial, because the fairness of the redistribution of efficiency gains largely depends on how fairly these gains are quantified. Moreover, assessing the levels of gains is not enough from a regulatory viewpoint: it is also important to understand the sources of the potential gains to be realized. For ports this is a politically sensitive issue because many critics of port reform argue that most of the efficiency gains from restructuring are due to job reductions.

This paper provides the first systematic analysis of the decomposition of the sources of productivity changes from port reform in a developing country.[2] We calculate productivity changes of port infrastructure[3] in Mexico using a Malmquist total factor productivity (TFP) index. From the viewpoint of a regulator, this index has the advantage of not requiring input prices or behavioral assumptions. We then decompose the total changes into total technical efficiency change and technological change, relying on a nonparametric (data envelopment analysis, or DEA) framework outlined by Färe and others (1990) and Fare, Grosskopf, and Lovell (1994).[4] This approach allows us to assess the relative importance of the catching-up effects and the frontier shift effects resulting from reforms aimed at increasing competition between ports. We also separate the catching-up effects into technical efficiency effects and scale efficiency effects to give a sense of the extent to which the efficiency gains are achieved from adjustments to input use (including labor reductions) or from better adjustment of port size to demand.

The paper is organized as follows. We begin with a brief overview of the theory, followed by a summary of Mexico's reforms. After that we describe the data and its limitations, then present the TFP results and their decomposition. We then discuss some policy implications, and conclude with final comments.

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2 In fact, this paper is one of the few to assess port efficiency at all. The first such paper, Roll and Hayuth (1993), uses hypothetical data. Liu (1995) relies on a stochastic frontier to assess the performance of 28 U.K. ports. More recently, Martinez and others (1999) use a data envelopment analysis (DEA) to assess the performance of Spanish ports, while Tongzon (2001) uses a DEA to assess 16 ports from around the world. Baños, Coto, and Rodríguez (1999) and Coto, Baños, and Rodríguez (2000) estimate port efficiency in Spain and Estache, Gonzalez, and Trujillo (2002) estimate port efficiency in Mexico using a stochastic frontier to assess the overall efficiency gains from reform, but do not examine the composition of the changes.

3 A first important characteristic of a port as on economic organization is that it can not be considered as an entity producing a single service. A diversity of activities take place within the boundaries of a port area. Thus, it is quite important to take into account the diverse characteristics of each particular service that may lead to different regulatory schemes, as some present natural monopoly properties while others could be better produced under competition. This paper is interested only with the port infrastructure services.

4 Malmquist indices have been used to measure efficiency changes in other regulated infrastructure sectors such as electricity (Hjalmarsson and Veiderpass 1992), natural gas (Price and Weyman-Jones 1996), and airports (Abbot and Wu 2002). To our knowledge, the only other application to ports is Martín Bofarrul (2003).

Measuring and decomposing changes in productivity: the tools

Interest in analyzing efficiency has grown significantly over the past 30 years, generating major improvements in the techniques available to measure the performance of firms. Over the past 10 years regulators of privatized infrastructure services have become major consumers of these techniques, and the measure of efficiency is increasingly becoming a basic mandate for regulators—mostly in developing countries because that is were most infrastructure reforms have occurred outside Australia, New Zealand, and the United Kingdom.

One of the main challenges in using efficiency concepts in regulated industries is getting policymakers, interest groups, and operators to accept that the concept of efficiency differs from the partial productivity indicators they tend to be familiar with. Indeed, in ports perhaps more than in other infrastructure sectors, performance tends to be measured simply by relating one output to one input (for example, containers handled per crane or per worker). But in practice this type of index is too simple, because most operators rely on a combination of inputs (such as labor, various types of equipment, and other intermediate inputs such as electricity) that can have varying importance across operators. Moreover, many regulated industries also offer multiple outputs (bulk cargo, grain, liquids, containers, storage, and so on).

This suggests that as databases improve, regulators will have to develop productivity measures that take into account the multiple outputs (say, M) and inputs (say, K) used in the production of these outputs. Since not every output has the same importance for every operator and since the importance of every input for every output type can differ, the general formula reflecting the common intuition on the concept of productivity should be:

$$\mathrm{TFP} = \sum_{m=1}^{M} a_m Y_m \Big/ \sum_{k=1}^{K} b_k X_k \,, \qquad (1)$$

where a_m and b_k are weights, the choice of which is quite important (see below). The output weights and input weights must each sum to 1, a basic property of any TFP measure. Hence standard practice has been to assume that output and input markets achieve productive efficiency—that is, output prices equal marginal cost and input prices equal marginal product value, so that the weights are estimated by the share of output in total revenue and the share of input in total cost.[5] But these are strong assumptions for regulated industries, and these simple weights are best not used.

Moreover, the evolution of this measure over time for a given operator or operators picks up productivity changes due to the adoption of new technologies—shifts over time in the outputs generated by evolving combinations and levels of inputs. But it does so in a biased way, because it ignores that productivity improvements can also result from changes in behavior due to the restructuring process or the design of the regulatory regime. These changes in behavior are reflected in additional concepts of efficiency.

The first is technical efficiency. This related concept is defined as the capacity to maximize the output to be achieved from a specific set of inputs (if the regulator follows an output orientation and imposes input levels) or the capacity to achieve a given level of output at the minimum input use (if the regulator imposes output levels and follows an input orientation in the definition of its efficiency concept). Most regulated industries impose service obligations, so output is exogenous, and hence input orientation is the most relevant because input choice is endogenous (Coelli and others 2003). That is the approach followed in this paper. From the viewpoint of a regulator, the main interest in this measure is that its change shows the extent to which an operator catches up with best practice in the field for a given technology.

Finally, it is important to recognize that efficiency gains can also be achieved by changing the scale of operation in many regulated industries. Thus it is crucial for a regulator to be able to assess the extent to which an operator adjusts the scale of its operations to the demand side of the business, trying to optimize the productivity from the available technology. This information is provided by a measure of scale efficiency.

In sum, the potential efficiency gains to be shared with users can come from technological changes as well as from improvements to catch up with best practice and changes in the scale of operations.[6] The main problem from the last source of gains is that it can be driven by the demand side, over which operators do not always

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5 This is what the Törnqvist (1936) index proposes.

6 There are also possible changes in input and output mix allocative efficiency. These are not addressed in this paper but are discussed in Coelli and others (2003)

have much control.[7] This means that the potential for scale efficiency is not always something a regulator can force an operator to share with users.[8] But being able to measure it is necessary to ensure that the regulator can do the right thing when assessing the share of the efficiency gains that an operator can share with users in a sustainable way.

To incorporate these various sources of efficiency changes while recognizing the limitations of the assumptions used in the simple index discussed above, regulators tend to adopt a Malmquist index approach. The Malmquist TFP index measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. The Malmquist (input-orientated) TFP *change* index between period 0 (the base period) and period 1 (using period 1 technology as the reference technology) is given by:

$$\mathrm{TFP}_1 / \mathrm{TFP}_0 = \frac{D_1(Y_0, X_0)}{D_1(Y_1, X_1)}, \qquad (2)$$

where $D_t(Y_s,X_s)$ represents the distance from the period s observation to the period t technology. A value of the ratio in equation (2) greater than 1 indicates an improvement in TFP. For example, a value of 1.025 corresponds to a 2.5 percent increase in TFP.

This index has the main advantage of avoiding having to work with input and output prices and the related input and output market-clearing assumptions. It relies on input and output weights estimated directly. In addition, from the viewpoint of regulated industries where many production decisions (in terms of timing and levels) are driven by the regulatory framework and various obligations rather than only self-centered rational behavior by operators, the index has the advantage of not having to work with behavioral assumptions (such as profit maximization or cost minimization) for these operators. Finally, the Malmquist index makes it easy to compare the

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7 Demand for port infrastructures and related services is a derived demand which is mostly reacting to business generated elsewhere in the economy. It is hence mostly by macroeconomic circumstances (including trade reform and exchange rate policies). Clearly, there is some degree of inter-port competition and market shares for individual can change but it is unlikely that ports can generate new demand on their own.

8 This is, in fact, the concept of efficiency that tends to be picked up, albeit in a biased way, by the most conventional partial measures of productivity.

catching-up effort with the frontier shift for a given sector or operator (see Nishimizu and Page, 1982 and Grifell and Lovell, 1993).

Increasingly, however, to avoid having to chose between technologies in period 0 and 1, the practice is to rely on an alternative Malmquist index defined by Färe, Grosskopf, and Lovell (1994) as the geometric mean of two indices—one evaluated with respect to period 1 technology and the second with respect to period 0 technology. Doing this yields:

$$TFP_1 / TFP_0 = \left[\frac{D_1(Y_0, X_0)}{D_1(Y_1, X_1)} \frac{D_0(Y_0, X_0)}{D_0(Y_1, X_1)} \right]^{0.5} \quad (3)$$

An equivalent way of writing this productivity index is:

$$TFP_1 / TFP_0 = \frac{D_0(Y_0, X_0)}{D_1(Y_1, X_1)} \left[\frac{D_1(Y_0, X_0)}{D_0(Y_0, X_0)} \frac{D_1(Y_1, X_1)}{D_0(Y_1, X_1)} \right]^{0.5}, \quad (4)$$

where the ratio outside the square brackets measures the change in the input-oriented measure of technical efficiency between periods 0 and 1; we can call this the total technical efficiency change (TTEC).[9] The remaining part of the index in equation (4) is a measure of technical change (TC). It is the geometric mean of the shift in technology between the two periods, evaluated at the period 0 data point and at the period 1 data point. That is:

$$TFPC = TTEC \times TC \quad (5)$$

The main problem with this index is that to properly measure TFP change, constant returns to scale (CRS) distance functions are required; otherwise the implicit weights will not add up to 1 and hence any scale efficiency gains (or losses) will be missed. Färe, Grosskopf, and Lovell (1994) use CRS distance functions to calculate the index in equation (5). They also suggest a further decomposition of equation (4) in which the CRS technical efficiency change measure (TTEC) can be decomposed into a "pure" technical efficiency change component and a scale efficiency change component. This is done by introducing some variable returns to scale (VRS) distance functions, to obtain:

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9 Farrell measures of efficiency correspond in each case to the expansion, or reduction, of the ray that pass through the origin. Such measures refer to Farrell' seminal paper (1957).

$$TFP_1 / TFP_0 = \frac{D_0^V(Y_0, X_0)}{D_1^V(Y_1, X_1)} \left[\frac{D_1^V(Y_1, X_1)}{D_0^V(Y_0, X_0)} \frac{D_0^C(Y_0, X_0)}{D_1^C(Y_1, X_1)} \right] \times \left[\frac{D_1^C(Y_0, X_0)}{D_0^C(Y_0, X_0)} \frac{D_1^C(Y_1, X_1)}{D_0^C(Y_1, X_1)} \right]^{0.5}, \quad (6)$$

where the *V* superscripts refer to VRS technology and the *C* superscripts refer to CRS technology.[10] Equation (6) thus gives a technical efficiency change (TEC) measure, a scale efficiency change (SEC) measure, and a technical change (TC) measure. That is:

$$TFPC = TEC \times SEC \times TC \quad (7)$$

The product of TEC and SEC is also sometimes known as total technical efficiency (TTEC).

This is the decomposition sought in this paper. It is particularly interesting in ports because specialists often argue that it is not uncommon to have port authorities operating with technical efficiency (using the lowest possible level of inputs for a given level of production) but not enjoying the appropriate scale (either too small or too big). In that case there is not much an operator can do in the short run, and it would be unfair for a regulator to penalize the operator for this scale issue.

A final logistical detail associated with this index is that the estimation of the weights relies on a concept of distance that requires estimation of a frontier from which the distance is measured. There are two main ways to estimate this frontier: one is through data envelopment analysis (DEA), the nonparametric programming method, and the other is through stochastic frontier analysis (SFA).[11] Both methods allow the derivation of estimates of relative efficiency levels for all operators compared. In this paper we construct the Malmquist TFP index using input distance functions calculated from a DEA.

As seen in equation (6), six distance functions must be calculated: four defined

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10 This decomposition has been criticized by some authors because it measures technical change against the CRS technology instead of the VRS technology. Various alternatives have been proposed, but none of them has gained widespread acceptance. See Grifell and Lovell (1999) and Balk (1999) for discussion on this issue.

11 For more details, see Coelli and others (1998, 2003)

under constant returns to scale (CRS) and two under variable returns to scale (VRS). A standard way of presenting the underlying optimization program for CRS used here is:

$$\begin{aligned} &\text{Min } \theta_0 \\ &\quad \text{s.a.} \quad Y\lambda \geq Y_0 \\ &\qquad\qquad \theta X_0 - \lambda X \leq 0 \\ &\qquad\qquad \lambda \geq 0 \end{aligned} \tag{8}$$

where λ is a vector describing the percentage of the other operators used to construct the efficient operator, X and Y are the inputs and output vectors of the efficient operator, and X_0 and Y_0 are the inputs and outputs of the operator under evaluation. The value of θ reflects the efficiency of this operator.

The CRS linear programing problem can be easily modified to account for VRS by adding the convexity constraint: $Nl'\lambda=1$, to the program (8) to provide:

$$\begin{aligned} &\text{Min } \theta_0 \\ &\quad \text{s.a.} \quad Y\lambda \geq Y_0 \\ &\qquad\qquad \theta X_0 - \lambda X \leq 0 \\ &\qquad\qquad \lambda \geq 0, \\ &\qquad\qquad Nl'\lambda=1 \end{aligned} \tag{9}$$

where N1 is an Nx1 vector of ones.

Mexico’s industrial ports and the 1993 reforms

Until 1993 the Mexican port system was centrally managed by a network of public firms. The 1993 modernization and reform of the system were based on a three-prong strategy: decentralization, introduction of competition within ports and between decentralized port authorities, and eventual privatization of these decentralized authorities and of most port services.

Decentralization was built around the creation of an autonomous, self-financed port administration (Administración Portuaria Integral or API) in each port or group of small ports. The federal government supervises the APIs created by the 16 main ports, while provincial governments are responsible for monitoring 5 provincial APIs. APIs act as landlords rather than full port authorities because they cannot act as operators. They are managed by a board containing representatives of their owners (mostly federal, provincial, and municipal governments and the national development bank, as well as private users). APIs enjoy property rights over the assets they control and can award them in concessions to private operators. They make annual payments to the federal governments for the transfer of the assets.

The Transport Secretary is the de facto regulator of the sector. Although port tariffs have generally been liberalized, the fee that APIs charge ships to use common infrastructure is still subject to regulation. This fee, one the main sources of revenue for APIs, is subject to a price cap regime. This allows APIs to compete on price if they so desire while allowing the government to control it to ensure that efficiency gains can eventually be passed on to users in case there is collusion between ports. Safety matters are under the supervision of the navigation authority (Capitania de Puertos)

While only one API (Acapulco) has been privatized, the introduction of competition and of private service providers in ports quickly generated significant investments and hence capacity increases in the system. In less than a decade after reforms were introduced, capacity to handle commercial cargo almost doubled, to more than 100 million tons. Capacity use increased by a similar proportion. Public employment has dropped significantly, but this decline is being offset by increases in private employment (at least in some of the largest ports, such as Manzanillo, where it has doubled in less than five years, and Veracruz, where it has increased by about 25 percent since the start of reforms).

All this is happening in a new legal framework, built into the Ports Law passed in 1993, that allows private firms to enter the port industry as operators. The law also required the dismantling of the public agency Puertos Mexicanos (PUMEX), until then responsible for the port network and the only agency authorized to build port infrastructure and provide port services.

The market structure that emerged from these reforms can be summarized as follows. APIs and some provincial governments share responsibility for the 108 ports and terminals along Mexico's 11,500-kilometer coastline, with a total berth length of 110 kilometers. Half these facilities are on the Pacific coast and half are on the Atlantic coast.[12] There are 39 commercial ports, about as many fishing ports, 22 specializing in passengers, mostly tourism, and 8 specializing in oil traffic.

Total cargo movement in the Mexican port system increased from 169 million tons since the early 1990s to 255 million tons in 2002. Passenger traffic has more than doubled, while container traffic has quadrupled during the same period . Oil and oil derivatives account for 62 percent of the cargo handled by Mexican ports (measured in tons), and mineral ores for 23 percent. General cargo, including bulk and containerized goods, accounts for 9 percent. Only 36 percent of general cargo is transported in containers (the containerization index), which is very low by international standards but is improving. The ports of Manzanillo and Veracruz move about three-quarters of the traffic units (twenty-foot equivalent units, or TEUs) handled by the port system. These two ports have the country's most modern container terminals, and thus are expected to be more productive and efficient than other ports.

Because the port system handles 85 percent of international trade, its efficiency is crucial to Mexico's competitiveness. Most of this trade goes through 27 commercial, industrial, and tourist ports, and the terminals specializing in oil and mineral ore traffic. In 2002 the eight main ports—four on the Atlantic coast, four on the Pacific—handled nearly three-quarters of cargos exceeding 1.5 million TEUs. If oil is excluded, half of cargo movements go through five ports: Veracruz, Tampico, and Altamira on the Atlantic coast , and Manzanillo and Lázaro Cárdenas on the Pacific.

In general, the port reforms have led to lower cargo handling charges, as shown in Table 1. Between January 1995 and December 1998 charges for moving agricultural bulk cargo, mineral bulk cargo, and palletized goods fell by 22–35 percent, while charges for moving containers fell by 5.6 percent. The smaller change for containers may be due to the fact that the cost of capital is higher for specialized container terminals, and before the reforms this fact might have not been considered when calculating charges.

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12 Facilities located outside port areas, as defined by the government, dedicated to port operations.

The data sample

The available data are annual and span four years, from 1996 to 1999, and cover the 11 main APIs, which are not too specialized.[13] This provides a data panel with 44 observations, which allows for a fair assessment of the evolution in the relative performance of the main APIs and of the sources of efficiency changes.

The APIs covered are those under federal responsibility: Ensenada, Guaymas, Topolobampo, Mazatlán, and Manzanillo on the Pacific coast and Altamira, Tampico, Tuxpan, Veracruz, Coatzacoalcos, and Progreso on the Atlantic coast. Excluding oil and oil derivatives, in 2002 these APIs handled 70 percent of the traffic going through Mexican ports and almost 100 percent of the container traffic. Among the country's largest ports, the main ones missing are Puerto Madero, Puerto Lázaro Cardenas, Puerto Vallarta, and Acapulco due to lack of sufficient data. Puerto Madero was closed for a number of years while under repair. Puerto Vallarta is mostly a tourist port and handles very little cargo. Acapulco, also mainly a passenger port, is the only API that has been privatized (in 1997). The country's other ports are generally too small to allocate major resources to meet detailed regulatory requirements for information and also tend to be owned by subnational governments, which do not impose the same information requirements.

The production variable reflecting the output of the infrastructure can be approximated by the volume (in tons) of merchandise handled (loading and unloading) in each API.[14] We would have liked to be able to address the multiproduct nature of API activities through a disaggregation of the various types of cargo handled and through the explicit recognition that APIs also provide other services such

13 Specialized APIs would be outliers because they are so specialized that they are almost unique in their traffic type (i.e. oil ports). When relying on a DEA approach, this kind of outliers can change the frontier, resulting in misleading efficiency measures because unique ports can appear to be much more efficient than they would be assessed to be by any other methodlogy. This is why we focused only on ports which offer similar characteristics of traffic type (which is the case for the majority of the large Mexican ports on which our sample focus)

14 This follows the approach used by Roll and Hayuth (1993), Liu (1995), Baños, Coto, and Rodríguez (1999), and Coto, Baños, and Rodríguez (2000,) who all assume a single output technology and measure output using the volume of merchandise handled.

equipment rental, commercial building and space rental, water services to ships, and so on. But the quality of the data available on these other activities simply did not allow it.

The available data allow us to focus only on the two main inputs: capital and labor. The capital input is approximated by the length of docks concessioned by the government to each API, the only variable available for all ports on a systematic basis. [15] We also collected data on intermediate expenditures for all APIs, but these data failed some basic consistency tests, so we decided not to use them. Labor is measured by the number of workers in each API—a fairly standard variable available for most ports and hence used by most studies.[16] Table 2 summarizes the main statistics.

Table 3 summarizes the main partial productivity indicators for each port. The left side of the table measures the productivity of capital as a ratio of production (in tons) to capital (in meters). The right side measures the labor productivity of each API in production (tons) per worker. The emerging big picture can be summarized as follows. On both coasts capital productivity generally increased while labor productivity decreased. For capital this reflects the improvements in capacity utilization rates. For labor it reflects the fact that after the initial layoffs from the reforms, employment recovered somewhat at the beginning of the period being studied. Moreover, East Asia's 1997–98 crisis had an obvious impact on capital productivity. Although capital productivity continuously increased on the Atlantic coast, it deteriorated somewhat on the Pacific coast.

However interesting the comparison of these two indicators may be, it illustrates quite well the difficulties of using standard performance indicators in regulatory processes. Should regulators have an optimistic view of the world and look

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15 This definition is equivalent to the quasi-fixed capital used by Baños, Coto, and Rodríguez (1999). However, for Liu (1995) capital is the net value of fixed capital, including land, buildings, docks, berths, roads, storage, and equipment. For Roll and Hayuth (1993) it is the annual average of all capital invested in ports and installations. Martínez and others (1999) assume that it can be approximated by depreciation expenditures.

16 These data exclude workers who load and unload ships because those activities are not being measured. This is an issue only for the four APIs that provide merchandise handling: Topolobampo, Guaymas, Mazatlán, and Salina Cruz.

at the partial productivity indicators for capital? Or should they be concerned with the deterioration in the labor indicators, which imply that employment is growing faster than production? Ports would receive very different treatment depending on the indicator adopted. This kind of dilemma is one of the main reasons economic regulators tend to look for synthetic indicators, such as the one measured next.

The Malmquist index of productivity change

The Malmquist index of productivity change makes it possible to assess the changes in TFP for the main Mexican ports in the first four years after reforms were fully implemented (again, 1996–99). Table 4 shows that Altamira and Ensenada were the best-performing ports during that period. It also shows the evolution of the various sources of efficiency for each port. A value larger than 1 for the Malmquist index or any of its components indicates an improvement in that source of inefficiency. A value smaller than 1 indicates a deterioration. The average growth rate in the specific source is the difference between the measured index and 1.

The results suggest that TFP in Mexican ports rose by an average of 4.1 percent a year in 1996–99. Because Tampico is an outlier--because is a much longer port than the others and at current traffic levels it is bound to be less efficient--, we also compute the average without it—and find that the annual TFP change is much larger, reaching 5.6 percent. In addition to Tampico on the Atlantic coast, two Pacific coast ports, Guaymas and Topolobampo, suffered a decline in TFP. If the 4.1 percent average TFP growth were used as the “X” factor across ports as part of a tariff review, 6 of the 11 ports would be penalized because their measured efficiency gains would be below the minimum gain required for the period.

On a year to year basis the 4.1 percent average is driven by the first three years of the period (immediately after the reforms), when efficiency scores were quite high. In fact, during the last (fourth) year there was a generalized “technological” regression because all ports saw their TFP deteriorate, an expected result since world trade shrank—leading to less traffic being handled by the same number of inputs. This assumption seems to be confirmed by the detailed information presented in the annex for each API (with the exception of Manzanillo).

The full sample suggests that the adoption of better technologies by the operators led to dramatic improvements, with and without Tampico in the sample. This seen in the fact that TC (column (1)), is not very different with (1.024) and without Tampico (1.026). In other words, the reforms have allowed the port to benefit from technological improvements in port infrastructure available in the market. This has allowed the sector to witness a frontier shift which will benefit Mexico's competitiveness in the long run.

Columns (3) and (4) in Table 4 show the decomposition of the sources of the total technical efficiency (TTEC) into its pure technical effect (TEC) and scale economy effect (SEC). It reveals that with the exception of Tampico, all the APIs maintained or improved their pure technical efficiency during the sample period. In fact, five improved it. Indeed, when Tampico is ignored, technical efficiency gains become very significant and drive the TFP change. This means that the reforms are indeed effective in promoting an incentive for port operators to catch up with their potential, on the main concerns for the regulators of monopolistic facilities.

The story on the changes in scale efficiency is more complex. The results seem to suggest that on average, the operators adjusted the scale of their operations for the better. But six of them have seen a deterioration in their scale economy, a result of the combination of some additional investment with a view to the long term potential of the ports and of the down turn in trade at the end of the period covered by the panel of data.

Overall, with the exception of Manzanillo, the catching-up effect (TC) dominates the shift (TEC) for all ports on the Pacific coast—while the opposite is true for all ports on the Atlantic coast,. because this ports saw their scale efficiency deteriorate as a result of the effects of the East Asia crisis.

Policy issues

The above analysis suggests several important policy lessons for Mexico as well as for other countries considering major port reforms. The first is that while labor adjustments were a factor in the improvements in TFP—as suggested by many critics of privatization—they were clearly not the only one Indeed, adoption of new technologies and increases in capacity resulting from large investments made right after the reforms began were the main contributors to these improvements, as seen from the major share of the TFP change that can be attributed to technological changes and improvements in scale efficiency.

The second lesson is that a regulator's job does not stop with these data. While developing this database, we identified many data problems that need to be addressed if regulatory estimates of efficiency are to be credible. The port industry is typically multiproduct and has far more than two main inputs, yet the current database allows us to generate enough data only to launch the regulatory debate—not settle it. Regulators simply need to improve their monitoring capacity to generate policy-relevant data on a more systematic basis. But production and cost data on ports are not the only data needed. Many other "environmental" factors that we were not able to pick up would help explain the relative performance of the operators. In particular, we have not picked up the changes in quality associated with the changes in service levels and types adopted by the operators. Quality adjustments are one of the main sources of cost adjustments that regulators tend to fail to take into account sufficiently when making decisions.

The third lesson is that the approach adopted in the paper may be too "gentle" from a regulatory viewpoint if the purpose is to promote competition between ports. Indeed, the operators identified as best practice may be inefficient to some extent. If this situation persists, the regulator is unlikely to be able to pick up the full potential for efficiency gain.

A fourth lesson is that while the distribution of gains has been relatively fair when the evolution of prices and efficiency gains are compared, it is important for regulators to maintain pressure on APIs—particularly with respect to the pricing of container traffic. Most of the new technologies adopted by APIs as part of their scaling-up processes have been designed to allow Mexico to catch up with the rest of the world in terms of containerization, yet container prices fell by only 5.6 percent during the period covered by the sample—while overall efficiency gains were three to four times as much.

The final lesson is that in industries with increasing returns to scale it is easy to be unfair to operators by penalizing them for demand shocks which are not under their control but which result in drops in efficiency levels simply reflecting losses in scale of operation. This risk is particularly clear in the results presented since they are based on a period that saw major shocks to international trade volumes due to various international crises, particularly the East Asian crisis. During this period the scale of operations was indeed sensitive to demand conditions about which operators could do little. Operators can engage in port promotion or adopt equivalent policies to stimulate demand or at least improve somewhat the relative competitive position in the country, but such policies tend to be insufficient to quickly mitigate major demand shocks. Scale adjustments to these demand shocks are probably just as slow as the responsiveness of demand management policies in the sector. This means that, ideally, regulators should consider TFP net of SEC. Table 5 shows that doing so would reduce the average efficiency gains considered as part of a tariff revision from 4.1 percent to 2.5 percent. Only three ports, rather than six, would be below that average. Still, the extreme case of Tampico shows that under such an approach, it becomes quite important for the operator to actively use the scale to adjust.

Conclusion

Overall, the results suggest that port reforms were quite successful in contributing to improvements in Mexico's economic competitiveness. The least that can be said is that the reforms facilitated the adoption of new technologies, and for many ports they also allowed a significant catching-up. A regulator would probably use the result to audit the less effective ports from a TFP viewpoint—such as Guaymas, Topolobampo, and Tampico—although the first two improved their pure technical efficiency during the period under analysis (the component of TFP that operators seem to control best) while having problems adjusting the scale of their operations.

But the odds are that if these ports were audited, their managers would be able to vigorously debate this regulatory approach. Indeed, while the results presented here provide a number of policy insights that any regulator should be ready to address, the data on which they are based are far from ideal. Rather than simply denying regulators the right to use efficiency estimates on the basis of their imperfection, governments could use the opportunity to introduce due processes to structure the interactions between regulators and operators, and generate more data than are currently available to improve the fairness of regulatory decisions. These processes have become relatively standard in the utilities sector in developing countries, and there is no reason not to adopt them in the transportation sector.

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Table 1: Changes in Cargo Handling Tariffs in Mexican Ports, January 1995–December 1998

(1998 pesos)

Port	Agricultural bulk goods		Mineral bulk goods		Palletized goods		Containers	
	Dec 1998	Jan 1995	Dec 1998	Jan 1995	Dec 1998	Jan 1995	Dec 1998	Jan 1995
Veracruz	34.0	56.3	46.7	77.1	64.5	96.9	1,467.5	1,554.9
Manzanillo	25.0	41.4	25.0	39.8	57.0	75.1	1,554.0	1,466.0
Lázaro Cárdenas	27.7	31.7	36.3	45.0	58.2	72.2	1,247.4	1,655.8
Altamira	—	49.3	—	67.5	68.0	81.7	1,315.0	1,655.8
Tampico	41.3	49.3	57.2	67.5	69.2	81.7	968.9	1,143.6
Weighted average reduction	-34.5 %		-24.5 %		-21.7 %		-5.6 %	

Source: Data provided by the Mexican Transport Secretariat.

Table 2: Basic Indicators for Mexico's Main APIs

	Production (tons)	**Capital (square meters)**	**Labor (workers)**
Average	5,265,930	4,393	70
Maximum	12,487,349	10,465	226
Minimum	719,459	1,092	13
Standard deviation	3,424,588	3,051	56
Pearson coefficient	0.65	0.69	0.81

Source: Data provided by the Mexican Transport Secretariat.

Table 3: Labor and Capital Partial Productivity Indicators for Mexico's Main APIs, 1996-99

	1996	**1997**	**1998**	**1999**	**1996**	**1997**	**1998**	**1999**
Port	**Production/capital**				**Production/labor**			
	Pacific Coast Ports							
Ensenada	122	143	170	245	164	156	148	148
Guaymas	721	651	595	540	157	131	167	174
Mazatlán	358	437	442	425	166	151	147	147
Manzanillo	5751	6435	6749	6787	14	15	19	19
Topolobampo	1395	1761	1823	1654	159	129	94	94
Coast average	**1669**	**1885**	**1956**	**1930**	**132**	**116**	**115**	**116**
	Atlantic Coast Ports							
Altamira	1244	1590	2220	2475	23	25	24	24
Coatzacoalcos	1094	1031	1353	1104	32	39	37	37
Progreso	2215	2272	2568	2775	27	27	27	27
Tampico	800	766	832	819	120	116	116	86
Tuxpan	2617	3110	3658	3469	128	96	84	84
Veracruz	1305	1207	1585	1644	34	34	34	35
Coast Average	**1546**	**1663**	**2036**	**2048**	**61**	**56**	**54**	**49**
Sample Average	**1608**	**1774**	**1996**	**1989**	**96**	**86**	**84**	**83**

Source: Author's computation based on data provided by the Mexican Transport Secretariat.

Table 4: Malmquist (TFPC) Input-based Productivity Index and Its Decomposition by API, 1996-99

Port	TC (1)	TTEC (2)=(3)*(4)	TEC (3)	SEC (4)	TFPC (5)=(1)*(2)
Pacific Coast Ports					
Ensenada	0.955	1.277	1.151	1.110	1.219
Guaymas	0.955	0.985	1.123	0.877	0.940
Manzanillo	1.085	1.000	1.000	1.000	1.085
Mazatlán	0.955	1.063	1.143	0.930	1.015
Topolobampo	0.958	0.930	1.000	0.930	0.891
Atlantic Coast Ports					
Altamira	1.105	1.152	1.036	1.111	1.273
Coatzacoalcos	1.092	0.937	1.041	0.900	1.024
Progreso	1.102	0.974	1.000	0.974	1.074
Tampico	0.977	0.926	0.631	1.467	0.905
Tuxpan	1.011	1.000	1.000	1.000	1.011
Veracruz	1.095	0.990	1.000	0.990	1.084
Geometric Average	**1.024**	**1.017**	**1.001**	**1.016**	**1.041**
Geometric Average (without Tampico)	**1.026**	**1.029**	**1.048**	**0.979**	**1.056**
Annual Averages (including Tampico)					
1996-1997	1.013	1.012	0.832	1.215	1.025
1997-1998	1.096	1.021	1.226	0.833	1.119
1998-1999	0.967	1.018	0.982	1.037	0.984

Note: A value of the index or of any of its components larger than 1 indicates an improvement in that source of inefficiency. A value lower than 1 indicates a deterioration. The average growth rate in the specific source is obtained by the difference between the measured index and 1.

Table 5: Effect of TFPC Net of SEC as the "X" Factor in a Tariff Revision

Port	TFPC (1)	SEC (2)	TFPC* =(1)/(2)
Ensenada	1.219	1.11	1.098
Guaymas	0.94	0.877	1.072
Topolobampo	0.891	0.93	0.958
Mazatlán	1.015	0.93	1.091
Manzanillo	1.085	1	1.085
Altamira	1.273	1.111	1.146
Tampico	0.905	1.467	0.617
Tuxpan	1.011	1.0	1.011
Veracruz	1.084	0.99	1.095
Coatzacoalcos	1.024	0.9	1.138
Progreso	1.074	0.974	1.103
Geometric Average	**1.041**	**1.016**	**1.025**

Note: A value of the index or of any of its components larger than 1 indicates an improvement in that source of inefficiency. A value lower than 1 indicates a deterioration. The average growth rate in the specific source is obtained by the difference between the measured index and 1.

Annex

Table A1: Malmquist (TFPC) Input-based Productivity Index and Its Decomposition by API, 1996-97

PORT	TTEC	TC	TEC	SEC	TFPC
Ensenada	1.249	0.891	1.166	1.071	1.113
Guaymas	0.844	0.891	0.897	0.941	0.752
Topolobampo	1.151	0.891	1.000	1.151	1.026
Mazatlán	1.245	0.891	1.119	1.112	1.109
Manzanillo	1.000	1.132	1.000	1.000	1.132
Altamira	1.167	1.142	1.031	1.131	1.333
Tampico	0.984	0.954	0.301	3.267	0.939
Tuxpan	1.000	1.005	1.000	1.000	1.005
Veracruz	0.812	1.139	0.326	2.487	0.925
Coatzacoalcos	0.898	1.139	1.121	0.801	1.022
Progreso	0.899	1.141	1.000	0.899	1.026
Geometric Average	**1.012**	**1.013**	**0.832**	**1.215**	**1.025**

Table A2: Malmquist (TFPC) Input-based Productivity Index and Its Decomposition by API, 1997-98

PORT	TTEC	TC	TEC	SEC	TFPC
Ensenada	1.097	1.029	1.306	0.840	1.129
Guaymas	1.135	1.029	1.520	0.746	1.168
Topolobampo	0.731	1.040	1.000	0.731	0.761
Mazatlán	0.954	1.029	1.335	0.715	0.982
Manzanillo	1.000	1.122	1.000	1.000	1.122
Altamira	1.168	1.188	1.044	1.118	1.388
Tampico	1.054	1.029	1.111	0.949	1.085
Tuxpan	1.000	1.085	1.000	1.000	1.085
Veracruz	1.117	1.176	3.063	0.365	1.313
Coatzacoalcos	1.098	1.171	0.995	1.104	1.286
Progreso	0.955	1.184	1.000	0.955	1.130
Geometric Average	**1.021**	**1.096**	**1.226**	**0.833**	**1.119**

Table A3: Malmquist (TFPC) Input-based Productivity Index and Its Decomposition by API, 1998-99

PORT	TTEC	TC	TEC	SEC	TFPC
Ensenada	1.520	0.948	1.000	1.520	1.442
Guaymas	0.999	0.948	1.040	0.961	0.947
Topolobampo	0.956	0.948	1.000	0.956	0.907
Mazatlán	1.012	0.948	1.000	1.012	0.960
Manzanillo	1.000	1.006	1.000	1.000	1.006
Altamira	1.121	0.995	1.033	1.084	1.115
Tampico	0.766	0.948	0.752	1.019	0.727
Tuxpan	1.000	0.948	1.000	1.000	0.948
Veracruz	1.070	0.981	1.000	1.070	1.050
Coatzacoalcos	0.834	0.977	1.012	0.824	0.816
Progreso	1.077	0.990	1.000	1.077	1.067
Geometric Average	1.018	0.967	0.982	1.037	0.984

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